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Applying Welfare Science to Cetacean Strandings

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CETACEAN ECOLOGY RESEARCH GROUP

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Dedication

In loving memory of my Mum

Rosemary Elizabeth Boys (Née Toms)

1962–1996

Dedicated to my Dad

Nigel Leonard Boys

LFROK

Abstract

Animal welfare science can provide critical knowledge to inform ethical wildlife management and human intervention efforts. Despite live stranding events being recognised by the International Whaling Commission as a major welfare concern for free-ranging cetaceans, little research has to date, been conducted on stranded cetacean welfare. Live cetacean stranding events offer a quintessential exemplar of wildlife management, where assessment or integration of welfare has been limited in the decision-making process. This thesis contributes new understanding of how welfare science can be applied to cetacean stranding events to inform decision-making processes. Here, the first welfare-centric data regarding live stranded cetaceans is presented. Specifically, this research presents novel contributions to science via: (1) conceptualisation of stranded cetacean welfare and survival likelihood; (2) recognition of key knowledge gaps and concerns that must be addressed to ensure optimal welfare and survival likelihood outcomes; (3) identification of potential valuable and practical indicators for assessing stranded cetacean welfare and survival likelihood; (4) evidenced feasibility of welfare indicator application to live cetacean stranding events; (5) incorporation of indicators to undertake holistic welfare assessments; (6) identification of potential welfare implications of strandings management, including efficacy of euthanasia; and (7) provision of key recommendations and requirements to ensure humane end-of-life outcomes for non-viable stranded cetaceans. This thesis documents inextricable links between animal welfare and survival likelihood of stranded cetaceans and demonstrates a clear need for integration of welfare science alongside conservation biology at live stranding events. Systematic, standardised data collection and welfare-centric assessment of stranded cetaceans can, if applied scientifically, inform intervention decisions, to ensure consistent guidance and improve strandings management to safeguard humane outcomes for affected cetaceans. Collectively, this research provides a significant contribution to the current scientific understanding of stranded cetacean welfare, by providing key knowledge required for the development of a welfare assessment framework that can support decision-making at stranding events.

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Statement of publication and co-authorship

The candidate was the lead author for each manuscript and was responsible for research design, data collection, analyses and interpretation, and preparation of manuscripts. Co-authors contributed towards data collection, data analyses and interpretation, and manuscript reviewing and editing. All co-authors have approved inclusion of the research in this doctoral thesis. The contributions of co-authors are outlined below:

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Chapter 6: **Boys, R.M**.; Beausoleil, N.J.; Betty, E.L.; Stockin, K.A. When and how to say goodbye: An analysis of Standard Operating Procedures that guide end-of-life decision-making for stranded cetaceans in Australasia. Marine Policy 2022, 138, 104949, https://doi.org/10.1016/j.marpol.2021.104949

Chapter 7: **Boys, R.M**.; Beausoleil, N.J.; Betty, E.L.; Stockin, K.A. Deathly silent: Exploring the global lack of data relating to stranded cetacean euthanasia. Animals 2021, 11, 1460. https://doi.org/10.3390/ani11051460.

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Boys, R.M.; Beausoleil, N.J.; Pawley, M.D.M.; Littlewood, K.; Betty, E.L.; Stockin, K.A. Using expert opinion to highlight how we can achieve effective and ethical management at cetacean stranding events. Oral presentation, 33rd European Cetacean Society Conference, Ashdod Israel, 5th–7th April 2022.

Boys, R.M.; Beausoleil, N.J.; Pawley, M.D.M.; Betty, E.L.; Stockin, K.A. Establishing the ethology of stranded cetaceans to inform decision-making at stranding events. Oral presentation, 58th Animal Behavior Society Conference, 3rd–6th August 2021.

Boys, R.M.; Beausoleil, N.J.; Betty, E.L.; Pawley, M.D.M.; Stockin, K.A. Ethology of stranded cetaceans in New Zealand: First insights for an *a priori* ethogram. Universities Federation for Animal Welfare Conference, Virtual, 29th–30th June 2021.

Boys, R.M.; Beausoleil, N.J.; Betty, E.L.; Stockin, K.A. Deathly silent: Exploring the lack of peer-reviewed literature relating to euthanasia methods and efficacy. Invited speaker International Cetacean Symposium "Interaction", Hong Kong, 11 June 2021.

Boys, R.M.; Palmer, E.I.; Betty, E.L.; Stockin K.A. Deathly silent: Exploring the lack of peer-reviewed literature relating to euthanasia methods and efficacy. Poster presentation, 2nd World Marine Mammal Conference, Barcelona Spain, 9th–12th December 2019.

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Clegg, I.L.K.; **Boys, R.M.**; Stockin, K.A. Increasing the awareness of animal welfare science in marine mammal conservation: Addressing language, translation and reception issues. Animals 2021, 11, 1596. https://doi.org/10.3390/ani11061596

Stockin, K.A.; **Boys, R.M.**; Palmer, E.I.; Clegg, I.L.; Simmonds, M.P. Mind the gap: A striking absence of welfare science in marine mammal conservation. Oral presentation 2nd World Marine Mammal Conference, Barcelona Spain, 9th–12th December 2019.

Chapter 1 Introduction

Mass stranding event of long-finned pilot whales (*Globicephala melas edwardii*).

Photo credit: Rebecca M. Boys.

1.1 Cetacean strandings

Cetacean (whale, dolphin and porpoise) strandings have been occurring for at least centuries in most coastal nations (Aristotle 350AD). Stranding events can be categorised based on causation and numbers of individuals involved. Most stranding events involve beach-cast carcasses, but in other cases animals strand alive. These strandings can be further classified as passive or active. Passive strandings are where animals that die or are debilitated at sea are brought to shore by wind and tide (Sergeant 1982), whilst active strandings involve live animals in adverse situations which can further impact their health or welfare (Simeone and Moore 2018b; Harms et al. 2018).

Understanding the stranding type is important as it influences human strandings response and the associated animal welfare implications for live animals. There are four main types of strandings, 1) single, 2) mass strandings, 3) unusual mortality events and 4) out-of-habitat situations. The characteristics of individual animals that strand in each of these situations vary significantly, with some animals appearing outwardly healthy, while others range from being clinically ill, to moribund or dead (Gales 1992).

Single strandings are the most common type, involving one animal alone or a mother-calf pair, and are observed in all marine mammal taxa (Moore et al. 2018a). These events are often linked to illness, with many single stranded animals being in poor nutritional condition (Colegrove et al. 2005; Arbelo et al. 2013; Raverty et al. 2020), or associated with human impacts such as harassment (Bechdel et al. 2009; Vail 2016; Barcenas-De la Cruz et al. 2018), ship strike (Sierra et al. 2014; Alvarado-Rybak et al. 2020b; Schoeman et al. 2020; Visser et al. 2021) and entanglements in debris and fishing gear (Stockin et al. 2009; Cassoff et al. 2011; Moore et al. 2013a; Dolman and Moore 2017; Marks et al. 2020). Single strandings are generally unrelated to other stranding events, though patterns may be identified related to migration and distribution of species (McGovern et al. 2016; Foord et al. 2019; Alvarado-Rybak et al. 2020a).

Mass stranding events (MSEs) refer to those involving more than one individual (excluding mother-calf pairs) within a relatively similar spatio-temporal area (Geraci and Lounsbury 2005). Mass stranded individuals often appear outwardly healthy but may become compromised due to the stranding event itself. Factors such as the time spent in receding waters and/or on the beach, trauma due to stranding or scavengers and thermal stress can affect the health of animals and therefore the final stranding outcome

(Gales 1992; Geraci and Lounsbury 2005; Herráez et al. 2007, 2013; Fernandez et al. 2017; Câmara et al. 2020).

The majority of MSEs involve a few pelagic odontocete species, including pilot whales (*Globicephala* spp.), false killer whales (*Pseudorca crassidens*), white-sided dolphins (*Lagenorhynchus* spp.), common dolphins (*Delphinus delphis*) and sperm whales (*Physeter macrocephalus*) (Sergeant 1982; Geraci and Lounsbury 2005; Hamilton 2018). In such species, it is hypothesised that the strong social cohesion among individuals are a causal factor in stranding events (Connor 2000; Oremus et al. 2013; Mazzariol et al. 2018; Brakes and Rendell 2022). There are several other natural risk factors suggested for MSEs, including topography (Brabyn and McLean 1992; Sundaram et al. 2006) and changes in environmental conditions such as atmospheric and oceanographic variations (Bradshaw et al. 2006; Zellar et al. 2021). However, there has been increased reporting of mass strandings, which may be due in part to increased observer effort and improved global communication, especially with the advent of social media (Pitchford et al. 2018; Coombs et al. 2019; Liu et al. 2022). Nevertheless, changes in the species composition involved in mass strandings has also occurred, such as a significant increase in beaked whale (Ziphiidae) MSEs, which have been related to anthropogenic activities (Bernaldo de Quiros et al. 2019).

Unusual mortality events (UMEs) also involve large numbers of individuals, but these may comprise beach-cast (i.e., carcasses washing ashore) animals, sometimes as a sporadic event or spanning over a wide temporal and spatial scale (Moore et al. 2018a). These events are often caused by viral epidemics, such as cetacean morbillivirus (Van Bressem et al. 2007; Kemper et al. 2016; Pautasso et al. 2019; Cunha et al. 2021), although toxic algal blooms have also been implicated (Gulland and Hall 2007; Fire et al. 2011, 2021). Anthropogenic impacts, such as oil spills, may also cause UMEs, with chronic impacts often observed over long time scales (Venn-Watson et al. 2015; Colegrove et al. 2016; Ruberg et al. 2021). Furthermore, naval sonar has also played a role in UMEs; these events often begin with a mass stranding, but beach-cast individuals continue to come ashore over prolonged periods (Jepson et al. 2003; Fernández et al. 2013; Simonis et al. 2020; Wang et al. 2021; Bernaldo de Quiros et al. 2019). These events appear to have increased in frequency in recent decades (Gulland and Hall 2007; Simeone et al. 2015), a trend likely to continue due to climate change (Sanderson and Alexander 2020) and human disturbance (Collier et al. 2022).

Out-of-habitat situations are quite unusual as individuals are displaced into areas that are not considered part of their normal habitat, such as rivers or estuaries (Chit et al. 2012). Such cases often receive wide media attention, such as the beluga whale (*Delphinapterus leucas*) in the London Thames River (Deaville et al. 2018), humpback whales (*Megaptera novaengliae*) in Sacramento River, California (Gulland et al. 2008) and melon-headed whales (*Peponocephala electra*) in a lagoon in Antsohihy, Madagascar (Southall et al. 2013). These animals can vary from being outwardly healthy to moribund. Although natural return to their habitat is preferred, in many cases human intervention is required to guide them out before they become significantly compromised or to provide humane end-of-life procedures where necessary (Moore et al. 2018a).

Overall, it is recognised that most strandings are complicated by multifactorial causations, and these vary case-by-case. Understanding the stranding type and possible causations are, therefore, important to recognise the potential effects on animal welfare and enable informed decision-making for strandings response.

1.1.1 Implications of stranding and human responses for animal welfare

Human responses to cetacean strandings have changed significantly over time (Bearzi et al. 2010; Campagna and Guevara 2022), from purposely killing animals to use them as a resource, to today's desire to rescue and rehabilitate (Moore et al. 2018a; Mazzoldi et al. 2020). It is this societal vision to 'save the whales' that drives many of the 'rescue' attempts during strandings response, rather than being based on scientific evidence of what is best for the individual animal. At many live strandings, despite the lack of empirical evidence and generally logistically complex and costly operations, 'rescue' attempts are carried out with the aim to re-float and release cetaceans back to sea. Yet little is known about the fate of the 'rescued' individuals (Gales et al. 2012; Sampson et al. 2012; Sharp et al. 2014) and how factors of stranding, including human intervention and manipulations, impact upon the welfare and survival of individuals.

As anthropogenic activities in the marine environment increase (Halpern et al. 2019), there is likely an increase in reporting of events by the public (Geraci et al. 1999; Liu et al. 2022). The significant media attention given to stranding events has further led to changing human attitudes and increased expectations regarding stranded cetacean management (Gales et al. 2008b; Stockin et al 2022). For similar reasons, strandings response has become common practice in many countries (ca. 200 stranding networks in over 75 regions (Simeone and Moore 2018a)), both for the purpose of gathering information from carcasses and to provide care to live animals (Gales et al. 2008b; Dennison et al. 2012; Sharp et al. 2014, 2016). Therefore, it is likely that strandings response will play an increasingly important role overtime.

The primary goal of live strandings response is to ensure animal welfare, by assessing health and providing supportive care (Geraci and Lounsbury 2005; Gales et al. 2008b; Moore et al. 2018a) to inform intervention decisions. Intervention procedures include first aid, involving righting animals into a position on the sternum to relieve pressure on internal organs, and placing wet sheets and pouring water over stranded animals to reduce the likelihood of hyperthermia (Geraci and Lounsbury 2005). The next stage depends upon the condition of the animals and the management procedures of the area. Animals deemed to be in good condition may be moved into the water to enable re-floatation, whilst animals in poor condition may be taken into rehabilitation if their size permits (in countries where this is legal and facilities are available) or end-of-life decisions, such as euthanasia, may be undertaken (Moore et al. 2007).

Despite the various forms of human intervention, there continues to be a lack of empirical data regarding the welfare of stranded cetaceans and the survival of ‘rescued’ individuals. In many regions, management procedures are either not available or contain limited details to inform decision-making, including a lack of information on how to assess the condition of an animal. In some cases, the expectation of rescuers can conflict with and increase pressure on those responsible for decision-making, this can be particularly challenging when considering end-of-life decisions (Dubois 2003; Moore et al. 2007; Gales et al. 2008b). Indeed, during some strandings response, individuals have undergone multiple re-strandings, likely due to being significantly debilitated, which will only prolong suffering (Geraci and Lounsbury 2005; Perrin and Geraci 2008; Sharp et al. 2014; Brownlow et al. 2015b; Ogle 2017).

It is crucial that scientifically rigorous data relevant to the welfare and survival likelihood of stranded cetaceans is gathered and used to inform intervention decisions (Warburton and Norton 2009). Indeed, knowledge of the physical, behavioural, and physiological indicators observed in live stranded cetaceans, and how these may reflect welfare state, could significantly improve decision-making and intervention procedures.

Furthermore, increased studies correlating indicators observed when an animal was alive with pathological data at post-mortem could enhance the prognostic value of indicators applied to predict survival likelihood. Knowledge of the prognostic importance of these indicators could also be further enhanced through correlation with post-release survival data (Sharp et al. 2016); which is being facilitated by improvements in technology, such as satellite tags (Gales et al. 2012; Sampson et al. 2012). However, data on indicators must first be systematically collected and validated to understand how they reflect welfare state. They can then be applied to better inform decision-makers and ultimately improve animal welfare and conservation outcomes at future stranding events.

1.1.2 Strandings in Aotearoa, New Zealand

Since the centralisation of reporting of cetacean strandings in Aotearoa, New Zealand — herein New Zealand — began in 1978, there have been over 3,370 stranding events, involving more than 13,700 individuals reported and documented (DOC National Strandings Database, December 2021), with over half of the individuals (n = 9,498) being long-finned pilot whales (*Globicephala melas edwardii*) (Betty et al. 2020). Temporal and spatial trends in stranding occurrence are documented, with most events, particularly mass strandings of long-finned pilot whales, herein pilot whales, occurring during austral summer (November-February; Betty et al. 2020). The high incidence, widespread distribution, and extensive public engagement at stranding events around New Zealand, has led to strandings being managed through the New Zealand Coordinated Incident Management System (CIMS), used for emergency management.

Management of stranding events comes under the jurisdiction of the New Zealand Department of Conservation/Te Papa Atawhai (DOC), in partnership with local tribes of indigenous Māori people (iwi). Additionally, there are several NGO stranding networks; with one, Project Jonah, recognised as the official service providers to DOC, providing trained personnel to assist with strandings response. Management of stranding events is guided by a Standard Operating Procedure (SOP) (Boren 2012). The SOP aims to provide consistent and high-quality responses to marine mammal strandings, and acts as a field guide to enable DOC staff to respond to a range of stranding types. It includes aspects of human safety and cultural relations, as well as considering the welfare of stranded animals, through decisions of re-floatation versus euthanasia, and guidance for performing euthanasia. The SOP was developed by DOC by incorporating knowledge gained from national stranding events over time combined with the international published literature (Geraci and Lounsbury 2005). It includes the assessment of health and likely survival of individuals in the decision-making process.

According to the New Zealand SOP, the assessment of individuals includes consideration of breathing rate and character, changes in heart rate, temperature, physical responses, jaw tone and gum colour, presence of injuries, skin blistering or sloughing, emaciation and whether animals are dependent (Boren 2012). However, such SOPs often lack detailed guidance on undertaking assessments and how the outcomes of these assessments should be evaluated in terms of animal condition, signifying that, decision-making processes remain scientifically limited. For example, in New Zealand the re-floatation and release of stranded cetaceans is generally seen as a 'success' (Hunter et al. 2017; Ogle 2017), yet the fate of these 'rescued' animals and the effects of stranding and human intervention on their welfare remain unknown. Furthermore, the lack of rigorous evaluation of management plans (Gore et al. 2008; Hampton et al. 2016; Sells et al. 2016) and data regarding direct animal welfare outcomes, generates uncertainty as to whether management operations are causing suboptimal animal welfare (Hampton et al. 2016; Hampton and Hyndman 2019).

This void of science in the decision-making process leaves uncertainty as to whether conservation or animal welfare objectives have actually been met. This thesis seeks to contribute to this knowledge gap by providing the first welfare science-oriented data related to cetacean strandings. Consequently, the research presented in this thesis provides an important novel contribution to our scientific understanding of conceptualising and assessing animal welfare at cetacean stranding events. Furthermore, it provides the initial steps for animal welfare science to be considered at stranding events and serves as a foundational base for a scientific, systematic, and holistic welfare assessment framework (WAF) to be developed.

1.2 Concepts of animal welfare

Animal welfare has been variously characterised with no single accepted definition. It is often defined as 'the state of an animal as it attempts to cope with its environment' (Fraser and Broom 1990) and characterises how well an individual is faring at a given time (Broom and Fraser 2007; Broom 2008). There are three views regarding what is important for understanding animal welfare and therefore, how it should be assessed scientifically: biological function, affective (mental) state and natural state. This is important, as the evaluation of welfare assessment outcomes will vary depending on which approach is emphasised (Fraser 2003; Nordenfelt 2006).

Those emphasising the biological function view believe that good welfare is the minimisation of physiological stress (Hurnik and Lehman 1988; Broom 1991; Barnett and Hemsworth 2003). In contrast, the affective state view, developed with animal preference and motivation (Dawkins 1990; 2003), followed by affective neuroscience (Panksepp 2005; Broom 2010), focuses on what the animal is feeling and how it is experiencing its life (Preece and Chamberlain 1993; Duncan 1996, 2004; Fraser 2003). Lastly, the natural state view, reflects the idea that the environment should enable animals to perform their natural behaviours (Kiley-Worthington 1989; Alrøe et al. 2001). Contemporary animal welfare science generally agrees that all these aspects are interrelated (Appleby 1999). Therefore, most current definitions of animal welfare encompass physical (basic health and functioning) and behavioural states, and the cumulative effects that these have on animal mental (affective) state (Mellor 2016; Mellor et al. 2020).

Concepts of animal welfare evolved in relation to production animals and aimed to protect against deliberate cruelty that was of public concern (Mellor et al. 2009a; Ohl and van der Staay 2012). However, this concept has waned as understanding that non-cruel human actions may affect animal welfare, and that these should also be considered. As such, animal welfare now focuses on the needs of animals rather than on human actions alone. This understanding led to the development of animal welfare science. Welfare science provides a systematic approach to assessing animal welfare and is theoretically independent of morals (Fraser 2008). Therefore, information generated by these scientific explorations can guide ethical decisions about treatment of animals.

As animal welfare evolved, farms began implementing welfare science through systematic welfare assessment frameworks (WAFs; Table 1.1), to better understand animal needs and improve production (Stott et al. 2012). In contrast, the application of welfare science to wild species remains limited (Beausoleil 2014; Ramp and Bekoff 2015; Dubois et al. 2017; Beausoleil et al. 2018; Harvey et al. 2020). There are differing ethical perspectives on human responsibilities towards wild species in terms of what should be done, and which animals qualify for protection and/or intervention (Kuba 2018; Miller et al. 2018). So far, welfare science for wild species has been driven by public concerns for animals held in captive facilities such as zoos and aquaria (Zoo Licensing Act 1981; Melfi 2009; Honess and Wolfensohn 2010). WAFs in these captive settings have focussed on animal needs and preferences, mainly targeting terrestrial mammals (Table 1.1). Welfare continues to be incorporated in other areas where wild animals are under human care, such as rehabilitation centres, though this generally focuses on how to apply WAFs (Dubois 2003; Wolfensohn et al. 2018).

Table 1.1 Examples of settings and taxa where welfare assessment frameworks (WAFs) have been applied.

Setting	**Taxa**	**Example references**
Farming	Cattle	WelfareQuality 2009a, Andreasen et al. 2013, Hernandez et al. 2017, Kaurivi et al. 2019
Farming	Sheep	Goddard et al. 2006; Llonch et al. 2015; Richmond et al. 2017; Munoz et al. 2019
Farming	Pigs	WelfareQuality 2009b, Renggaman et al. 2015
Farming	Horses	McGreevy et al. 2018
Farming	Donkeys	Dalla Costa et al. 2014
Farming	Goats	Battini et al. 2015
Farming	Turkeys	WelfareQuality 2009c, Marchewka et al. 2015
Farming	Foxes and mink	Mononen et al. 2012
Captive: Zoo	Primates	Hosey 2005, Melfi and Thomas 2005, Honess and Wolfensohn 2010, Pomerantz et al. 2013, Wolfensohn et al. 2015, Justice et al. 2017
Captive: Zoo	Ungulates	Maple 2007, Clubb et al. 2008, Mason and Veasey 2010
Captive: Zoo	Marsupials	Jones et al. 2005, Hogan et al. 2011, 2012
Captive: Zoo	Carnivores	Frézard and Le Pape 2003, Pifarré et al. 2012
Captive: Zoo	Bears	Wechsler 1992; Renner and Lussier 2002; Owen et al. 2004; Montaudouin and Pape 2004; Maher et al. 2021

Captive: Aquaria	Fish	Håstein et al. 2005, Soo and Todd 2009, Volpato 2009
Captive: Aquaria	Delphinids	Waples and Gales 2002; Castellote and Fossa 2006; Ugaz et al. 2013; Clegg et al. 2015; Delfour et al. 2021

In recent years humans have acknowledged their increasing effects on free-ranging wildlife and the need for welfare to be considered in conservation (Paquet and Darimon 2010; Butterworth 2017; Scholtz 2017; Hampton and Hyndman 2019; Freire et al. 2021). It is acknowledged that free-ranging wildlife may often be in a state of welfare compromise to survive in their environment (Dawkins 2012), however it is likely that human activities may further compromise their welfare both directly and indirectly (Fraser and MacRae 2011). Such compromise may occur through habitat alterations (Kirkwood et al. 1994), hunting (Broom 2013; Nunny et al. 2016), pest control (Warburton et al. 2008; Littin 2010; Beausoleil et al. 2016; Nunny 2020), wildlife sport/entertainment (Huntingford et al. 2006; Stafford 2006; Lott and Williamson 2017), industrialisation of areas (Fraser and MacRae 2011; Feber et al. 2016), social and/or cultural disruptions (Brakes et al. 2019; Brakes 2019; Brakes and Rendell 2022) , research and conservation (Blanchet et al. 2018), and wildlife rescue and rehabilitation (Moore et al. 2007; Câmara et al. 2020). It is, therefore, necessary that animal welfare science and WAFs are implemented to inform how humans interact with free-ranging wildlife and their habitats. This understanding has led to the development of the emerging concept of conservation welfare (Paquet and Darimon 2010; Beausoleil 2014, 2020; Beausoleil et al. 2018).

Conservation welfare is an emerging discipline that aims to achieve integration of conservation biology and contemporary animal welfare science, to provide the most scientifically-informed, holistic evaluation of animals (Beausoleil et al. 2018). Importantly, these disciplines have generally been seen to be disparate, yet it is increasingly understood that animal welfare can impact upon conservation outcomes if not considered in parallel (Papastavrou et al. 2017; Dubois et al. 2017; Beausoleil et al. 2018; Hampton and Hyndman 2019; Clegg et al. 2021). Therefore, development of WAFs that integrate both conservation and animal welfare are crucial to achieve optimal outcomes through appropriate decision-making in wildlife management. Notably, an understanding of how welfare is being conceptualised by these two disciplines is important, as the approach to understanding welfare will influence how it is assessed and how the outcomes of such assessments are evaluated in terms of decision-making (Beausoleil et al. 2018).

1.2.1 Welfare assessment

Welfare assessments provide insight into the state of an animal, relating to the outcome of sensory information from internal and external inputs processed by the animal's brain (Mellor and Reid 1994). This incorporates both biological functioning and affective state approaches, since biological functioning underlies affective experience and affective experience influences biological functioning (Mellor and Beausoleil 2015). Therefore, to perceive their welfare state, animals must be both sentient (able to perceive and feel) and conscious (Mellor and Reid 1994).

Affective states are subjective and cannot be measured directly but may be inferred through indices of physical, behavioural and physiological states, many of which have validated links to mental experiences (Beausoleil and Mellor 2015a, 2017). WAFs provide a systematic way of using discrete variables and interpreting data from these in terms of the likely affective state of an animal (Wemelsfelder 2001; Mellor et al. 2009a; Meagher 2009). Affective states are valenced, that is they are either negative or positive. Negative states are welfare compromising, such as behavioural and physiological indicators of pain (Beausoleil and Mellor 2017). In contrast, positive states are welfare enhancing (Mellor and Beausoleil 2015) such as affiliative behaviour (Spinka and Wemelsfelder 2011), or behaviours that reduce negative experiences (e.g., relief of thirst). Although, the reduction of negative experiences may improve welfare state, they alone cannot represent good welfare. Hence, the priority should be to relieve negative experiences and then provide opportunities for positive experiences if possible (Fraser and Duncan 1998; Yeates and Main 2008; Mellor 2016).

A WAF which has been extensively used as part of the scientific method to assess animal welfare, is the Five Domains Model (Mellor and Reid 1994). The model explicitly separates physical/functional impacts from affective experiences that impact animal welfare (Mellor and Reid 1994). The most recent update to the model includes three physical/functional domains (nutrition, physical environment, health) and one situation-related domain (behavioural interactions) (Mellor et al. 2020; Figure 1.1). The impact of different experiments, manipulations and husbandry can then be evaluated quantitatively through changes in animal-based indicators such as behaviour, physiology, pathology and pathophysiological disruption (Broom and Fraser 2007; Fraser 2008; Mellor et al. 2009a). Welfare-relevant resource-based indicators, such as food and water availability, can also be included to provide contextual information for the given situation (Harvey et al. 2020). Compromise in any of the four domains are used to infer the potential cumulative impacts on the fifth domain (mental state) which determines the animal’s overall welfare state (Mellor and Reid 1994, Mellor and Stafford 2001; Figure 1.1). Thus, animal welfare varies along a continuum from extreme suffering to good welfare, depending on the outcomes from the sensory inputs of the domains (Mellor et al. 2009a).

To enable the appropriate application of WAFs, species-specific knowledge of what is ‘normal’ under various conditions in each physical domain is necessary (Harvey et al. 2020). Such knowledge is used to build a comprehensive list of practically measurable indicators (animal- and resource-/management-based) which together may be used to infer affective state (Beausoleil and Mellor 2017). Indicators are well-established for domesticated species and include behaviours such as resting, indices of pain, seeking water/food and affiliative behaviours (Andreasen et al. 2013; Dalla Costa et al. 2014). Physiological indicators may include coat condition, body mass index, body temperature and injuries (Dalla Costa et al. 2014; Battini et al. 2015; Richmond et al. 2017). Finally, resource-/management-based indicators can include stock density, feeding regime and production procedures (Richmond et al. 2017).

Unfortunately, detailed behavioural and physiological data from free-ranging wildlife is often lacking (Hill and Broom 2009), precluding the assessment of animal-based indicators. Although the need to assess wild animal welfare has been highlighted, until now there has been limited systematic, scientific protocol for such assessment during their daily lives (Harvey et al. 2021). Notably, this has been hampered due to habitat accessibility, human avoidance and unobservability for prolonged periods (Harvey et al. 2020). Yet the application of innovative technologies, including camera-traps and drones, may enable insights into the welfare impacts that wildlife experience and the implications of these. The applicability of such technology to welfare science was highlighted in a study that assessed cardiopulmonary signals (physiological indicator), in carnivores, marsupials, bears and primates using video methods (Al-Naji et al. 2019). Furthermore, it was recently demonstrated that camera-trapping is a feasible method for assessing a variety of animal-based welfare indicators in wild horses (*Equus ferus caballus*) (Harvey et al. 2021). Such technologies have already provided some insight into wild marine mammal population health (Pirotta et al. 2017; Christiansen et al. 2019, 2020; Horton et al. 2019; Chung et al. 2022) and have potential for application in welfare assessments.

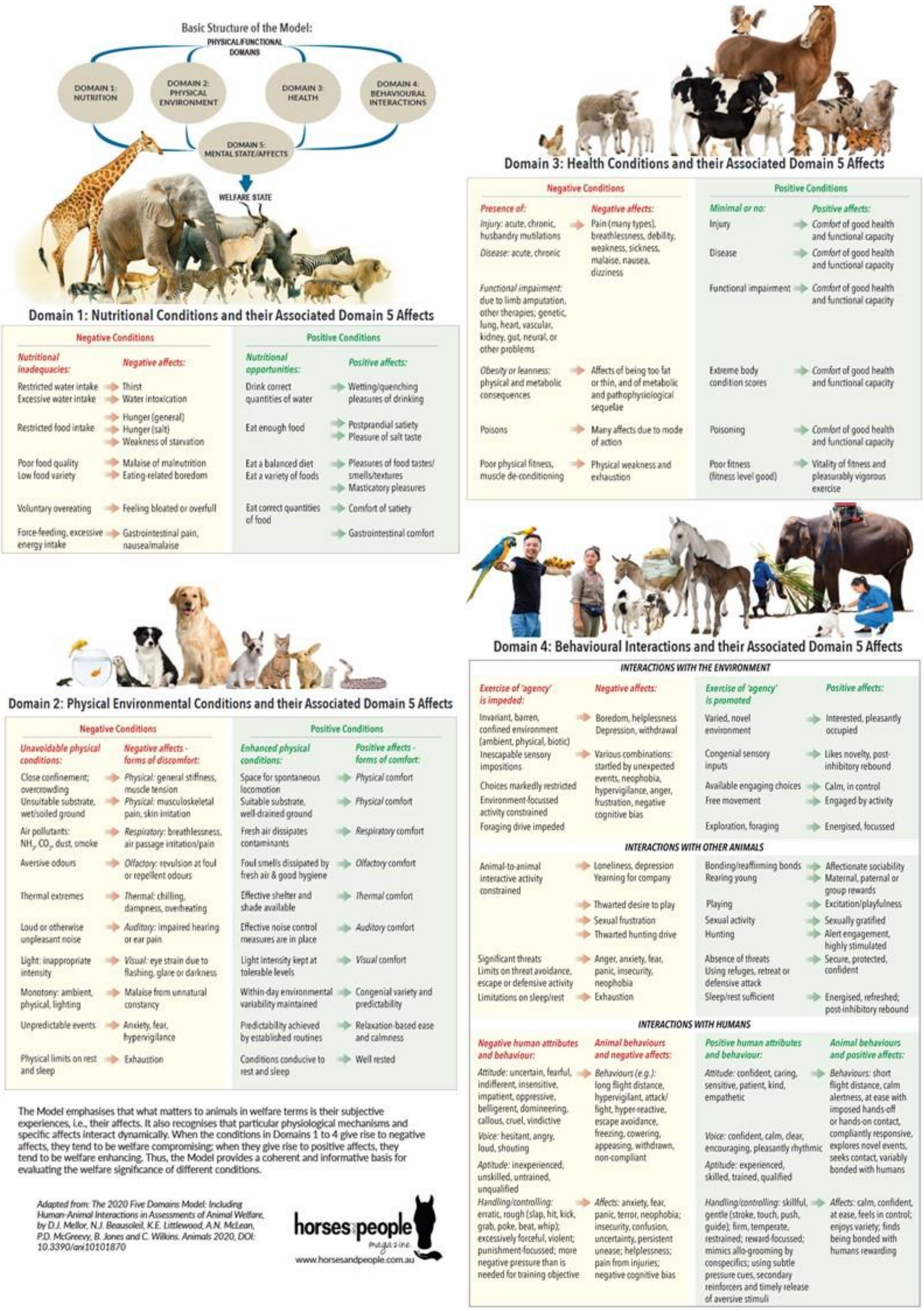

Figure 1.1 The Five Domains Model for animal welfare assessment adapted from Mellor et al. (2020) highlighting survival-related and situation-related factors in the four physical domains with examples of negatively or positively valenced affects. The overall affective experience in

the mental domain equates to the welfare status of the animal (Poster prepared by Horses and People Magazine 2020).

1.2.2 *Marine mammal welfare*

The marine environment is heavily influenced by human activities. Marine mammal welfare may be affected by a range of anthropogenic activities directly or indirectly (IWC 2011; Moore 2014; Wright et al. 2016; Butterworth 2017; de Vere et al. 2018; Simmonds 2018a; Table 1.2). Despite the likely welfare impacts of many of these human activities (Moore 2014), most current research efforts focus solely on conservation in the marine environment (Brakes et al. 2019; Dolman et al. 2020; Clegg et al. 2021).

Table 1.2 Exemplars of anthropogenic impacts that have welfare implications for free-ranging marine mammals.

Anthropogenic impact	**Welfare impact**	**Example references**
Ship strikes	Significant injuries or death	Moore et al. 2013b; Sierra et al. 2014; Schoeman et al. 2020; Smith et al. 2020; Visser et al. 2021; Reeves 2022
Noise e.g., increased maritime traffic, seismic exploration	Changes to behaviour and foraging ability	Wright et al. 2007; Nowacek et al. 2007; Kastak et al. 2008; Clark et al. 2009; Hildebrand 2009; Rolland et al. 2012; Ramesh et al. 2021; Stevens et al. 2021; Jacobson et al. 2022
Interactions with vessels, including whale watching	Changes to behaviour	Bejder et al. 2006; Stockin et al. 2008; Parsons 2012; Karenina et al. 2013; Götz and Janik 2015; Meissner et al. 2015; Bas et al. 2017; Filby et al. 2017; Holt et al. 2021; Quintana Martín-Montalvo et al. 2021
Interaction with fisheries e.g., net entanglement, depredation	Physical injuries or death	Read 2005; Edwards 2007; Chilvers 2008; Baird 2009; Stockin et al. 2009; Butterworth and Richardson 2013; Moore et al. 2013b; van der Hoop et al. 2014; Dolman and Moore 2017; Dolman and Brakes 2018; Dolman et al. 2018,

		2022; Northridge 2018; Nunny 2020; Herr et al. 2020; Knowlton et al. 2022
Pollution e.g., plastics and contaminants	Health	Reijnders 2003; Stamper et al. 2006; Teuten et al. 2009; Jacobsen et al. 2010; de Stephanis et al. 2013; Jepson et al. 2016; Fernandez et al. 2017; Simmonds 2017b, 2018b; Bourgeon et al. 2017; Schlingermann et al. 2020; Stockin et al. 2021a, b; Eisfeld-Pierantonio et al. 2022
Changing environment e.g., urbanisation, climate change	Changes in food availability, habitat loss and increased disease	Evans et al. 2005; Marsh et al. 2011; Edwards 2013; de Stephanis et al. 2013; Molnár et al. 2014; Simmonds 2017a, 2021; Derville et al. 2019; Warlick et al. 2022
Interactions/intervention with humans, including stranding response	Physical injuries and behavioural changes	Geraci and Lounsbury 2005; Wilke et al. 2005; Perrin and Geraci 2008; Eisfeld et al. 2010; IWC 2014, 2016a; Christiansen et al. 2016; Vail 2016; Ogle 2017; Nunny and Simmonds 2019; Senigaglia et al. 2019; Simmonds and Nunny 2022
Hunting	Significant injuries or death	Brakes et al. 2004; Knowles and Butterworth 2006; Daoust and Caraguel 2012; Bass and Brakes 2013; Butterworth and Richardson 2013; Butterworth et al. 2013, 2017; Vail et al. 2020; Mamzer 2021; Nunny et al. 2021; Parsons and Rose 2022

While conservation of species has become well integrated in policies and is understood by the public to ensure that wild populations do not become extinct, welfare is often dismissed as a disparate discipline that is guided by emotive environmental crusaders (Papastavrou et al. 2017; Clegg et al. 2021). Yet these scientific disciplines should be aligned, as the impact of anthropogenic activities will affect not only a species survival, but also the welfare of the individual animals, highlighting ethical responsibilities (Papastavrou et al. 2017; Beausoleil et al. 2018). Furthermore, the impacts on individual welfare may become apparent much earlier than the effects on populations, and so welfare science could improve species conservation (Lusseau and Bejder 2007; New et al. 2014; King et al. 2015; Bejder et al. 2022).

1.2.3 Cetacean welfare assessment

The assessment of welfare in wild populations poses many challenges, some of these relate to all free-ranging animals (Harvey et al. 2020), but are further compounded in the marine environment due to difficulties in finding, restraining, marking and recapturing marine mammals. Furthermore, the heterogeneous environment in which marine mammals reside can also influence which welfare indicators can be applied. Despite this, it has recently been suggested that the Five Domains Model may be applicable to assess the welfare of aquatic mammals (Miller et al. 2018; Dolman et al. 2020; Nicol et al. 2020).

Cetaceans are sentient animals (Reiss and Marino 2001; Simmonds 2006; Marino et al. 2007; Broom 2013), and although they have been kept in captivity for more than 150 years, there is a paucity of data regarding their welfare (Waples and Gales 2002; Castellote and Fossa 2006; Ugaz et al. 2013; Serres et al. 2020a). Studies have focussed only on a few measures of welfare from captive animals without reference values, including vocalisation behaviour (Castellote and Fossa 2006) and salivary cortisol levels (Waples and Gales 2002; Ugaz et al. 2013; Rickert et al. 2022). However, Clegg et al. (2015) successfully built a WAF for captive cetaceans (C-Well model), using bottlenose dolphins (*Turisops truncatus*) as a case study. This model focuses on animal-based measures adapted from published literature of captive and wild bottlenose dolphins, to gain understanding of normal and abnormal indicators of health, behaviour, physiology, anatomy, cognition and ecology (Clegg et al. 2015). The C-Well model allows for further development of captive cetacean welfare assessments that compare among individuals, demographics, and captive facilities.

Key welfare concerns for free-ranging marine mammals have been highlighted (IWC 2011; Butterworth 2017), yet methods to assess the welfare implications remain limited. Recently, Nicol et al. (2020) highlighted the application of the Five Domains Model, using expert opinion, to assess the likely welfare implications of several anthropogenic activities on free-ranging cetaceans, including whale watching, ship strikes, entanglements and contaminants. This framework was subsequently applied to develop a species-specific assessment for North Atlantic right whales (*Eubalaena glacialis*)

(King et al. 2021). These studies highlighted the challenges of applying WAFs to scenarios where there is limited behavioural and physiological data, and proposed that such assessments were useful to identify important information gaps (Dolman et al. 2020; Nicol et al. 2020). This is the case for cetacean strandings, where the paucity of data collected, and understanding of both animal-based (physical, behavioural, and physiological) and resource-/management-based indicators, precludes the application of a systematic, scientific welfare assessment, leaving decision-making uninformed.

During live stranding events, cetaceans are open to both anthropogenic and natural stressors that likely affect their welfare. Strandings are often associated with human intervention, including first aid, transportation and rehabilitation, and re-floatation at sea or euthanasia (Geraci and Lounsbury 2005). Thus, strandings response has the potential to impact animal welfare due to the presence, intervention, and associated noise of humans. In addition, there are physiological stressors such as the depletion of nutritional resources (blubber), intense exertion, homeostatic extremes and myopathy (Fernandez et al. 2017; Câmara et al. 2019a) that occur during live strandings. These anthropogenic and natural stressors have the potential to elicit physical, behavioural, physiological and pathological responses in live stranded cetaceans, which could provide a basis for assessing cetacean welfare during a stranding event (IWC 2016a).

The assessment of stranded cetacean welfare should be an important part of the decision-making process during strandings response, ensuring that appropriate intervention occurs and minimising further welfare compromise (IWC 2016a). However, this first requires the identification of practically measurable animal- (physical, physiology and behaviour) and resource-/management-based indicators, and their monitoring at a range of strandings, so that these can be assessed for their feasibility and reliability before being applied in a WAF (Beausoleil and Mellor 2017; Harvey et al. 2020). Furthermore, the validity of indicators should be assessed based on how well they reflect welfare state to ensure appropriate interpretation of outcomes in WAFs. This is best achieved through scientific links between indicators and impacts upon each domain, for example by correlating externally observed indicators with known physiological changes or pathological findings, potential subjective affective states can be inferred (Fraser 2008; Fernandez et al. 2017). However, in cases where data is limited, expert knowledge can be used to provide consensual and face validity to such indicators (Phythian et al. 2011; Campos-Luna et al. 2019).

Until now there have been no WAFs implemented at cetacean strandings, since comprehensive, systematically collected data on both animal- and resource-/management-based indicators are lacking. Although some welfare-relevant indicators have been noted (Table 1.3), such data is not routinely evaluated and/or reported on. In the few regions where strandings response personnel are trained in clinical assessments (e.g., Cape Cod, USA), some welfare-relevant evaluations are undertaken to inform decision-making, though these have tended to focus on survival prognoses (Sampson et al. 2012; Sharp et al. 2014). These clinical assessments have included behavioural observations (alertness, responsiveness, body posturing, vocalisations, arching and thrashing), physical examinations (heart rate, respiratory rate, thoracic/abdominal auscultation, wound evaluation, ocular and blowhole examination) and blood analyses (Sampson et al. 2012; Sharp et al. 2014). However, in general, limited information has been provided on how these indicators have been assessed and the relative importance of the outcome of each indicator's evaluation to inform decision-making remains unknown. Systematically collecting animal- and resource-/management-based data at each stranding event will enable a comprehensive appraisal of practically measurable and reliable indicators that have the potential to inform decision-making. Importantly, improved understanding and filling of this knowledge gap may enable welfare-relevant data to be collected in areas where personnel with clinical training are limited.

Table 1.3 Suggested welfare-relevant indicators from the scientific literature which may have applicability to live stranded cetaceans.

Indicator	**Indicator type**	**Reference**
Body posturing, arching, thrashing	Behavioural	Townsend 1999; Geraci and Lounsbury 2005; Sampson et al. 2012; Sharp et al. 2014
Visual laterality	Behavioural	Karenina et al. 2010, 2013; Blois-Heulin et al. 2012; Siniscalchi et al. 2012; Leliveld et al. 2013
Reflexes- eye, blowhole	Behavioural	Townsend 1999; Geraci and Lounsbury 2005; Brakes et al. 2006; Gales et al. 2008b; Sampson et al. 2012; Barnett et al. 2014; Sharp et al. 2014
Vocalisations	Behavioural	Sampson et al. 2012; Sharp et al. 2014
Heart rate	Physiological	Gales et al. 2008b; Sampson et al. 2012; Sharp et al. 2014; Gulland et al. 2018

Temperature	Physiological	Geraci and Lounsbury 2005; Gales et al. 2008b
Respiratory type and rate	Physiological	Gales et al. 2008b; Sampson et al. 2012; Sharp et al. 2014; Gulland et al. 2018
Skin condition and rake marks	Physiological	Waples and Gales 2002; Van Bressem et al. 2009; Marley et al. 2013; Gulland et al. 2018
Ocular and blowhole examination	Physical	Sampson et al. 2012; Sharp et al. 2014; Gulland et al. 2018
Body condition score/ blubber thickness	Physical	Joblon et al. 2014; Clegg et al. 2015
Wound evaluation	Physical	Geraci and Lounsbury 2005; Sampson et al. 2012; Sharp et al. 2014; Gulland et al. 2018
Amount of time stranded	Resource	Geraci and Lounsbury 2005
Human intervention	Management	Geraci and Lounsbury 2005; Gales et al. 2008b; Gulland et al. 2018

1.3 Assessing survival likelihood

Humans often intervene in situations where survival of marine wildlife is considered to be at risk, this often occurs due to anthropogenic activities, such as oil spills (Newman et al. 2003; Ruoppolo et al. 2013; Orós et al. 2016), entanglement in fishing gear or debris (van der Hoop et al. 2014; Adimey et al. 2014; Butterworth 2016; Butterworth and Sayer 2017; Dolman and Moore 2017), collisions with watercraft (Lightsey et al. 2006) and habitat displacement (Derocher et al. 2013). Intervention may also occur due to human concern for animals in natural situations, such as orphaned seal pups (Barnett et al. 2000) and when ill or injured (Geraci and Lounsbury 2005; Kruuk 2006). These interventions typically include rescue, rehabilitation and release of animals, and have become common practise in many areas (Pyke and Szabo 2018; Innis et al. 2019). However, there is limited data available on the long-term survival of animals following release and little is known about the implications of human intervention on these individuals (Lunney et al. 2004; Cooper and Cooper 2006; Moore et al. 2007; Guy and Banks 2012; Wells et al. 2013; Guy et al. 2014; Adimey et al. 2016; Cope et al. 2022).

To be successful, rescue and/or rehabilitation, and release, should include triage assessments, to evaluate both an animals likelihood to survive and its welfare state (Hall 2005; Kelly et al. 2011; Cope et al. 2022). These triage assessments should evaluate whether an animal can be released and/or rehabilitated or if its state of debilitation requires end-of-life decision-making (Meredith 2017). This should include veterinary examination of health, e.g., body condition, disease screening and injury assessment (Mellish et al. 2006; Vogelnest 2008; Barlow et al. 2010; Kelly et al. 2010) and behavioural assessments, e.g., locomotion, foraging ability and predator avoidance, to consider survival-critical factors (Tribe and Brown 2000; Beck et al. 2007). Such assessments require knowledge of species biology and behaviour (Miller 2012) and should be expedited to minimise suffering (Kelly et al. 2011; Cope et al. 2022).

For animals considered viable, further situation-related factors, such as environmental conditions (weather, time of year and site suitability), which may affect survival should be considered (Tribe et al. 2005; Mullineaux and Keeble 2017; Cope et al. 2022). Nevertheless, even suitable release candidates may become compromised due to being handled and surrounded by humans throughout the intervention process, which may lead to short term behavioural abnormalities (Tyson Moore et al. 2020). Such impacts can affect their survival likelihood, as well as welfare long-term (Mullineaux and Keeble 2017; Cope et al. 2022). In some cases, animals should not be released following assessment due to low survival likelihood or significantly compromised welfare (Molony et al. 2007; Mullineaux and Keeble 2017). In these cases, end-of-life decision-making, such as euthanasia, should be implemented.

1.3.1 Factors affecting cetacean post-stranding survival

Decision-making at cetacean stranding events should also be informed by assessments of an animal's likelihood to survive, with viable cetaceans being re-floated, and those with low survival likelihood undergoing end-of-life procedures, such as euthanasia or palliative care. However, there are limited data on prognostic indicators for stranded cetacean survival likelihood. This is due, in part, to a lack of post-release monitoring at most stranding events (Gales et al. 2012; Sampson et al. 2012; Wells et al. 2013; Sharp et al. 2016; Tyson Moore et al. 2020), which means the outcomes of strandings response generally remain unknown. Instead rescue attempts at stranding events are often considered 'successful' if an animal is re-floated (Ogle 2017). However, re-floatation of a stranded cetacean does not indicate survival, indeed many animals have re-stranded following re-floatation (Wiley et al. 2001; Brownlow et al. 2015a; Hunter et al. 2017). Furthermore, although post-mortem examination of non-surviving cetaceans is often undertaken, limited studies have compared live prognostic indicators with observed pathology (Câmara et al. 2020).

A number of factors are likely to affect cetacean survival likelihood following a stranding, including pre-existing illness, time spent on the beach, thermal stress and, any natural and anthropogenic stranding induced conditions, such as capture myopathy, trauma and shock (Gales et al. 2008b, 2012; Cowan and Curry 2008; Sampson et al. 2012; Wells et al. 2013; Sharp et al. 2014; Fernandez et al. 2017). Based on pre-existing health, mass stranded animals are more likely to survive than single stranded animals (Geraci and Lounsbury 2005; Bogomolni et al. 2010). Yet the effects of the stranding event itself, including human intervention, likely compromise the welfare of even healthy individuals and reduce their survival likelihood (Herráez et al. 2013; Câmara et al. 2020). In fact, some studies have shown short term abnormal behaviour, such as increased swim speeds, following re-floatation, likely reflecting a period of acclimation due to stranding and human intervention (Pulis et al. 2018; Tyson Moore et al. 2020).

Constructing reliable prognostic indicators for survival likelihood requires increased data collection on animal physical state, physiology, and behaviour, as well as considering environmental factors and the context of intervention procedures (Wiley et al. 2001; Gales et al. 2008b; O'Brien et al. 2014; Cope et al. 2022). These data can then be integrated with post-release monitoring (Guy and Banks 2012), such as through mark-recapture (Grogan and Kelly 2013; Guy et al. 2013) and tagging (Llewellyn 2003; Green et al. 2005; Cross et al. 2009) to provide an evaluation of triage assessments and intervention that was undertaken (Cope et al. 2022). However, few studies have correlated such parameters with post-stranding survival. Furthermore, these studies found that health parameters did not always correctly predict post-stranding survival (Sampson et al. 2012; Sharp et al. 2014), indicating that whilst useful, these assessments would benefit from further improvement (Zagzebski et al. 2006; Sharp et al. 2014, 2016).

Furthermore, in cases where animals do not survive, detailed post-mortem data collection can be integrated with the indicators observed ante-mortem to provide an enhanced understanding of how the indices may reflect an animal's state (Fernandez et al. 2017; Câmara et al. 2020). Such work would improve knowledge on the predictive value of animal- and resource-/management-based indicators for assessing survival likelihood (Molony et al. 2007) and would ensure appropriate intervention procedures are employed (Pyke and Szabo 2018; Cope et al. 2022). Unfortunately, the current lack of systematic data collection at live strandings precludes such studies, hampering improvements to survival likelihood assessments and generating uninformed intervention decisions.

1.4 Euthanasia

The word euthanasia is derived from the Greek 'eu' meaning good, and 'thanatos' meaning death. The basic concept of euthanasia is therefore a good death, through the humane ending of life. The Royal College of Veterinary Surgeons defines euthanasia as "painless killing to relieve suffering" (RCVS 2019), whilst the American Veterinary Medical Association (AVMA) defines it as "the use of humane techniques to induce the most rapid, painless and distress-free death possible" (Leary et al. 2020). The latter definition was adopted by the International Whaling Commission (IWC) in 2014 at a workshop relating to cetacean euthanasia (IWC 2014). Euthanasia is employed to humanely kill debilitated and/or moribund animals, both wild and domesticated. There is contention around the use of euthanasia where humane killing of animals that are no longer of use to humans (e.g., laboratory animals, shelter animals) occurs, since these animals may not be in ill-health (Pavlovic et al. 2011).

Euthanasia not only relates to the events at an animal's death, but also considers the use of pre-euthanasia techniques, such as sedatives, as well as the handling of the animals and appropriate disposal of animal remains (Leary et al. 2020). Methods employed should result in a rapid loss of consciousness followed by cardiac arrest and the loss of brain function and, should minimise the level of anxiety or distress experienced by the animal prior to loss of consciousness. Though the AVMA guidelines on euthanasia are consistently used, it has been recognised that the methods considered as acceptable by AVMA (Leary et al. 2020) may not always be appropriate to the situation, e.g., in free-ranging wildlife, and that all possible methods should be implemented in the most humane way rather than leaving an animal to suffer (Julien et al. 2010; Barco et al. 2016).

1.4.1 *Euthanasia methods applied to animal species*

Methods of euthanasia cause death by disrupting the function of the central nervous system, which can be achieved through three mechanisms: physical disruption, functional disruption (chemical and electrical) and deprivation (e.g., hypoxia) (Leary et al. 2020). The methods of euthanasia have been reviewed and classified by AVMA (Leary et al. 2020), based on being 'acceptable', 'acceptable under certain conditions' or 'unacceptable'. A number of criteria have been used to assess the classification (Leary et al. 2020), including: ability to euthanise with minimum pain and distress, time-to-death or time to insensibility (loss of consciousness; TTD), reliability, safety (personnel, environment and other animals e.g., scavengers), irreversibility, compatibility with intended use (species, age, size, post-mortem use of tissue), effect on observers, and availability of equipment e.g., drugs and legal requirements.

It is imperative that insensibility (loss of consciousness) and death of the animal are confirmed following euthanasia procedures; the techniques of doing so will vary depending on the methods applied and the species being euthanised (Leary et al. 2020). The methods of euthanasia that are employed will vary depending on the species and the environment that euthanasia is carried out under, as well as the availability of trained personnel, equipment, and laws in the country. The types of euthanasia described by AVMA include inhaled agents, chemical and physical methods (see Leary et al. 2020 for a review).

Inhaled agents for euthanasia involve vapours or gases, where animals are kept in an enclosed space allowing gases to reach a high concentration in their blood; this may take time and could adversely affect welfare (Leary et al. 2020). These gases can be dangerous to human health but have been widely used on a range of animals, both unwanted (Noell and Chinn 1950; Sharp et al. 2006) and farmed species (Enggaard Hansen et al. 1991; Raj and Gregory 1996; Jongman et al. 2000; Webster and Fletcher 2004; Gerritzen et al. 2006; Dalmau et al. 2010).

Chemical euthanasia through parenteral administration (Leary et al. 2020) is commonly used for laboratory animals, companion animals and some wildlife. The route of injection differs depending on the species, the drug being used and the conscious state of the animal (Grier and Schaffer 1990; Mahl et al. 2000; Jackson et al. 2011; Harms et al. 2014; Gutierrez et al. 2016). It will also depend on the risk to personnel involved

(Weese and Jack 2008) and the possibility of relay toxicity in the environment and to scavengers (O'Rourke 2002; Campbell et al. 2009; Bischoff et al. 2011).

There are several ways to physically kill, which have been applied to a wide range of animals and scenarios, including laboratory, farming, domesticated, wildlife in captivity and free-ranging wildlife. These include shooting (Longair et al. 1991; Blackmore et al. 1995b, a; Hampton et al. 2014b; Shearer 2018), decapitation (Holson 1992), cervical dislocation (Carbone et al. 2012), captive bolt (Gilliam et al. 2012; Shearer 2018), electrocution (Anil and McKinstry 1991, 1992), exsanguination (Gregory and Shaw 2000), and stunning and pithing (Appelt and Sperry 2007). When used appropriately by skilled personnel, taking account of anatomical differences (Grandin 2002), physical methods may cause less fear and anxiety in animals, and be more rapid and practical than chemical or inhalant agents (Leary et al. 2020). However, these methods typically augment risk to personnel (e.g., from ricochet bullets) and if not undertaken by sufficiently trained personnel can result in animals being injured rather than killed, adversely affecting their welfare.

1.4.2 Euthanasia at cetacean stranding events

The conditions under which euthanasia of a marine mammal may be necessary can be challenging and may be further complicated by the large size of some species. Euthanasia may occur in captive settings due to illness or injury (Miller et al. 2008; Barnett et al. 2014; Silpa et al. 2015) and generally involves chemical methods. At cetacean stranding events, end-of-life decision-making, including euthanasia or palliative care, should always be considered an option for animals in poor welfare states and/or with low survival likelihood. In these stranding situations a combination of both physical and chemical methods has been applied (Dunn 2006; Coughran et al. 2012).

Methods for euthanasia of stranded cetaceans remain variable, with limited empirical data and a general lack of guidelines to inform personnel at stranding events (Barco et al. 2016; Stringfellow et al. 2022). Chemical euthanasia can be complex; large quantities of agents are often required and trained personnel are essential for administration (Barco et al. 2016). Furthermore, the position of stranded cetaceans and vasoconstriction of peripheral vessels — which often occurs in debilitated animals (Greer et al. 2001) — can cause complications. Additionally, chemicals may bioaccumulate in the environment, leading to potential secondary toxicosis (Greer and Rowles 2000; O'Rourke 2002; Bischoff et al. 2011; Harms et al. 2014).

Physical methods used on stranded cetaceans include ballistics (Blackmore et al. 1995b; Hampton et al. 2014b) and explosives (Coughran et al. 2012; IWC 2014). These methods aim to cause significant disruption to the brain stem and/or sever the spinal cord at the occipital condyles (Greer et al. 2001). Explosives are not commonly employed (Coughran et al. 2012), due to the significant human safety risk, the need for skilled licensed personnel, and legal requirements. However, in the case of large whale strandings where debilitated animals are likely to endure prolonged suffering, such cranial implosion may be the most effective, humane method (IWC 2014).

Ballistics euthanasia is more common at strandings (Barco et al. 2016). Due to cetacean cranial anatomy, with the melon and thick skull at the forefront, orientation of firearm discharge to access the occipital condyles (Figure 1.2) is recommended to be lateral (between the eye and pectoral fin at eye level) or dorso-ventral (aiming posterior to the blowhole at 45˚ caudo-ventral) (Blackmore et al. 1995b). Unfortunately, there is a general lack of data regarding the use of physical methods for cetacean euthanasia, along with some conflicting recommendations (Barco et al. 2016), which appear further complicated by the availability of different firearm calibres and ammunition types (IWC 2014).

There has been little assessment as to the humaneness and efficacy of the methods, based on the duration and intensity of suffering that occurs before the animal loses consciousness (Leary et al. 2020). It is recommended that multiple criteria be evaluated to indicate insensibility and likely death, including lack of reflexes, loss of jaw tone, no capillary refill time and ocular/skin temperature differentials (Butterworth et al. 2004a; Brakes et al. 2006). Yet, there have been limited studies to validate these criteria against stages of insensibility or death (Knudsen 2005). The lack of data collection on stranded cetacean euthanasia events leaves a gap in knowledge regarding the efficacy and humaneness of euthanasia methods being employed.

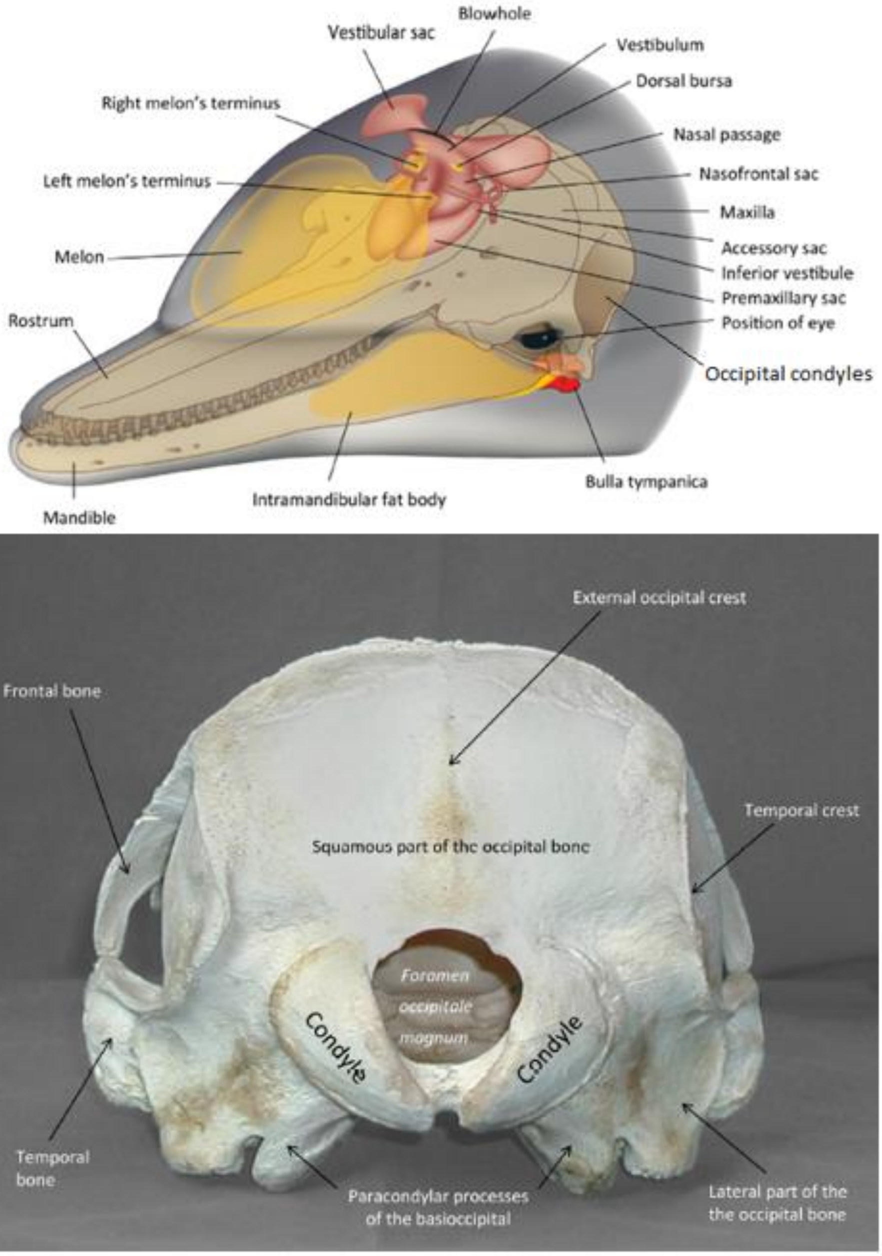

Figure 1.2 Anatomical diagram in oblique view (top) and caudal view (below) of delphinid cranial anatomy, showing the placement of occipital condyles at the base of the skull (Cozzi et al. 2016).

1.5 Rationale and significance of study

The current lack of data relating to the welfare implications of stranding and human intervention, and the unknown survival of 'rescued' individuals, leaves uncertainty as to whether conservation and animal welfare outcomes are achieved. Therefore, it is crucial that welfare and survival relevant data are systematically collected and analysed at cetacean stranding events to ensure scientifically-informed decision-making. Due to the high incidence of strandings, New Zealand provides an unprecedented opportunity to investigate the application of welfare science alongside conservation biology. The research steps in this thesis are guided by a protocol for developing wildlife welfare assessments (Harvey et al. 2020). This ensured the development of a comprehensive and robust foundation on which welfare science can be integrated alongside conservation at cetacean stranding events.

1.5.1 Aims and objectives

This thesis will provide an understanding of how by applying animal welfare science at cetacean stranding events, animal welfare and conservation outcomes can be improved. As such, the overarching aim of this thesis is to undertake the first steps towards the development of a conceptual framework to facilitate the practical integration of welfare science alongside conservation biology at strandings. Ultimately, the findings of this thesis will bridge significant knowledge gaps by generating novel foundational data for the scientific study of stranded cetacean welfare, stimulating future interdisciplinary studies. Furthermore, results of this research will be fundamental in the future development of a welfare assessment framework (WAF) to scientifically inform decision-making, leading to effective, ethical strandings management. To achieve this aim, five key research objectives of this thesis are presented:

1) Characterise welfare and survival likelihood in terms of stranded cetaceans and highlight major knowledge gaps and key concerns likely to affect individual animals.
2) Identify and provide face validity to potential feasible welfare and survival relevant indicators for stranded cetaceans.
3) Ascertain the feasibility of potential welfare indicators, providing preliminary welfare assessments in stranding situations and highlighting welfare concerns.
4) Evaluate current management procedures for undertaking end-of-life decision-making and technically enacting euthanasia of stranded cetaceans.
5) Assess current euthanasia procedures and potential welfare outcomes to ensure the use of appropriate techniques and equipment for humane outcomes.

1.5.2 *Thesis structure*

This thesis is organised into eight chapters (Table 1.4), which comprise six research chapters (Chapters 2–7), that are written in publication format and represent manuscripts that are either published or currently in peer-review with international journals. While this has led to some unavoidable repetition, particularly in relation to introduction and method sections, duplication has been reduced where possible.

In Chapter 1 (present chapter), the background to the thesis topic is introduced and the overarching context of the research is set in terms of the relevant literature, as well as identifying the critical knowledge gaps. Here, my thesis aims, and objectives are outlined.

In Chapter 2, an exploration of the conceptualisation of welfare and survival likelihood in the context of cetacean strandings are presented. Major knowledge gaps and key concerns, as perceived by experts in conservation biology, animal welfare science and veterinary medicine, are also identified. This chapter is a reformatted version of a published manuscript in *Diversity* (Boys et al. 2022b) co-authored by NJ Beausoleil, MDM Pawley, KE Littlewood, EL Betty, and KA Stockin.

In Chapter 3, the opinions of the same group of experts are presented to identify and provide face validity to valuable and practical indicators of stranded cetacean welfare and survival likelihood. This chapter is a reformatted version of a published manuscript in *Royal Society Open Science* (Boys et al. 2022d). This manuscript was co-authored by NJ Beausoleil, MDM Pawley, KE Littlewood, EL Betty, and KA Stockin.

In Chapter 4, potential welfare indicators for stranded cetaceans are identified at live pilot whale stranding events around New Zealand. Animal- and resource-/management-based indicators are qualitatively and quantitatively evaluated to understand their feasibility for use in welfare assessments, providing the first insights into a range of welfare-relevant parameters for stranded cetaceans. This chapter is a reformatted version of a published manuscript in *Animals* (Boys et al. 2022a) that was co-authored by NJ Beausoleil, MDM Pawley, EL Betty, and KA Stockin.

In Chapter 5, the feasible welfare indicators are applied at a live stranding event of pygmy killer whales to undertake a holistic welfare assessment and identify potential welfare concerns. Specifically, insights are provided into the potential welfare implications of ballistics euthanasia for stranded cetaceans, and key research priorities for end-of-life decision-making are highlighted. This chapter also provides data on potential relationships among observed welfare indicators and pathology. This chapter is a reformatted version of a manuscript under peer-review within *Marine Mammal Science* (Boys et al. In review), that was co-authored by S Hunter, EL Betty, B Hinton, and KA Stockin.

In Chapter 6, end-of-life management decisions for stranded cetaceans across New Zealand and Australia are reviewed. Current standard operating procedures guiding these decisions are analysed and key recommendations are provided to ensure the best animal welfare outcomes. This chapter is a reformatted version of a published manuscript in *Marine Policy* (Boys et al. 2022c) that was co-authored by NJ Beausoleil, EL Betty and KA Stockin.

In Chapter 7, euthanasia methods and their associated animal welfare implications are investigated at a global scale to provide further context to end-of-life management at strandings and highlight areas to improve the welfare outcomes for stranded cetaceans requiring such interventions. This chapter is a reformatted version of a published manuscript in *Animals* (Boys et al. 2021) that was co-authored by NJ Beausoleil, EL Betty and KA Stockin.

In the final chapter (Chapter 8), the key findings of this thesis are synthesised, and discussed to produce a cohesive narrative outlining the novel scientific contributions to the emerging discipline of conservation welfare. Importantly, the findings will be pivotal in facilitating scientifically-informed strandings management. As such, the management implications are discussed, and future research priorities identified.

Table 1.4 Thesis chapter structure, outlining the purpose and methods applied.

Chapter	**Purpose**	**Method**
1 Introduction	Establish the context of the research Introduce relevant literature Highlight knowledge gaps Outline the thesis objectives	Literature review

2 Conceptualising welfare and survival likelihood and key concerns	Achieve objective 1 Conceptualise welfare and survival likelihood Identify major knowledge gaps Highlight key concerns	Literature review Delphi method Reflexive thematic analysis
3 Identifying indicators of welfare and survival likelihood	Achieve objective 2 Identify indicators Ascertain indicator value and practicality	Literature review Delphi method Reflexive thematic analysis
4 Evaluating feasibility of welfare indicators	Achieve objective 3 Identify observable/measurable indicators at stranding events Evaluate indicator feasibility Provide baseline data on indicators	Literature review Video footage analysis Qualitative and quantitative evaluation
5 Evaluating welfare indicators and investigating welfare concerns	Achieve objective 3 Provision of additional data on feasible indicators Assessment of euthanasia-related welfare concerns Describe potential relationships among indicators and pathology	Literature review Video footage analysis Qualitative and quantitative evaluation Histopathology
6 Exploring end-of-life decision-making	Achieve objective 4 Evaluate current guidance for end-of-life decisions Provide recommendations to improve welfare	Literature review Evaluation of Standard Operating Procedures
7 Investigating euthanasia	Achieve objective 5	Literature review

	Investigate current euthanasia methods and associated humaneness Provide recommendations to improve welfare	Review unpublished database
8 Conclusions	Synthesise key findings Demonstrate novel contributions Describe implications of the research Describe knowledge gaps Identify future research priorities	Literature review Self-reflection of research

Chapter 2 Fundamental concepts, knowledge gaps and key concerns relating to welfare and survival of stranded cetaceans

Rebecca M. Boys examines stranded sperm whales (*Physeter macrocephalus*) that died following live mass stranding.
Photo credit: Deborah Casano-Bally.

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Abstract

Wildlife management can influence animal welfare and survival, although both are often not explicitly integrated into decision-making. This chapter explores fundamental concepts and key concerns relating to the welfare and survival of stranded cetaceans. Using the Delphi method, the opinions of an international, interdisciplinary expert panel were gathered, regarding the characterisation of stranded cetacean welfare and survival likelihood, knowledge gaps and key concerns. Experts suggest that stranded cetacean welfare should be characterised based on interrelated aspects of animals' biological function, behaviour, and mental state and the impacts of human interventions. The characterisation of survival likelihood should reflect aspects of stranded animals' biological functioning and behaviour as well as a 6-month post-re-floating survival marker. Post-release monitoring was the major knowledge gap for survival. Welfare knowledge gaps related to diagnosing internal injuries, interpreting behavioural and physiological parameters, and euthanasia decision-making. Twelve concerns were highlighted for both welfare and survival likelihood, including difficulty breathing and organ compression, skin damage and physical traumas, separation from conspecifics, and suffering and 'stress' due to stranding and human intervention. These findings indicate inextricable links between perceptions of welfare state and the likely survival of stranded cetaceans and demonstrate a need to integrate welfare science alongside conservation biology to achieve effective, ethical management at strandings.

Keywords: Animal welfare; Conservation decision-making; Delphi; Expert opinion; Management; Marine mammals; Wildlife

2.1 Introduction

Wildlife management and decision-making are most often conservation-focused, despite increasing recognition that animal welfare can affect the outcomes of management decisions if not considered in parallel (Dubois et al. 2017; Beausoleil et al. 2018; Hampton et al. 2019). Traditionally, conservation and wildlife management have focused on assessing population fitness, yet animal welfare is usually considered to be a property of the individual animal. Importantly, survival does not necessarily mean good welfare (Paquet and Darimon 2010; Ashley and Holcombe 2011; Kaurivi et al. 2020), and poor animal welfare can negatively impact conservation efforts by reducing fitness (Dickens et al. 2010; Germain et al. 2017) and even survival itself (Armstrong et al. 1999). Therefore, to achieve optimal outcomes for wildlife, a multidisciplinary approach to management that includes the consideration and assessment of both welfare and survival is required (Beausoleil et al. 2018; Clegg et al. 2021).

Consideration of both welfare state and survival likelihood is particularly important in cases where humans engage with wildlife likely to be in distress. Such interventions include rescue and/or rehabilitation and release of animals (Pyke and Szabo 2018; Innis et al. 2019). In many cases, intervention may improve animal welfare, by returning animals to wild environments, providing vital medical treatment or performing humane killing (sometimes termed euthanasia) (Meredith 2017). Additionally, human intervention may be used as a tool to improve survival as part of a wider conservation strategy (Pettett and Yates 2005; Guy et al. 2014; Nelms et al. 2021). However, there is limited knowledge regarding the immediate and longer-term effects of human interventions on welfare and survival for many species (Lunney et al. 2004; Wells et al. 2013; Guy et al. 2014; Adimey et al. 2016). In particular, systematic, science-based evaluations of welfare state and survival likelihood are lacking (Hall 2005; Molony et al. 2007). Such assessments are required to inform decisions regarding appropriate interventions, including whether an animal is suitable for release (Hall 2005) or if end-of-life decisions, such as euthanasia or palliative care, should be undertaken (Meredith 2017).

Live cetacean strandings are a classic exemplar of wildlife management situations that involve human intervention but for which there is limited empirical evidence to inform management decision-making. Cetacean strandings are a global phenomenon (Hamilton

2018; Mazzariol et al. 2020; Clarke et al. 2021) that appear to occur both naturally (Bradshaw et al. 2006; Arbelo et al. 2013) and due to anthropogenic activities (Bernaldo de Quiros et al. 2019; Simonis et al. 2020). The physical state of live stranded cetaceans can range from animals appearing outwardly healthy to those that are clinically ill or moribund (Gales 1992; Stockin et al. 2009; Sharp et al. 2014). Despite the often-compromised state of the animals, most stranding events focus on attempts to 'rescue' the animals by re-floating them. Yet, the current lack of empirical data informing response procedures (Moore et al. 2018a) means that appropriate intervention (Barnett and Bexton 2017) may not be reliably undertaken. This has been identified as a major potential concern for cetacean welfare (IWC 2016a; Nelms et al. 2021) and one for which further work is needed to develop optimal response procedures (IWC 2016a).

The first step to address this lack of data is to develop an understanding of the fundamental concepts relating to the welfare and survival of stranded cetaceans. This is particularly important since the disciplines of conservation biology and animal welfare science have generally emphasised different facets of welfare. The former has tended to focus on fitness and the latter on 'feelings' (i.e., affective experiences) and fitness (Dubois and Fraser 2013; Papastavrou et al. 2017; Beausoleil et al. 2018; Clegg et al. 2021) which can lead to different practical approaches to welfare assessments (Fraser et al. 1997). There is also a need to identify the degree to which knowledge exists to support evaluations of welfare state and survival likelihood, and to identify the key factors or features of stranding and/or human intervention likely to affect stranded cetacean welfare and survival.

An initial way to acquire such data is to harness the expertise of those working in various relevant interdisciplinary fields. Previously, expert opinion has been used to identify welfare issues and indicators for several terrestrial mammals (Bracke et al. 2008; Phythian et al. 2011; Rioja-Lang et al. 2020) and to inform wildlife management policies (O'Neill et al. 2008; IJsseldijk et al. 2018). Concerning the management of live stranded cetaceans, expert opinion can provide consensual and face validity to concepts relevant to the development of practical assessments of welfare and survival (Patyk et al. 2015). Such information can then be applied in the field and re-evaluated for further refining.

This chapter aimed to develop consensual and face validity through expert opinion on (1) fundamental concepts relating to the characterisation of stranded cetacean welfare and likelihood of survival, (2) current knowledge gaps that hamper the ability to assess stranded cetacean welfare and the likelihood of survival, and (3) key concerns about stranded cetacean welfare and the likelihood of survival. The self-declared area of expertise within the expert panel was also explored to understand whether this influenced the way welfare and survival likelihood are understood, the knowledge gaps considered to be important and the key concerns to be addressed. These data can be applied to develop in-field welfare and survival likelihood assessment protocols to inform cetacean stranding response.

2.2 Methods

2.2.1 The Delphi method

The Delphi method is a questionnaire-based approach that enables structured group communication among experts to explore complex issues (Hasson et al. 2000; Mukherjee et al. 2015). It consists of two or more iterative rounds of questionnaires, with summarised responses from expert respondents informing the next round of questions (Bracke et al. 2008; Orsi et al. 2011; Eycott et al. 2011; Mukherjee et al. 2015; Rioja-Lang et al. 2019a, b). The questionnaires are structured to enable review of previous questions. This allows for the confirmation and revision of responses, ensuring an accurate representation of opinions. A particular strength of the Delphi method is that respondents remain anonymous to each other, reducing the potential for social bias, and allowing both formal and informal knowledge to be collected in a transparent manner (MacMillan and Marshall 2006).

A two-round online Delphi process was employed using the questionnaire tool Qualtrics (2005) to explore concepts relating to stranded cetacean welfare and survival likelihood. Expert opinion on fundamental concepts, knowledge gaps and key concerns relating to the welfare and survival of stranded cetaceans were elicited using an exploratory sequential mixed method design (Creswell and Creswell 2017). The findings from the first round (mainly open-ended questions) were subsequently used to inform the development of the second round (predominantly closed-ended questions) (Keeney et al. 2010). To achieve the aims of this chapter, the findings reported here pertain to the quantitative and qualitative data from the second round and the quantitative data from the first round.

2.2.2 *Recruitment and characterisation of expert participants*

Invited participants (n = 168) were identified as experts in the fields of cetacean biology/ecology and/or wild animal welfare by first searching the peer-reviewed literature, documents from related workshops and stranding network lists. The inclusion of stranding network lists and workshops ensured that individuals who may not have published peer-reviewed research but who still have extensive in-field experience (e.g., senior first responders/medics) were included. Prospective respondents were contacted via email and provided with a detailed information sheet regarding the project (Appendix 1) as well as an invitation to participate. The email also included an anonymous link to the questionnaire on Qualtrics, where experts provided their consent to participate. All participants were invited to both rounds although there was no requirement to complete both, and individual responses from the first questionnaire were not personally linked to responses from the second. Therefore, some participants who provided scores in the second round for data generated from the first round may not have participated in the generation of those data in the first round and vice versa (MacMillan and Marshall 2006; Mehnen et al. 2013).

2.2.3 *Questionnaire design and implementation*

Data collection was conducted between February and April 2021. The first questionnaire was available for participants to complete for 15 working days, after which time the questionnaire closed, and no further responses were accepted. Three weeks later, the second questionnaire was initiated for 30 working days (Delbecq et al. 1975; IJsseldijk et al. 2018).

Prior to initial questionnaire distribution, a pilot study was conducted. A draft Qualtrics questionnaire was completed by four participants, two with expertise in animal welfare science and two in cetacean biology/ecology. Participants were asked to assess question clarity, questionnaire useability and the amount of time required to complete. These results were used to refine the questions and format for the final questionnaires sent to expert participants in rounds one and two. Pilot data were not included in the final dataset.

2.2.3.1 Final questionnaire design implementation

No identifiable data were collected, ensuring full anonymity (McKenna 1994; Hasson et al. 2000). Each questionnaire contained three questions regarding the demographics of the participants. This information was collected to assess the variety of expertise and geographical coverage of the participants. Experts were asked to self-identify their area of expertise by choosing a single pre-defined category in a closed question, based on which they felt was most applicable: 'cetacean expert (including cetacean conservation and biology)', 'animal welfare expert (including animal welfare science, welfare/animal ethics)', 'cetacean expert with knowledge and/or focus on welfare', 'animal welfare expert with knowledge and/or focus on cetaceans', 'veterinarian' or 'other'. Participants were also asked for their current field of work (open-ended question) and region of work (closed-ended question).

Aside from the questions on demographics, each questionnaire was split into two sections: the first related to the welfare of stranded cetaceans and the second to their survival. Similar questions were asked in each section relating to (1) characterising welfare or survival, (2) knowledge gaps relevant to welfare or survival and (3) key concerns regarding welfare or survival. The first questionnaire applied a mixture of twelve unstructured, open-ended questions and two closed-ended questions. Responses to the latter were made on a continuous numerical scale (0–10, measured to two decimal places) and reflected the perceived usefulness of currently available knowledge to assess stranded cetacean welfare and survival (Appendix 2). The questions with continuous scalar responses in the first questionnaire offered the option to choose "Not applicable" if an expert felt that they did not have sufficient knowledge about the currently available information. Participants were also encouraged to provide any additional comments if desired.

Following completion of data collection from the first questionnaire, I worked independently to review the responses. All responses were recorded as intelligent verbatim transcription and, using reflexive thematic analysis, common ideas for each topic were collated into major themes (Braun and Clarke 2006, 2019). Major theme collations were subsequently reviewed by myself and the supervisory team to generate final major themes for each topic (Appendix 4). These themes were subsequently used in the development of the second, quantitative questionnaire. Due to the large number of themes identified for some topics (e.g., key concerns regarding survival), a maximum of 20 major themes per topic were provided as categories for scoring in the second questionnaire, minimising questionnaire fatigue whilst maximising data collection (Lavrakas 2008). In such cases, themes were identified for subsequent inclusion as 'categories' based on their common nomination by expert participants, as well as being the most important and relevant elements for the chapter as identified by myself and supervisors (Braun and Clarke 2012).

The second round required participants to review and score multiple major categories within each topic using a semi-structured questionnaire (Appendix 3; Orsi et al. 2011). Twelve closed-ended questions with continuous scalar responses (0–10) and five open-ended questions were provided. All questions with a scalar response, except those characterising welfare or survival, contained an option to select "Don't know" if experts felt they had insufficient knowledge to score a particular theme. The major categories to be scored within each topic were presented in a randomised order among participants to remove possible bias from a list that may otherwise have appeared ranked (Choi and Pak 2005; Lavrakas 2021). That is, within a single topic (e.g., key survival concerns), up to 20 major categories (e.g., 20 different survival concerns) were presented for scoring, and the order in which these appeared varied for each participant.

Participants were encouraged to provide any additional comments throughout the questionnaire. In addition to these comments, qualitative data were collected regarding the barriers perceived by experts to hinder assessment of how key concerns may affect welfare or survival.

2.2.3.2 Characterising concepts of stranded cetacean welfare and survival

In the first questionnaire, participants were asked to explain, in their own words, what 'animal welfare/well-being' and 'survival likelihood' mean to them in relation to stranded cetaceans. These answers were collated into major themes which were provided back to participants in the second questionnaire as 'categories' to score their importance for characterising stranded cetacean welfare or survival likelihood. Scoring was on a continuous scale (0–10) where '0 = No importance', '5 = Some importance', and '10 = Great importance' for each of the categories.

2.2.3.3 Highlighting knowledge gaps for assessing stranded cetacean welfare and survival

In the first questionnaire, participants were asked to score, on a continuous scale of 0–10, the usefulness of the body of information currently available to undertake assessments of stranded cetacean welfare or survival likelihood, where ‘0 = Not useful at all’ and ‘10 = Very useful’. Participants were subsequently provided with the opportunity to identify, in their own words, the most significant knowledge gaps (i.e., the gaps that, if filled, would improve the ability to assess stranded cetacean welfare or survival likelihood). For each of the major themes arising from the open responses in the first questionnaire, participants were asked to score (as categories in the second questionnaire) their agreement that filling that knowledge gap would improve the ability to assess stranded cetacean welfare or survival likelihood, where ‘0 = Would not improve’ and ‘10 = Would greatly improve’.

2.2.3.4 Identifying key concerns regarding the welfare and survival of stranded cetaceans

Concerns identified by participants in the first questionnaire were collated into themes for welfare and survival likelihood and provided in the second questionnaire as ‘categories’ for scoring. Participants scored the extent to which each category may be expected to affect welfare or survival likelihood on a continuous scale from 0 to 10 where ‘0 = This will not have an effect’, ‘5 = This will have a bad effect’ and ‘10 = This will have a severely bad effect’.

Participants were also asked to score the extent to which knowledge is currently available to assess how each of these categories affects the welfare or survival likelihood of stranded cetaceans with ‘0 = Knowledge is insufficient’, ‘5 = Some knowledge is present’ and ‘10 = Knowledge is complete’. Finally, participants were invited to provide their opinions on any barriers to determining how these categories affect stranded cetacean welfare or survival likelihood.

2.2.4 Analysis of data

The quantitative data collected in questionnaire 1 were used to calculate descriptive statistics (median, range, mean and mode) to provide an overall impression of how useful experts consider the existing information to be for assessing welfare or survival likelihood. Additionally, to examine whether there were differences in opinion regarding the usefulness of information among participants based on their background, the rank for raw scores were calculated from three expertise super-groups: (1) cetacean experts ('cetacean expert including cetacean conservation and biology' and 'cetacean experts with knowledge and/or focus on welfare'), (2) welfare experts ('animal welfare expert including animal welfare science, welfare/animal ethics' and 'animal welfare expert with knowledge and/or focus on cetaceans') and (3) veterinarians. The rank scores of each group for welfare or survival likelihood were compared using Kruskal–Wallis non-parametric tests to account for the unequal group sizes.

For each of the major categories presented in the second questionnaire regarding (1) characterisation of welfare or survival likelihood, (2) knowledge gaps and (3) key concerns, the median score and range were calculated. Higher median scores for categories within a topic reflected (1) greater relative importance of the category for characterising welfare/survival likelihood; (2) higher agreement that filling the knowledge gap would improve the ability to assess welfare/survival likelihood; and (3) greater level of concern that the category affects welfare/survival likelihood, respectively. When calculating median scores, responses of "Don't know" were not included.

Similarly, median scores and ranges were calculated for experts' perceptions of the sufficiency of knowledge available to assess each of the key welfare and/or survival likelihood concerns presented in questionnaire 2. This enabled an appraisal of the relationship between the level of concern and the perceived sufficiency of knowledge about that specific concern, using a Spearman's rank correlation test.

Quantitative data from the categories in questionnaire 2 were collected on a continuous scale, as this has been suggested to be more precise for questionnaires examining people's subjective perceptions (Chyung et al. 2018). However, to evaluate consensus among experts, the raw scores for each category were pooled into four groupings (score: 0–3.99; 4–6.99; 7–10; "Don't know"). Consensus was considered reached when at least 70% of participants provided a score within the same group (Sumsion 1998; Campos-Luna et al. 2019; Whittaker et al. 2021).

Qualitative data regarding barriers to assessing key concerns presented in questionnaire 2 were investigated using reflexive thematic analysis to collate common themes (Braun and Clarke 2006, 2019). These themes are presented to provide context for interpretation of the experts' views on the sufficiency of current knowledge regarding specific concerns about welfare or survival likelihood.

To visualise whether self-identified participant expertise influenced the scoring of categories within each topic, linear discriminant analyses (LDA) was applied in R (V. 1.2.5033) using package MASS (Venables and Ripley 2013) on the raw scores for each topic from questionnaire 2. Where experts responded, "Don't know", data imputation was undertaken using the mean score for that category, which was calculated across the expertise group, ensuring sufficient data to undertake multivariate analysis. The LDA generated orthogonal axes that maximally separated the six expertise groups based on the participants' scores for each category within a topic. The first two axes of the LDA were used to provide a visual representation of differences and similarities, based on overlap, among expertise groups in relation to the major categories within each of the topics. Figures were prepared using the ggplot2 package (Wickham 2009).

2.3 Results

Of the 168 experts invited to participate, 40.5% (n = 68) participated in the first round, representing seven regions: Europe (n = 27; 40%), Oceania (n = 17; 25%), North America (n = 15; 22%), South America (n = 4; 6%), Asia (n = 3; 4%), Central America (n = 1; 1%) and Africa (n = 1; 1%). These participants reported primary expertise in cetacean conservation and biology (n = 18; 26%), veterinary medicine (n = 16; 24%), animal welfare science/ethics (n = 11; 16%), cetacean biology with a focus on welfare (n = 11; 16%) and animal welfare with a focus on cetaceans (n = 2; 3%). A further 10 chose 'other' with four (6%) of these involved in active stranding response.

In the second round, 37.5% (n = 63) of experts participated. These experts represented the same seven regions in approximately the same proportions: Europe (n = 26; 41%), Oceania (n = 19; 30%), North America (n = 10; 16%), South America (n = 4; 6%), Central America (n = 2; 3%), Africa (n = 1; 2%) and Asia (n = 1; 2%). Their reported expertise was in veterinary medicine (n = 20; 32%), cetacean conservation and biology (n = 16; 25%), cetacean biology with a focus on welfare (n = 12; 19%), animal welfare science/ethics (n = 9; 14%) and animal welfare with a focus on cetaceans (n = 3; 5%).

three (5%) participants chose ‘other’ and noted being involved in stranding response or broader ecology.

2.3.1 Characterising concepts of stranded cetacean welfare and survival likelihood

Twelve major themes were generated from the reflexive thematic analysis for characterising the concept of ‘welfare/well-being’ as it relates to stranded cetaceans, and seventeen major themes were identified for characterising survival likelihood. All these themes were provided to participants in the second round for scoring as categories. Ten of the welfare categories and seven of the survival likelihood categories were considered by more than 70% of the participants to be of great importance (scores ≥7; Table 2.1). No categories reached consensus as being unimportant for characterising welfare or survival likelihood.

Table 2.1 The major categories for characterising the concepts of welfare and survival likelihood arising from reflexive thematic analysis of participant responses to questionnaire 1, and median score and range for each category from questionnaire 2. Categories are ranked by the percentage of experts that scored them as having great importance for characterising the concepts (score in ≥7 grouping). Those categories above the bold line reached consensus (≥70%).

Welfare Category	**Median Score (Range)**	**% Experts Scored ≥7**	**Survival Likelihood Category**	**Median Score (Range)**	**% Experts Scored ≥7**
Pain and suffering, distress, stress, or fear	10.0 (5.7–10.0)	98.4	Animal alive 6 months after stranding	9.3 (1.2–10.0)	94.3
Physical state and well-being, health, injury, and disease status	10.0 (3.7–10.0)	93.7	Animal returns to normal life and full functioning in its natural environment	9.7 (4.9–10.0)	90.6
Normal physiology and homeostasis	9.1 (4.7–10.0)	91.9	Animal alive 1 year after stranding	10.0 (0.4–10.0)	90.4
Appropriate decision-making about re-floating or euthanasia, and targeted rescue/re-floatation efforts to prioritise animal welfare	9.2 (2.2–10.0)	88.7	Animal is able to respond and cope with natural conditions to ensure its survival	9.0 (4.6–10.0)	86.0

Physical comfort/discomfort	9.1 (2.6–10.0)	87.3	Animal returns and socially re-integrate with its conspecific group/pod	8.9 (4.8–10.0)	84.9
Animal’s experience/perception of situation, mental or psychological state or well-being, affective states, or feelings	8.4 (1.8–10.0)	82.5	Animal returns to pre-stranding life and health status	9.4 (4.1–10.0)	84.6
Ability to live in normal/natural social and environmental conditions or habitat	9.1 (0.5–10.0)	80.6	Animal’s health condition, disease and illness status	8.8 (4.7–10.0)	77.4
Overall well-being or quality of life	9.6 (0.0–10.0)	80.6	Animal alive 1 month after stranding	8.2 (3.8–10.0)	69.8
Treatment and care by humans, including during stranding response	8.7 (3.5–10.0)	73.3	The chance that the animal survives after stranding	8.7 (0.0–10.0)	66.0
Normal, natural, or wild behaviour	8.3 (0.8–10.0)	71.0	Cause of stranding still present	8.4 (1.0–10.0)	65.4
Sufficient food and water	8.0 (0.1–10.0)	65.5	Animal does not re-strand within days of re-float	8.0 (0.5–10.0)	62.3

Human activities in environment	6.9 (0.1–10.0)	49.2	Response of animal when re-floated	7.3 (1.6–10.0)	62.3
			Survival is affected by species and size	7.7 (1.8–10.0)	60.4
			Animal's body condition	7.3 (1.0–10.0)	60.4
			Animal does not die of stranding related injuries or damage	7.8 (0.6–10.0)	54.9
			Avoids suffering	7.0 (0.9–10.0)	54.2
			The number of re-stranded animals	7.1 (0.0–10.0)	51.9
			Animal survives after re-floating	7.0 (0.6–10.0)	49.1

2.3.2 *Knowledge gaps for assessing stranded cetacean welfare and survival likelihood*

In the first questionnaire, experts rated the knowledge currently available to assess stranded cetacean welfare as being somewhat useful, with a median score of 6.5 (range = 2–10; mean = 6.5, mode = 5, n = 53). The other fifteen (22%) experts responded with 'NA' to this question. The expertise group did not affect perceived usefulness scores (Kruskal–Wallis: H(46) = 6.23; P = 1.0), with a mean rank usefulness score of 30.1 for welfare experts, 27.0 for cetacean experts and 31.0 for veterinarians. Fifteen major themes were identified from reflexive thematic analysis as significant welfare knowledge gaps; all were presented as categories for scoring in the second round. Nine of these categories were scored by at least 70% of experts as greatly important knowledge gaps, i.e., if addressed, they would greatly improve the ability to assess welfare (scores ≥7 grouping; Table 2.2).

The knowledge currently available to assess survival likelihood was judged to be somewhat useful (median = 5.1; range = 1.3–10; mean = 5.7, mode = 4, n = 44) in the first questionnaire. A further 24 (35%) experts responded 'NA' to this question. No effect of expertise group on perceived usefulness of knowledge was detected (Kruskal–Wallis: H(40) = 3.20; P = 1.0), with a mean rank usefulness score of 28.2 for welfare experts, 18.3 for cetacean experts and 24.1 for veterinarians. Eighteen major themes were identified from reflexive thematic analysis as significant knowledge gaps; all were presented as categories for scoring in questionnaire 2. Of these, only 'lack of post-release monitoring' was scored as greatly important (score ≥7 grouping) by at least 70% of experts in the second questionnaire (Table 2.2).

Table 2.2 The major categories for knowledge gaps, that if addressed, would greatly improve the ability to assess stranded cetacean welfare and survival likelihood arising from reflexive thematic analysis of participant responses to questionnaire 1, and median score and range for each category from questionnaire 2. Categories are ranked by the percentage of experts that strongly agreed that filling the knowledge gap would improve the ability to assess welfare/survival likelihood (scores in ≥7 grouping). Categories above the bold line reached consensus (≥70%).

Welfare Knowledge Category	**Median Score (Range)**	**% Experts Scored ≥7**	**Survival Likelihood Knowledge Category**	**Median Score (Range)**	**% Experts Scored ≥7**
Understanding the health and disease status of the animal	8.5 (3.3–10.0)	84.1	Lack of post-release monitoring to measure survival outcomes	9.1 (4.7–10.0)	78.8
How to make decisions about when and how to euthanise stranded cetaceans	9.3 (0.7–10.0)	83.6	Ability to diagnose diseases and infections on the beach	8.4 (0.4–10.0)	66.7
Ability to diagnose internal injuries ante-mortem, including capture myopathy	9.0 (5.2–10.0)	82.5	Ability to determine presence of myopathy	8.4 (2.0–10.0)	63.0
Post-release monitoring to understand survival, outcomes, or success of re-floatation	9.1 (4.2–10.0)	82.0	Lack of data for species-specific survival	8.1 (1.2–10.0)	62.3

Collection and documentation of empirical data to assist triage/decision-making	8.6 (1.1–10.0)	82.0	How to make decisions about when and how to euthanise stranded cetaceans	8.1 (0.5–10.0)	62.3
Ability to assess physiological indicators and recognise deviations from normal/baseline	8.9 (2.0–10.0)	82.0	Lack of knowledge on the links between survival and welfare	8.2 (0.0–10.0)	60.4
Lack of specialist/expert advice and consultation from those with field experience and veterinarians	8.8 (4.0–10.0)	81.0	Ability to triage current state/condition	8.1 (3.0–10.0)	60.4
Ability to interpret stranded cetacean behaviour in terms of welfare state	8.7 (0.9–10.0)	74.6	Lack of knowledge on the links between external assessments and pathology	8.1 (3.0–10.0)	60.4
Ability to assess body condition	8.0 (2.0–10.0)	71.4	Lack of knowledge of treatments and their effectiveness	8.1 (0.1–10.0)	56.6
Assessment and interpretation of indicators of neurological state and responsiveness/sensibility	8.2 (1.1–10.0)	69.8	Lack of knowledge about hearing impairments	7.2 (0.0–10.0)	53.8

Effects of species, animal size and features of the stranding (geographical location and duration) on welfare	8.1 (1.9–10.0)	69.5	Lack of trained and skilled responders	7.7 (4.3–10.0)	50.9
Lack of information, education, and awareness for potential responders about if, when and how to respond	8.3 (0.3–10.0)	68.3	Lack of knowledge about causes and prevention of strandings and effects of local ecosystem changes	7.1 (0.0–10.0)	47.2
Ability to assess what animals feel or their mental state	7.6 (0.9–10.0)	60.3	Lack of data on the effects of conspecifics presence on survival	6.5 (1.0–10.0)	43.4
Causes of stranding and how to prevent stranding	8.0 (0.0–10.0)	58.1	Ability to assess internal body temperature	7.1 (1.0–10.0)	41.5
Understanding social support and communication among animals	7.5 (1.3–10.0)	54.0	Ability to assess body condition and blubber thickness	6.7 (0.6–10.0)	40.7
			Lack of standardised protocols to follow	6.8 (0.0–10.0)	40.7
			Lack of normal/baseline blood parameters and profiles	6.6 (0.0–10.0)	39.6

	Lack of data on species distribution	4.4 (0.0–10.0)	24.5

2.3.3 Key concerns about stranded cetacean welfare and survival likelihood

2.3.3.1 Level of concern that the category affects welfare or survival likelihood

Thirty-seven themes were identified from reflexive thematic analysis for concerns about the welfare and, likewise, about survival likelihood from the responses provided in the first questionnaire. From these, 19 major categories were presented for welfare and 20 major categories were presented for survival likelihood. Of these, 12 categories overlapped as concerns for both welfare and survival likelihood (bold in Table 2.3).

Participants scored all 19 categories as having 'bad' to 'severely bad' effects on welfare (median scores >6; Table 2.3). Eight of these were scored by at least 70% of participants as having severely bad effects on welfare (scores in ≥7 grouping; Table 2.3). Similarly, all 20 major categories were scored as having a 'bad' to 'severely bad' effect on survival likelihood (median scores >5; Table 2.3). Four of these categories were scored as having 'severely bad' effects on survival likelihood by over 70% of the experts (scores in ≥7 grouping; Table 2.3).

Table 2.3 The major categories for concerns about welfare and survival likelihood arising from reflexive thematic analysis of participant responses to questionnaire 1, and median score and range for each category from questionnaire 2. Categories are ranked by the percentage of experts that scored them as having severely bad effects (scores in ≥7 grouping). Categories above the bold line reached consensus (≥70%). Concern categories that overlapped for welfare and survival likelihood are shown in bold.

Welfare Concern Categories	**Median Score (Range)**	**% Experts Scored ≥7**	**Survival Likelihood Concern Categories**	**Median Score (Range)**	**% Experts Scored ≥7**
Physical damage, stress, pain, and thermal discomfort due to overheating, hyperthermia, heat stroke and hypothermia	9.4 (5.3–10.0)	91.2	**Animal suffering from illness, disease, and underlying health conditions**	9.0 (3.8–10.0)	86.8
Difficulty breathing, inhalation of water	9.6 (4.4–10.0)	86.4	Length of time stranded and number of re-strandings	9.2 (4.3–10.0)	83.0
Delays to deciding on euthanasia to relieve suffering	8.7 (5.0–10.0)	74.1	**Difficulty breathing, inhalation of water**	9.1 (4.3–10.0)	79.3
Separation from conspecifics/social group, including mother–calf separation	8.0 (0.6–10.0)	72.9	**Availability of appropriate and timely human intervention and handling, responder training and experience**	8.7 (0.0–10.0)	73.1

Pain and suffering due to physical injury or trauma caused by stranding, particularly substrate	8.2 (2.0–10.0)	72.4	**Feasibility and speed of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety**	8.7 (0.0–10.0)	69.8
Effects of gravity, body weight, pressure on animal’s organ function and physiology and causing internal injuries and pain as a result of not being supported by water	9.0 (2.0–10.0)	72.4	Cause of stranding still present	8.6 (1.9–10.0)	69.8
Suffering, stress, and anxiety associated with stranding	8.2 (1.8–10.0)	72.4	**Physical injury or trauma caused by stranding**	8.2 (2.7–10.0)	65.4
Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun	8.5 (1.0–10.0)	71.2	**Effects of gravity, body weight, pressure on animal’s organ function and physiology and causing internal injuries and pain as a result of not being supported by water**	8.7 (0.0–10.0)	65.4
Pain and its management	8.1 (0.4–10.0)	69.5	**Body condition and nutritional status**	8.0 (2.2–10.0)	60.4

Inappropriate human intervention, poor handling, responder training and experience, and public pressure influencing decisions	8.9 (2.4–10.0)	69.0	Abnormal movements and reduced limb function	8.0 (1.8–10.0)	60.4
Fear, stress, distress, or helplessness at being unable to move or help themselves	8.0 (1.2–10.0)	67.8	**Weather and environmental conditions, including tides**	7.5 (2.5–10.0)	55.8
Animals suffering from illness, disease, and underlying health conditions	8.6 (0.3–10.0)	67.2	Geographical location of stranding and being out-of-habitat or range	8.0 (1.1–10.0)	53.9
Feasibility of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety	8.5 (0.4–10.0)	62.1	Animal awareness and neurological status	7.5 (0.0–10.0)	52.9
Nutritional stress, poor body condition	7.7 (0.5–10.0)	59.3	**Stress, anxiety, and associated conditions caused by stranding**	7.4 (1.2–10.0)	50.9
Stress, fear, distress, or pain caused by human presence, interactions, noise	7.2 (0.5–10.0)	56.9	**Effect of species biology on survivorship**	7.0 (1.6–10.0)	47.1

Fear and stress at being in a strange, novel environment	7.2 (0.7–10.0)	53.5	**Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun**	6.9 (0.8–10.0)	45.3
Fear and pain from predation	7.3 (0.8–10.0)	46.6	**Separation from conspecifics/social group**	6.9 (1.6–10.0)	41.5
Effect of species biology, resilience, and stranding type on welfare outcomes	7.0 (0.5–10.0)	40.4	Presence of predators and scavengers	6.9 (2.0–10.0)	39.6
Weather and environmental conditions	6.2 (1.0–10.0)	37.9	Substrate/terrain at the stranding location	6.3 (0.0–10.0)	39.6
			Animal age based on length/weight and reproductive status	5.5 (0.8–10.0)	33.3

2.3.3.2 *Knowledge available to assess how various concerns affect welfare and survival likelihood of stranded cetaceans*

In terms of the 19 welfare concern categories presented, moderate knowledge (median range: 3.0–7.1) was considered to be available, and all were judged to have at least a ‘bad’ effect on welfare. Participants considered more knowledge to be available regarding concerns about the animal’s physical status, such as difficulty breathing, illness/disease, nutritional stress, skin damage, thermal status, and about the feasibility of undertaking rescue/re-floatation (Figure 2.1). In contrast, experts considered less information to be available regarding concerns related to animals’ mental status. The welfare concern categories perceived to have the least available knowledge (median scores ≤ 5) related to animal fear, “stress”, and pain. A moderate positive monotonic correlation was found between the participants’ rating of the level of concern and the available knowledge for welfare categories (Spearman’s Rank Correlation: $r_s(17) = 0.51$; $P = 0.03$), supporting a general trend for participants to report less relative concern about welfare categories for which they perceive less information to be available, although concern was high for all categories.

Similarly, of the 20 survival likelihood concern categories presented, moderate knowledge (median ranges: 4.4–7.0) was considered to be available, and all concerns were judged to have at least a ‘bad’ effect on survival likelihood. Participants considered that more knowledge was available related to concerns about the animal’s physical status, including illness/disease, difficulty breathing, skin damage and body condition, as well as about the length of time stranded, number of re-strandings and the feasibility of stranding response (Figure 2.2). In contrast, experts considered the least knowledge to be available related to animal awareness and neurological status (median score 4.4). A moderate correlation was found between the participants’ rating of the level of concern and the available knowledge for survival-related themes ($r_s(18) = 0.55$; $P = 0.01$), suggesting lower concern about survival likelihood categories for which less information is available, although concern was strong for all categories.

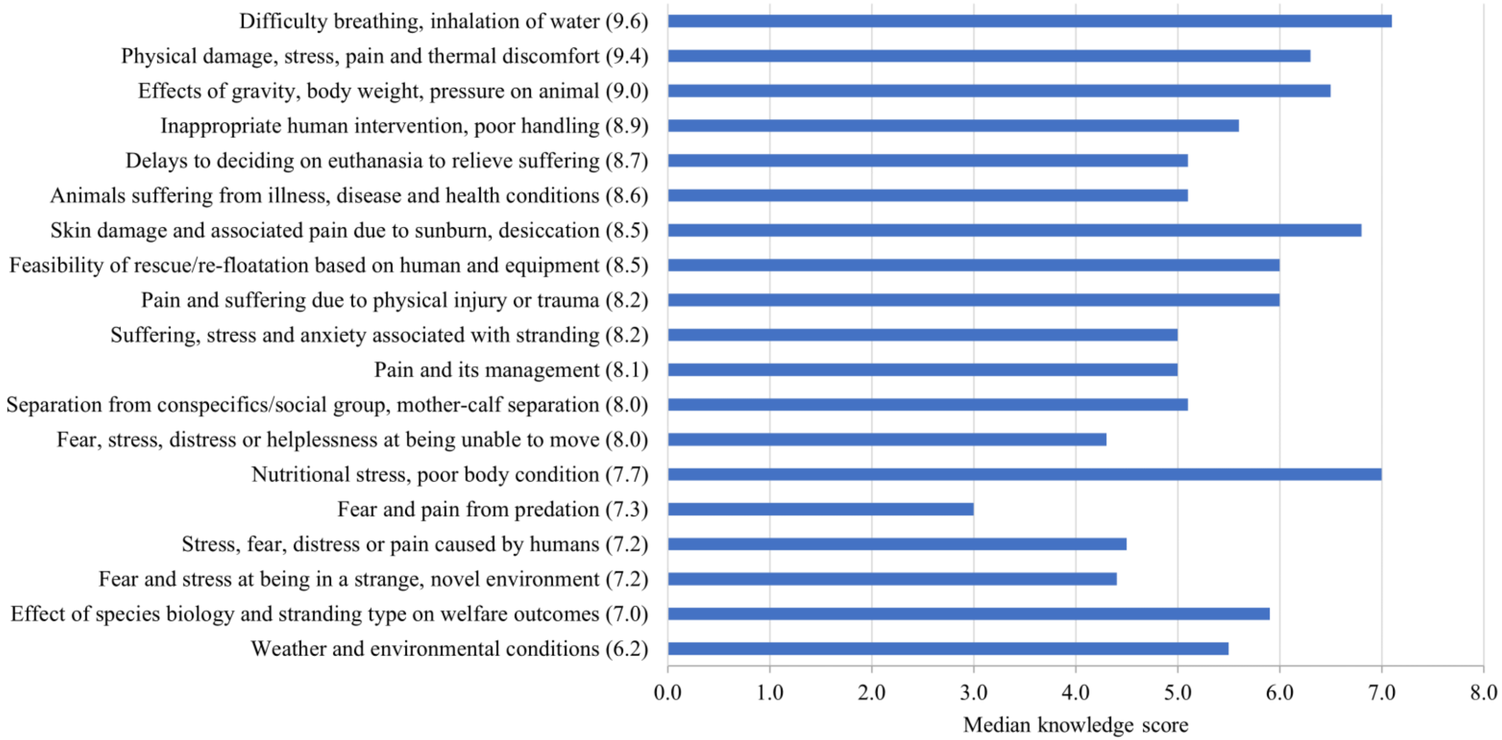

Figure 2.1 The median scores for the perceived level of knowledge available to assess concern categories about welfare. Ranked in order of the median scores for the perceived severity of the effect of each concern category (in parentheses) on cetacean welfare, arising from participants' responses on questionnaire 2. Category labels have been reduced to best fit; refer to Table 2.3 for full category labels.

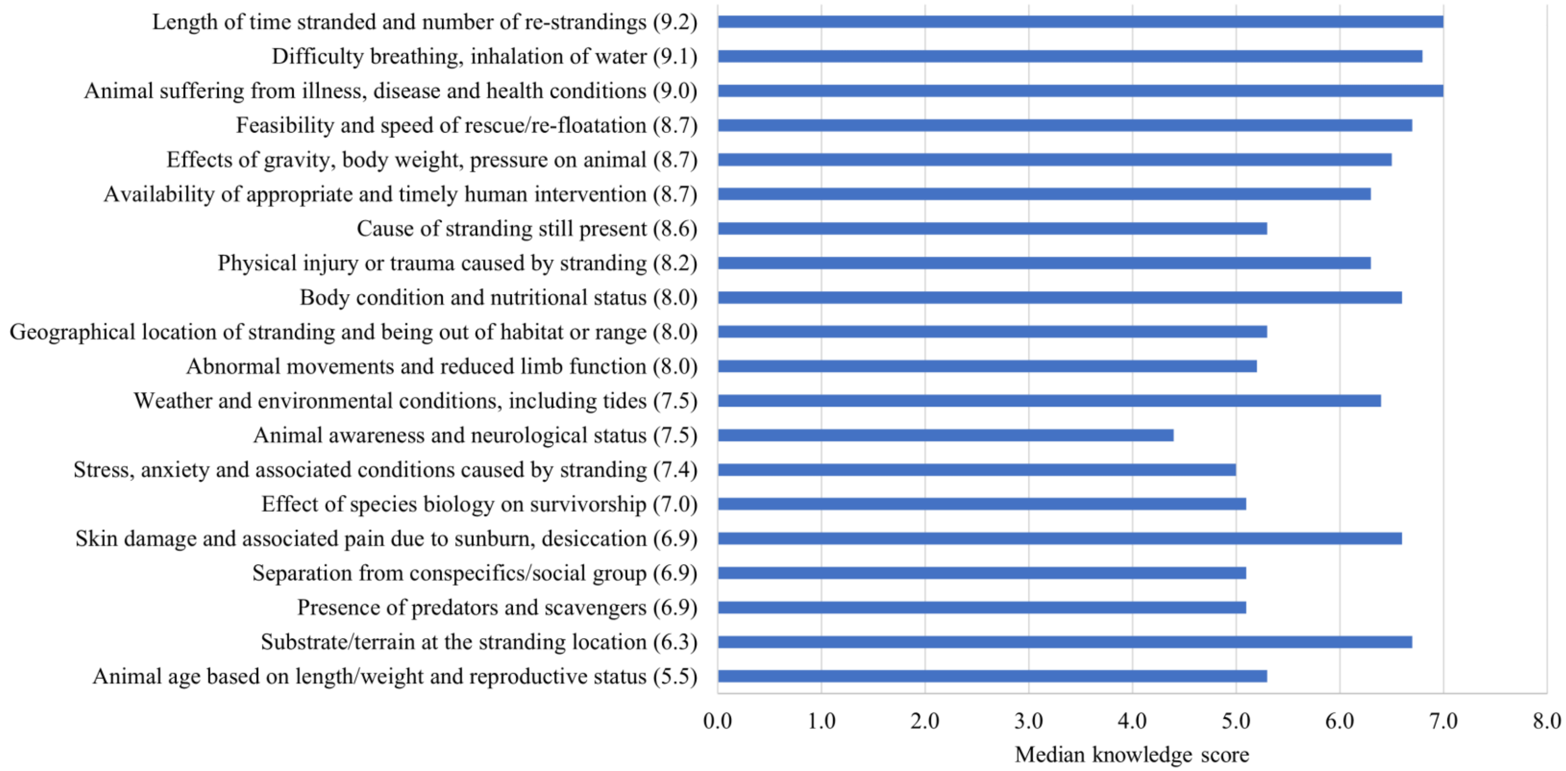

Figure 2.2 The median scores for the perceived level of knowledge available to assess concern categories about survival likelihood. Ranked in order of the median scores for the perceived severity of the effect of each concern category (in parentheses) on cetacean survival likelihood, arising from participants' responses on questionnaire 2. Category labels have been reduced to best fit; refer to Table 2.3 for full category labels.

2.3.3.3 Barriers to assessing concerns about welfare and survival likelihood of stranded cetaceans

For welfare, 25 participants (40%) provided written answers regarding barriers to assessing the effects of concerns presented in questionnaire 2. Three major themes were found from the reflexive thematic analysis of these qualitative responses:

- Skills/training/knowledge of responders;
- Complexity of factors influencing welfare;
- Lack of knowledge/data to enable welfare assessments.

Experts suggested a major barrier to determining how the welfare of stranded cetaceans might be affected relates to the skills, training, and knowledge of personnel on the beach carrying out assessments and stranding responses. Approximately one-third of experts who provided comments noted that in many instances, those responding to the animals are members of the public with no or limited experience/training. For example, one participant noted:

"Very often decisions may be taken by individuals or representatives of organisations that have very little knowledge and have failed to contact those that have the requisite skills and knowledge. [...]"

Related to this, in the question on welfare, participants highlighted that the amount of knowledge and available resources vary geographically:

"Large geographical difference. e.g., stranding response in Australia and NZ is likely high, with many trained volunteers. Same in EU, but not at all for Africa and Asia."

Related to the inadequacy and variability in responder knowledge and training, it was emphasised that no single welfare concern will occur in isolation at a stranding, and that it is important to understand the complexity of factors influencing the welfare of stranded cetaceans. One participant noted:

"Many of these topics occur in a gradation and/or categories are well known in one aspect but not in others (e.g., how size affects large whales compared to smaller cetaceans) or short term or shallow water grounding may have minimal effects, but long term may have greater effects. In addition, an animal that is grounded longer term

but also experiences hyperthermia will have compounding effects that cannot necessarily be teased apart."

Finally, the paucity of knowledge available to assess the welfare state of individual stranded cetaceans emerged as a barrier. In particular, there is a need for improved knowledge and data on measurable indicators of welfare to understand the impacts of stranding. This is reflected by one participant, with regard to understanding welfare concerns:

"Fundamentally, if we accept the current paradigm that welfare is a function of multiple layers, from the basic ability to breathe right up to maintaining a complex positive cognitive state, itself a function of multiple influences, then we quickly run up against a wall of what we can measure. If we can't measure something we then have to extrapolate the effect of what it means to the individual based on what we know in other mammals, including humans. We struggle to do this with cetaceans for all the obvious reason, so the barriers are that—what we can measure, and if we can't measure it, how reliable we think our estimates are."

Similar sentiments were expressed by other participants. For example:

"In my opinion, we need more foundational knowledge of indicators of affective states in cetaceans, before we can then assess how each of the above issues affect welfare. [….] Large datasets with post-release monitoring and post-mortem data are the only way to see whether our welfare assessments on the beach are accurate."

Regarding survival likelihood, only 14 participants (22%) provided written answers regarding barriers to assessing the effects of the concerns presented in questionnaire 2. Three major themes were found from the reflexive thematic analysis of these qualitative responses:

- Lack of data regarding survival likelihood and the need for post-release monitoring;
- Complexity of factors influencing survival likelihood;
- Skills/training/knowledge of responders.

A major barrier to determining how the survival likelihood of stranded cetaceans might be affected by concerns relates to the need for further monitoring of animals that are released to assess survival. For example:

"One of the biggest problems is that there is little study of the successfully rescued and refloated animals—there is more knowledge from the dead animals via necropsies. Tagging animals at refloat can create further stress and should never delay a refloat and the data received back is limited. Using data taken from animals in captivity can be hyped and provide incomplete guidance for wild animals due to the unnatural habitat. So, the biggest barrier to understanding how these factors really affect survival is that we know little about those that do survive and how they react to their stranding experience."

It was also highlighted that many concerns will not occur in isolation and determining how each may influence survival likelihood can be complex. One participant noted:

"Many of these items are difficult to separate and actually determine how much impact each individual indicator may have."

The ability to assess these concerns was emphasised, by several participants, to be hindered by the lack of knowledge and necessity to have trained, skilled personnel on the beach to undertake assessments. For example:

"Ability to assess some of these aspects, having trained people in place to take out the assessments"

2.3.4 Agreement across disciplines

Overall, LDAs revealed overlap among expertise groups in the scoring of categories within every topic in round two, suggesting that self-reported expertise did not have a major effect on the scoring of categories (results presented in Appendix 5). Therefore, results specific to expertise group were not further analysed, and results presented for each topic were based on the median scores and consensus of all participants.

2.4 Discussion

The primary aim of this chapter was to explore how experts understand animal welfare and survival likelihood in the context of cetacean strandings, their main concerns about stranded cetacean welfare and survival likelihood, and the knowledge gaps they feel need to be filled to improve our ability to assess welfare and likelihood of survival in such contexts. Overall, the results highlight how both welfare and survival are understood to be complex and multi-faceted. These multiple dimensions need to be considered when trying to understand the state of a stranded cetacean to inform management decisions. Experts considered many concerns to have negative ('bad' or 'severely bad') effects on stranded cetacean welfare and survival likelihood. Generally, the available knowledge was considered to be somewhat useful for assessing welfare and survival likelihood. Key barriers to improving assessment included a lack of empirical data about the state of stranded animals and post-release monitoring. Notably, the level of available knowledge seemed to influence the level of concern experts reported about specific issues.

2.4.1 Fundamental concepts of stranded cetacean welfare, concerns, knowledge gaps and barriers

Ten of the 12 major categories generated from reflexive thematic analysis of expert opinions were considered by the experts to be important for understanding stranded cetacean welfare, reaching consensus and with median scores of greater than eight. Many of these categories reflected the animal's physical state in terms of health, injury, disease, physiology, and comfort, as well as the animal's own experience of the situation including various negative mental states, such as "pain", "suffering", "distress", "stress", and "fear" and overall 'quality of life'.

Even though most of the experts did not identify themselves as animal welfare scientists, these categories are consistent with contemporary frameworks for understanding and assessing animal welfare. Animal welfare science now often conceptualises welfare to be the property of the individual animal, based on the animal's experience of its own life in terms of its mental state (Mellor 2016; Beausoleil et al. 2018). For example, for a physical aspect to be considered important for an animal's welfare, it must be likely that it is impacting upon the animal's mental state. Therefore, animal welfare applies only to those species that are sentient, including cetaceans (Marino et al. 2007; Broom 2013; Butterworth 2017; Clegg et al. 2018; Muka and Zarpentine 2021; Marino and White 2022), and that can experience both positive and negative mental states depending on their circumstances (Duncan 2006; Fraser 2008; Broom 2013; Mellor 2016; Beausoleil et al. 2018; Ledger and Mellor 2018).

Contemporary animal welfare science, therefore, considers the interrelated aspects of biological functioning—reflecting the animal's internal state—and its current circumstances, as well as behaviour, and the cumulative impacts that these have on the animal's mental (affective) state (Boissy et al. 2007; Mellor 2012, 2016). In this chapter, almost all these aspects were generated by experts unprompted and subsequently confirmed as important categories. This suggests that the welfare of stranded cetaceans is understood by those working in relevant fields to be consistent with contemporary animal welfare science. The findings also suggest that experts believe welfare should be approached considering the likely perspective of the individual animal (Mellor 2016). Overall, the results indicate that the welfare of stranded cetaceans should be approached holistically and assessed in a multidisciplinary manner. The way in which these concepts are conceived will influence how they are assessed and which features are emphasised when evaluating outcomes (Beausoleil et al. 2018).

Contrary to expectation, while the category 'Sufficient food and water' was considered important by experts based on the median score (8.0), it did not reach consensus (scored ≥7 by 65.5%). This is notable, since it is a common factor in most animal welfare assessments (Clegg et al. 2015; Dalla Costa et al. 2016; Beausoleil and Mellor 2017). The lack of consensus may have been due to experts feeling that it was not as relevant for the context of cetacean strandings, where animals are in an abnormal environment and unable to feed. Additionally, some cetaceans are known to feed minimally during migration and instead use nutritional reserves (Braithwaite et al. 2015). Therefore, experts may perceive that the inability to feed or obtain water during a relatively short stranding event, involving a cetacean in good nutritional condition or that fed prior to stranding, may not have a significant impact on welfare. However, in contrast, an animal in poor nutritional condition or that has not fed in the days prior to stranding may suffer additional compounding welfare impacts when already experiencing a negatively valenced welfare state (Beausoleil and Mellor 2017).

Based on expert consensus, the subjective affective states of stranded cetaceans may be affected by the animal's physical state (health and biological functioning) and behaviour as well as the impacts of its surrounding environment including stranding response procedures (see below). Therefore, stranded cetacean affective states may be inferred by cautiously interpreting measurable or observable indicators of these categories. Systematic frameworks that guide the interpretation of welfare indicators in this way are well-established in animal welfare science. A commonly utilised framework is the Five Domains Model for animal welfare assessment (Mellor et al. 2020), which systematically facilitates consideration of impacts in each of three physical/functional domains (nutrition, physical environment and health), the behavioural interactions animals may have (Domain Four), and the associated impacts these conditions have on the animal's affective state (Domain Five). This allows for scientifically grounded and transparent evaluation of affective states that are not directly measurable (Mellor et al. 2009a; Mellor and Beausoleil 2015; Beausoleil and Mellor 2017; Mellor 2017; Beausoleil et al. 2018). By applying such frameworks to cetacean strandings, we can use empirical data about the animals' welfare states to inform decision-making and ensure the most appropriate intervention for the welfare of the stranded cetacean.

Many of the concerns directly related to physical state would be due to a stranded cetacean being out of its natural environment and unable to alleviate or avoid the factors of concern. Importantly, all these physical concerns matter in terms of welfare as they are likely associated with negative affective experiences such as "stress", "pain" and "suffering". For example, hyperthermia, sunburn, and skin damage may occur simultaneously and will likely cause "pain" and "discomfort"; this suffering may severely impact welfare when strandings occur on summer days and/or during bright, sunny conditions. These physical impacts also have the potential to lead to dehydration and hypovolemic shock in stranded cetaceans (Groch et al. 2018; Harms et al. 2018), which are expected to lead to other negative affective states. Likewise, organ compression, occurring when the animal's weight is not supported whilst out of the water (Thewissen et al. 2009; Harms et al. 2018), can lead to pulmonary lesions and congestion (Mazzariol et al. 2015). These conditions may be associated with the negative state of breathlessness (Beausoleil and Mellor 2015b). Furthermore, rhabdomyolysis of the skeletal and cardiac muscle may occur, followed by acute renal failure (Fernandez et al. 2017), which could be painful.

Additionally, pre-existing health conditions were also highlighted to be an important welfare concern. These can have detrimental impacts upon animal welfare and may be the cause of the stranding itself, as is commonly reported in single stranding events (Bogomolni et al. 2010; Arbelo et al. 2013). Experts may consider this category important, since animals that are already suffering negative welfare states due to underlying health conditions will likely be subjected to compounding negative welfare states when stranded due to the additional "pain", "anxiety", and "stress" that may be experienced.

Notably, while experts felt that more information was available about these particular concerns than about others, they also highlighted major knowledge gaps in terms of diagnosing internal injuries, health and capture myopathy, and recognising deviations from the normal baseline for many physiological and behavioural parameters (Herráez et al. 2013; Sierra et al. 2014). This was reinforced by the major barriers described by several experts about the current lack of systematically collected data from stranding events and the limited availability of skilled/trained personnel to interpret parameters and inform decision-making. Additionally, lack of post-release monitoring was highlighted as a key knowledge gap, which was likely in relation to assessing long-term health and welfare following human intervention (Barratclough et al. 2019; Marks et al. 2020; McHugh et al. 2021).

Unfortunately, these knowledge gaps also affect the ability to understand key welfare concerns directly associated with mental states, including "suffering", "stress" and "anxiety" due to being stranded and in an abnormal environment; and "distress" and "helplessness" likely experienced due to stranded cetaceans' inability to move or help themselves. This lack of knowledge was reinforced by experts as they perceived these welfare concerns to be the least well understood, i.e., the least knowledge available to be able to assess their impact. This is because cautious inference of affective states requires interpretation of validated indicators of biological function, health and behaviour (Dawkins 1990, 2003; Hill and Broom 2009; Beausoleil and Mellor 2017). Although these are likely measurable at strandings, studies to validate the use of specific physiological and behavioural indicators in terms of the welfare state of stranded cetaceans are yet to be conducted.

Interestingly, the experts also regarded welfare at strandings to include consideration of the animal's ability to live in normal social and environmental conditions in the event it is re-floated. This relates to the concept of natural living, which reflects the idea that the environment should enable animals to perform their natural behaviours (Kiley-Worthington 1989; Alrøe et al. 2001). Natural living is often used as a key concept for evaluating welfare in captive settings such as zoos (Sherwen et al. 2018); i.e., good welfare occurs when the environment enables animals to live the most 'natural' life possible. However, a captive animal will never be in exactly the same situation as a wild counterpart, and therefore, too much emphasis may be put on naturalness as a way of 'improving' wild animal welfare in zoos, particularly as it is thought to reflect public perception of welfare (Melfi et al. 2004; Learmonth 2019). Similarly, stranded cetaceans are in an entirely abnormal environment; thus, the expression of normal or natural behaviour is almost impossible, and its use as a way of understanding variations in welfare state in this context is limited. The fact that humans commonly intervene in stranding situations exacerbates the abnormal circumstances of stranded cetaceans and it is difficult, currently, to interpret stranded cetacean behavioural responses to human intervention in terms of their welfare using a natural living approach.

Related to this, experts emphasised social separation, including maternal-filial separation as a major welfare concern. Socially separated cetaceans likely experience negative mental states such as anxiety and grief (Alves et al. 2015; Bearzi et al. 2018); and for maternally dependent calves, separation from mothers will compromise their welfare and survival likelihood. Indeed, maternally dependent calves that strand alone are typically candidates for euthanasia or captivity due to their inability to forage and integrate successfully (Whaley and Borkowski 2009; Boys et al. 2022c; Chapter 6).

Several categories that reached consensus for welfare characterisation related to the effects of human interventions on animal welfare rather than features of the animal itself. The fact that human intervention was considered as part of welfare characterisation may relate to the traditional resource-based understanding of animal welfare, which focused on resource/management inputs rather than on animal-centric outputs (Whay 2007), i.e., what we provide for animals rather than how the animal experiences what we provide. However, it could also reflect variation in participants interpretation of the question posed, providing responses to ‘what affects animal welfare?’ rather than ‘what is animal welfare?’.

Experts suggested that appropriate decision-making in terms of re-floatation versus euthanasia must be considered as part of characterising stranded cetacean welfare; such decisions are likely to be particularly important for welfare, since they can be contentious and are often delayed, which can prolong any suffering that may be occurring (Dubois 2003; Gales et al. 2008b; Boys et al. 2022c; Chapter 6). Consistent with that, the only concern directly related to stranding response that reached consensus was associated with delays to undertaking euthanasia decisions. Experts in this and previous studies emphasised that decisions on when and how to euthanise stranded cetaceans are a major knowledge gap (IWC 2014; Boys et al. 2022c; Chapter 6).

Unfortunately, the poorly defined criteria for identifying animals requiring end-of-life decisions (Barco et al. 2016; Boys et al. 2022c; Chapter 6), and the conflicting expectations of preservation of life (Moore et al. 2007; Bearzi et al. 2010; Boys et al. 2022c; Chapter 6), means that some compromised cetaceans likely experience prolonged suffering accordingly.

Other important management concerns (median scores >8) also related to the lack of skilled/trained personnel on beaches. Experts reinforced this point in the barriers to assessing welfare, including inappropriate human intervention and the feasibility of re-floatation based on available resources. These concerns are likely to be important as animals that are re-floated inappropriately, rather than undergoing comprehensive assessments prior to intervention procedures (e.g., Geraci and Lounsbury 2005; Perrin and Geraci 2008; Brownlow et al. 2015b), are likely to suffer additional physical injuries and prolonged negative affective states. Furthermore, experts noted that none of these concerns would occur in isolation and that adequately assessing the welfare impacts will require these to be understood cumulatively.

Importantly, the most recent update to the Five Domains Model framework for welfare assessment (Mellor et al. 2020) has included an understanding of the impacts of human interactions on animals, with various impacts suggested that could relate to stranded cetaceans during intervention procedures. For example, negative welfare impacts may occur since individual stranded cetaceans are likely to have had no or minimal contact with humans prior to stranding. Given that stranded individuals are in an atypical life-threatening situation, the presence and intervention of humans may induce additional anxiety and/or fear. Additionally, well-intentioned humans at stranding events often perceive themselves to have emotional bonds with the stranded cetaceans, which can cause delays to end-of-life decisions for compromised individuals (Gales et al. 2008b; Boys et al. 2022c; Chapter 6) and prolong animal physical and mental suffering. Conversely, some common stranding response procedures may minimise harm and the associated negative welfare states. For example, providing shade or cooling water over the animal's body (Geraci and Lounsbury 2005) may reduce concerns such as hyperthermia and skin damage, which likely cause "pain" and "discomfort" to stranded cetaceans.

2.4.2 *Fundamental concepts of stranded cetacean survival likelihood, concerns, knowledge gaps and barriers*

Seven of the 18 major categories were considered to be important—reaching consensus and with median scores of greater than eight—for understanding the likelihood of a stranded cetacean surviving. Expert conceptualisation suggests that the interrelated concepts of health, biological function, and behaviour (natural state) are considered important to understand survival likelihood.

Experts suggested that persistence to at least 6–12 months after re-floatation should be a criterion when characterising the likelihood of survival. This time period may have been scored as most important to ensure that individuals would have had time to re-integrate to normal life post-intervention (McHugh et al. 2021; Greenfield et al. 2021). Such characterising categories were also emphasised by experts in terms of understanding the animal's ability to socially and physically re-integrate and live a 'normal' life. Yet, these require re-floatation and post-release monitoring to have occurred.

Few studies have carried out post-stranding monitoring and have generally lasted only a few weeks, (e.g., 3–6 weeks, Wells et al. 2013; Sharp et al. 2016; Tyson Moore et al. 2020), due to technological limitations and difficulties locating individual cetaceans at sea. Consistent with this, the single major knowledge gap and main barrier to assessing survival likelihood was highlighted by experts as the lack of post-release monitoring. Nevertheless, a recent study on a small group of cetaceans found that most individuals (73%) surviving to one year were still traceable by field observation five years post-release (McHugh et al. 2021). Thus, the one-year criterion for post-stranding survival in this chapter would likely be a good predictive timeframe to assess long-term survivorship. Additionally, the application of tags to monitor survival requires trained personnel to ensure appropriate deployment and avoid additional welfare compromise (Andrews et al. 2019). This need for trained personnel at strandings was also highlighted as a barrier to assessing survival likelihood concerns.

Notably, most of the categories seemed to assume that the animal had already been re-floated. This may reflect the participants' interpretation of the question posed, providing responses to 'how can the animal's survival be understood?' rather than 'how can the animal's likelihood of survival be understood?'. In the latter case, characterisation would likely include categories that relate to survivorship prognosis such as 'normal haematological parameters' (Sharp et al. 2014). This distinction is important, as rescue attempts are often considered to be 'successful' once animals are re-floated, yet in most cases, post-release monitoring is not undertaken, and the fate of the released animals remains unknown (Wiley et al. 2001). This characterisation is likely to create unrealistic public expectations and increase pressure on decision makers at stranding events to re-float animals (Moore et al. 2007; Gales et al. 2008b).

'Animal health and disease status' also reached consensus and can provide direct understanding of an individual's likelihood to survive. Consistent with this, animal suffering from illness, disease and underlying health conditions was highlighted as a key concern for stranded cetacean survival likelihood. Previously, animals with underlying health conditions have mostly been associated with single strandings (Arbelo et al. 2013; Diaz-Delgado et al. 2018) and unusual mortality events (Van Bressem et al. 2014; Kemper et al. 2016; Pautasso et al. 2019), whereas mass strandings tend to involve outwardly healthy animals (Bogomolni et al. 2010) that strand due to social cohesion (Oremus et al. 2013) or navigational error (Mazzariol et al. 2011). Thus, animals involved in mass strandings are predicted to have increased survival likelihood when considering pre-existing health conditions (Bogomolni et al. 2010; Sharp et al. 2016). Importantly, understanding of this category could provide some indirect evidence of whether the animal is likely to survive for the 6–12-month period and return to 'normal' life in the event it is re-floated. However, as discussed in Section 2.4.1, there are currently difficulties in diagnosing health conditions in live stranded cetaceans (Acevedo-Whitehouse et al. 2010; Schwacke et al. 2014; Barratclough et al. 2019), which will limit the ability to predict survival likelihood.

Another physical disruption that was a key concern for stranded cetacean survival likelihood was difficulty breathing; it was likely emphasised since it has been linked to pulmonary congestion and can play a role in post-release mortality (Mazzariol et al. 2015; Diaz-Delgado et al. 2018; Câmara et al. 2019a). Other concerns perceived to be important (median scores ≥8) but that did not reach consensus related to animal physical state including physical injuries, organ compression, body condition, and abnormal movements with reduced limb function. Previous studies have highlighted that such physical disruptions can detrimentally affect survival (Fernandez et al. 2017; Diaz-Delgado et al. 2018). In some cases, these physical conditions can lead to mortality only after a substantial period of time (Campbell-Malone et al. 2008; Marks et al. 2020) while in others, death can occur soon after human intervention (Hunter et al. 2017; Câmara et al. 2020).

The length of time stranded and number of re-strandings were highlighted as key concerns for survival likelihood. Their perceived importance likely relates to the potential for compounding detrimental effects on animal physical state the longer the animal is out of its natural environment. For example, capture myopathy is more likely to occur in prolonged stranding events due to the sustained physiological stress response (Fernandez et al. 2017), causing ischemia and reperfusion injuries which often contribute to death (Herráez et al. 2007; Câmara et al. 2020). Such damage is untreatable and may cause re-floated animals to re-strand (Herráez et al. 2013). Therefore, the number of times that an individual re-strands can give some indication of its internal state, ability to function normally, and its likelihood to survive if re-floated again (Geraci and Lounsbury 2005; Mazzariol et al. 2015; Harms et al. 2018). Improved data collection to provide evidence-based recommendations for interventions involving re-stranded animals is vital. Experts emphasised this need for increased data collection and the necessity to have skilled responders interpreting parameters to be able to assess these complex, cumulative concerns.

Finally, the availability of appropriate and timely human intervention was highlighted as a key concern for survival. While well-intentioned members of the public may try to re-float animals, this often happens before comprehensive assessments can be undertaken and can involve the use of inappropriate interventions, increasing injury and/or mortality risk (Simeone and Moore 2018b). Conversely, timely, appropriate intervention could minimise the effects of internal damage such as caused by organ compression and capture myopathy, and lead to improved chances of survival (Fernandez et al. 2017; Câmara et al. 2020). Another human-related concern that was considered important (median score 8.7), but did not reach consensus, was the feasibility of rescue based on available resources. Such resources likely include the number of trained responders and the availability of appropriate re-floatation equipment. This will affect whether appropriate and timely intervention can occur, thereby affecting the animal's survival likelihood.

2.4.3 Similarities and differences in concepts relating to stranded cetacean welfare and survival likelihood

The expert panel emphasised the inextricable links between welfare and survival likelihood beginning with their characterisation of the concepts; both included interrelated aspects of health, biological function, and behaviour. The difference was that survival likelihood was not understood to be related to the animal's mental experience, and conversely, welfare did not relate to longevity in terms of the animal surviving until a particular timepoint. This suggests that experts consulted in this chapter may perceive there to be no requirement of survival to a certain point when considering welfare as the priority at strandings and that the animal's affective state would take precedence over longevity, permitting decisions such as euthanasia. This appears at odds with strandings response driven by societal desire, which typically focuses on re-floating animals (Gales et al. 2008b; Brownlow et al. 2015a; Boys et al. 2022c; Chapter 6).

The knowledge gaps and barriers to assessing concerns about welfare and survival were also similar, including the lack of empirical data available from stranding events and the critical need to have, and variable availability of, skilled personnel to interpret parameters and undertake assessments. However, the link between welfare and survival likelihood was most apparent in the key concerns for stranded cetaceans, with twelve concerns rated as having negative ('bad' or 'severely bad') effects for both concepts. Importantly, based on the key concerns generated in this chapter, welfare compromise of even healthy individuals is likely at strandings, and this compromise has the potential to affect an individual's survival likelihood. Breathing difficulty was the only concern that reached consensus for both welfare and survival likelihood. This likely reflects concern about the survival-critical nature of respiratory impairment and the inherent empathy for the unpleasantness and unnaturalness (Lansing et al. 2009; Beausoleil and Mellor 2015b) of the stranded environment for these marine animals.

A further six key concerns were scored as having a severe effect on both welfare and survival likelihood by at least 50% of the experts. These included illness/disease, physical injury/trauma, organ compression, body condition/nutritional status, 'stress'/anxiety caused by stranding, and appropriate human intervention. This is consistent with previous studies that have identified some of these factors as affecting the outcome of strandings (Townsend 1999; Geraci and Lounsbury 2005; Herráez et al. 2013; Fernandez et al. 2017; Câmara et al. 2020). Furthermore, contemporary animal welfare studies have highlighted some similar concerns for other mammal species (McGreevy et al. 2018; Munoz et al. 2019; Rioja-Lang et al. 2020) and cetaceans in other circumstances (Schwacke et al. 2014; Clegg et al. 2015; Barratclough et al. 2019; Nicol et al. 2020).

Interestingly, while social separation was noted as a concern for both welfare and survival likelihood, maternal-filial separation was only considered to have a 'bad' effect on welfare (i.e., it was not included as a specific category for survival). This is despite the low survival likelihood of maternally dependent animals; maternal-filial separation is a cause of high mortality for many stranding events involving a variety of species (Diaz-Delgado et al. 2018; Câmara et al. 2019a; Roberts and Hendriks 2020). It is possible that experts assumed that a decision of euthanasia would be implicit in the stranding of a maternally dependent calf (Whaley and Borkowski 2009; Boys et al. 2022c; Chapter 6), and that the survival likelihood of such an animal would therefore not be relevant. However, as has been previously reported, such decisions are not always undertaken promptly (Boys et al. 2022c; Chapter 6).

Fewer physical disruptions were included as key concerns for survival likelihood in comparison to those emphasised for welfare. This is despite the fact that these are likely to cause pathophysiological impacts which could play a role in mortality following live stranding events and reduce the effectiveness of any stranding response procedures (Fernandez et al. 2017). It is possible that experts did not consider some physical disruptions, such as skin damage, to be as relevant to survival likelihood as to immediate welfare, as this likely occurs naturally in the wild and animals must therefore have sufficient mechanisms to survive (Martinez-Levasseur et al. 2011, 2013). Additionally, physical concerns such as hyperthermia may not have featured for survival since experts may assume that some hyperthermic animals in mass strandings do survive (Gales et al. 2012; Sharp et al. 2016), but it may be concerning for welfare due to the likelihood of discomfort and associated pain. However, even post-release, some physical disruptions may continue to impact the animal over time and can lead to eventual death or reduced fitness, (e.g., Marks et al. 2020). The current lack of empirical data on such concerns and limited post-release monitoring hinders assessments of the effects of these factors on survival.

Surprisingly, the length of time stranded was only a concern for survival, even though welfare compromise could be expected to increase with time out of the water (see Section 2.4.1). Additionally, abnormal movements were also only considered a survival concern. It is possible that experts did not include abnormal movements as a welfare concern, since they are commonly understood to be indicators of welfare compromise (Dawkins 2003; McHugh et al. 2011) and therefore were likely not viewed as a welfare concern per se. For example, in captive cetaceans, abnormal behaviour is used as an indicator for concerns related to underlying health conditions (Clegg et al. 2017) and as part of rehabilitation-release assessments to predict survival likelihood (Whaley and Borkowski 2009).

2.4.4 Agreement across expert disciplines

This is one of the first studies to explicitly ask experts from different disciplines about their views on animal welfare; previously, most differences have been inferred from the peer-reviewed literature. Based on the results, the experts appear less siloed in their thinking than previously suggested (Paquet and Darimon 2010; Beausoleil et al. 2018; Clegg et al. 2021; see Appendix 5 for further discussion). Similar overlap in the opinions of conservation and welfare experts was also found in recent studies, where expertise groups provided comparable scores when assessing the welfare impacts of various scenarios on penguins (*Spheniscidae*; Freire et al. 2021) and of vessel traffic on free-ranging Orca (*Orcinus orca;* Nicol et al. 2020). These similarities may be due to the increase in conservation-welfare publications and discussions among disciplines over the past few years (IWC 2016b; Butterworth 2017; Papastavrou et al. 2017; Clegg et al. 2021).

2.4.5 Chapter considerations

The categories presented to the experts for scoring in the second questionnaire were generated using a data-driven, reflexive thematic analysis approach and using verbatim wording from experts. This enabled me to explore and draw conclusions from the data rather than approaching it with preconceived ideas (Braun and Clarke 2006, 2012, 2019). Nonetheless, I acknowledge that my perspectives as a researcher cannot be separated from the generated knowledge to create ‘objective’ data. Thus, I have had an active role in co-generating the categories presented (Yin 2016; Nowell et al. 2017). As a marine biologist focused on cetacean stranding events, I have personal experiences and beliefs relating to the concepts explored in this chapter. To provide further support for the outcomes of the reflexive thematic analysis, experts were able to provide additional comments throughout the second questionnaire. No comments on categories were received, suggesting that experts did agree with those presented for scoring, providing a degree of 'ground-truthing' to the data generated (O'Cathain and Thomas 2004).

Some aspects of the various characterising categories for welfare or survival, generated by me from reflexive thematic analysis of the expert opinions, appear to overlap. For example, the welfare category relating to 'physical health and injury' could also be considered to include 'normal physiology, physical comfort and discomfort'. For survival, overlap was observed in the categories of an animal remaining alive for both 6 and 12 months. This overlap arose through the reflexive thematic analysis due to the use of verbatim expert responses. However, the generation of categories in this way has ensured that the participants' concepts are mirrored, and over interpretation during researcher co-generation of categories has been minimised (Braun and Clarke 2006).

One limitation of the methods may be that some experts scoring categories in questionnaire 2 had not participated in the generation of themes in questionnaire 1. This could mean that some experts had additional concepts, knowledge gaps or concerns that were not presented for scoring in questionnaire 2. However, no additional themes were provided in the comments section of questionnaire 2, suggesting that experts responding did not feel that any important categories were missing. There were some differences in the proportion of respondents in each expertise group between questionnaires; however, the overlap in category scoring among expertise suggests this had minimal effects (see Appendix 5). Additionally, the geographical representation across questionnaires was similar, with approximately 87% of the experts from Europe, Oceania, and North America. These are areas that have been highlighted as common sites of cetacean stranding events (Hamilton 2018; Clarke et al. 2021) and have well-established stranding response networks (Simeone and Moore 2018a), indicating the relevance of the expert opinions gathered.

Importantly, while much of the discussion focused on those categories that achieved consensus, lack of consensus does not imply that a category was not considered important, just that not all participants rated it in the top grouping. For example, while only eight of the 19 major categories relating to concerns about stranded cetacean welfare reached the threshold for consensus, 18 had median scores of seven or greater, reflecting their overall importance to the topic. Therefore, future work should still consider those themes that did not reach consensus.

Finally, experts did appear to focus their characterisation on 'survival' rather than 'survival likelihood', which may be due to perception of the question asked (see Section 2.4.2). Despite this, it is proposed that the concerns emphasised by experts for survival likelihood could be used to extrapolate themes necessary to further conceptualise survival likelihood for stranded cetaceans. In this way, similar categories of characterisation would remain (health, biological function, and behaviour/natural state) with the addition of considering human intervention/stranding response.

A clear understanding of the concepts of welfare and survival likelihood and systematic approaches to addressing experts' concerns are required to ensure that decision-making is scientifically-informed as opposed to being driven by public sentiment (Boys et al. 2022c; Chapter 6). Systematic scientific approaches to animal welfare are well implemented in domesticated species and involve structured frameworks, such as the Five Domains Model for assessing welfare, to provide guidance, facilitating a more holistic understanding of animal welfare (Mellor et al. 2020). The development and implementation of such a framework are recommended to integrate animal welfare science and guide decision-making at stranding events.

2.5 Conclusion

The results highlight the inextricable link between welfare and survival, and the need to integrate welfare science alongside conservation biology to achieve management goals at stranding events. The high level of consensus among expertise suggests that a more holistic approach to understanding stranded cetaceans is supported by both conservation and animal welfare experts. The knowledge collected in this chapter should be considered as a starting point for developing a systematic, structured framework for welfare assessment in the strandings context. Specifically, this data can provide guidance on which parameters to use in stranded cetacean evaluations through the conceptualisation of welfare and survival likelihood; as well as highlight key concerns that will need to be addressed to ensure the best welfare outcomes and highest survival likelihood for viable stranded cetaceans. Increased data collection and comprehensive evaluation of both the welfare and survival likelihood of stranded cetaceans will provide the empirical evidence necessary to ensure informed decision-making at future stranding events. Chapter 3 moves on to consider how such evaluations of stranded cetacean welfare and survival likelihood can be achieved, through the identification of valuable and practical indicators.

Chapter 3 Identification of potential welfare and survival indicators for stranded cetaceans through international, interdisciplinary expert opinion

Live common dolphin (*Delphinus delphis*) that single stranded and subsequently died. Photo credit: Rebecca M. Boys.

This chapter is a reformatted version of the following manuscript (CC-BY):

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Abstract

Management of cetacean strandings generally focuses on re-floating animals, yet there is a lack of scientific data to inform decision-making. Valid indicators that are practical to measure are needed to assess welfare status and survival likelihood for stranded cetaceans. The Delphi method was used to gather international and interdisciplinary expert opinion to provide face validity to potential indicators of stranded cetacean welfare and survival likelihood. Two online questionnaires were conducted, in the first questionnaire these experts identified potential indicators of stranded cetacean welfare and survival likelihood. These indicators were subsequently scored by the same experts in questionnaire two, based on their value for assessing welfare/survival likelihood and being practical to measure. Indicators considered valuable and practical for assessing welfare and survival likelihood at strandings included animal-based indices of body and skin condition, signs of physical trauma, respiration rate and various behaviours. Resource-/management-based indicators related mainly to human intervention and should be correlated with animal-based indices to provide relevant evaluations. Importantly, the findings emphasise inextricable links between welfare and survival for stranded cetaceans, with 90% of indicators being similar for both. Investigations into these indicators should be conducted to develop a practical, science-based assessment framework to inform decision-making during stranding events.

Keywords: Animal welfare; Delphi; Management; Marine mammals; Strandings; Wildlife

3.1 Introduction

There is increasing recognition that animal welfare science must be integrated alongside conservation biology to achieve wildlife management goals (Dubois et al. 2017; Beausoleil et al. 2018; Hampton and Hyndman 2019; Clegg et al. 2021). While conservation efforts involving human intervention often claim to consider animal welfare, robust welfare assessments are rarely undertaken (Swaisgood 2010; Hampton et al. 2016; Thulin and Röcklinsberg 2020; Boys et al. 2022c; Stockin et al. 2022; Chapter 6). This is likely due to limited data and protocols for assessing the welfare of wild species (Harvey et al. 2020), and the need to apply practical and non-invasive indicators (Harvey et al. 2021; Eskelinen et al. 2021). Likewise, the current paucity of validated prognostic indicators (Sharp et al. 2014) and limited survivorship data for re-floated stranded cetaceans (Sampson et al. 2012; Sharp et al. 2016; Neves et al. 2020), hinders current ability to undertake informed decisions based on an animal's predicted likelihood to survive. Notably, inextricable links between welfare and survival of stranded cetaceans, and the need to assess both concepts to inform decision-making at stranding events, has been highlighted (Boys et al. 2022b; Chapter 2).

In contemporary animal welfare science, it is generally understood that physical and mental states are linked, and that an animal's welfare state is based on how it is experiencing its own life (Mellor 2016; Beausoleil et al. 2018). Therefore, to be considered important for animal welfare, a physical state or external condition must impact upon the animal's overall subjective mental state (Fraser 2008; Mellor et al. 2009a). Thus, animal welfare is only considered for sentient species, such as cetaceans (Butterworth 2017; Clegg and Delfour 2018; Serres et al. 2020b), that are able to experience both negative and positive subjective mental experiences depending on their circumstances (Duncan 2006; Fraser 2008; Mellor 2016).

Since subjective mental experiences cannot be measured directly, they must be inferred through scientific evaluation of an animal's physical state and their external conditions (Mellor et al. 2009a; Mellor and Beausoleil 2015; Beausoleil et al. 2018). To ensure a systematic approach towards evaluations, assessment frameworks, such as the Five Domains Model for assessing welfare, are commonly applied (Mellor 2017; Mellor et al. 2020). Using such a framework, indicators related to physical/functional domains (nutrition, physical environment, and health) and the situation-related (external conditions) domain (behavioural interactions) are observed and/or measured. The cumulative evaluation of these indicators are subsequently used to cautiously infer the animal's potential mental (affective) experiences (fifth domain) that they likely reflect (Beausoleil and Mellor 2015a, 2017; Beausoleil et al. 2018).

To appropriately apply this kind of systematic framework, observable and/or measurable indicators must first be identified and validated. Indicators can be animal-based (e.g., body condition or specific behaviours) or may be resource- or management-based (e.g., environmental conditions, human interventions). Animal-based indicators provide more direct evidence of the animal's welfare state than resource-/management-based indicators. Welfare indicators can be further categorised into 'welfare status' or 'welfare alerting'. Welfare status indicators provide explicit evidence of an animal's physical state or external situation and therefore more directly reflect its welfare status (i.e., subjective mental experience) (Harvey et al. 2020). They include some animal-based indicators (e.g., external injuries, specific behaviours). In contrast, welfare alerting indicators do not provide information directly related to an animal's welfare state, but rather represent factors that might compromise that state in some animals exposed to those conditions (i.e., they represent a welfare risk) (Harvey et al. 2020). These include some animal-based indicators (e.g., age class, reproductive status), but also include all resource-/management-based indicators. Importantly, this kind of contextual information regarding the animal's situation at the time of assessment is always required to appropriately interpret, and give valence to, animal-based indicators (Wemelsfelder et al. 2000; Harvey et al. 2021).

Live cetacean strandings are an example of conservation management that often involve costly and complex human intervention. Stranding response aims to achieve conservation goals through re-floatation of individual animals, and should also assess health and provide supportive care (Geraci and Lounsbury 2005; Gales et al. 2008b; Moore et al. 2018a). Stranded cetaceans deemed to be viable may be re-floated, whilst those in poor condition may be taken into rehabilitation centres (where legal and appropriate facilities exist) (Moore et al. 2007) or end-of-life decisions, such as euthanasia or palliative care, may be required (Geraci and Lounsbury 2005; Mazzariol et al. 2015; Boys et al. 2022c; Chapter 6). While intervention decisions should be informed by the status of the animal, based on both its welfare and its survival likelihood (Simeone and Moore 2018b; Boys et al. 2022b; Chapter 2), undertaking these assessments can be complex and there is limited empirical data to support decision-making at strandings (Gales et al. 2012; Nicol et al. 2020). This is considered to be a potential major cetacean welfare concern (IWC 2016a).

Since empirical data is lacking, a preliminary way to acquire information on potential indicators is to elicit expert opinion (Bracke et al. 2008; Gibert et al. 2010; EFSA 2014). One way this can be achieved is via the application of the Delphi method (Mukherjee et al. 2015), which assumes that group opinion is more representative than individual opinion (Keeney et al. 2010). This method has previously been employed to successfully identify and validate indicators of animal welfare state in varying animal species (Phythian et al. 2011; Campos-Luna et al. 2019; Pearson et al. 2021; Whittaker et al. 2021). With regard to management of live cetacean strandings, expert opinion can provide face validity to indicators (the extent to which indicators align with welfare state/survival likelihood) relevant to developing a framework (Skovlund et al. 2021) for assessing stranded cetacean welfare and survival likelihood. These data can then be applied at live cetacean stranding events to investigate the feasibility of evaluating the nominated indicators.

The aims of this chapter were to use expert opinion to (1) identify potential indicators of stranded cetacean welfare and survival likelihood, (2) evaluate those indicators based on their value for assessing stranded cetacean welfare and survival likelihood (i.e., how closely each indicator aligned with welfare state or survival likelihood), and (3) evaluate how easy/practical each indicator is to measure at cetacean stranding events. Additionally, this chapter aimed to explore expert opinion on the affective experiences that may be inferred if particular animal-based indicators in stranded cetaceans were observed. Development of these indicators will allow for unambiguous assessments of stranded cetaceans, providing measurable objectives for conservation goals which integrate animal welfare.

3.2 Methods

The methods in this chapter follow those described in Chapter 2 (Boys et al. 2022b), and key points are summarised here.

3.2.1 Recruitment and characterisation of expert participants

Potential participants were identified as experts in the fields of cetacean biology/ecology or wild animal welfare by searching the peer-reviewed literature, documents relating to relevant workshops, and stranding network lists. All participants were invited (Appendix 1) to complete two questionnaires in 2021, separated by a period of 3-weeks.

3.2.2 Questionnaire design and implementation

A two-round Delphi process was conducted online using the questionnaire tool Qualtrics (2005) to identify potential indicators of stranded cetacean welfare and survival likelihood. Expert opinions on valuable (how closely each indicator aligned with welfare state or survival likelihood) and practical (how feasible each indicator is to measure at strandings) indicators were elicited using an exploratory sequential mixed method (Creswell and Creswell 2017), with the findings from the first round informing the development of the second round. However, there was no requirement for participants to complete both, and some participants who provided scores in the second round may not have been involved in generating the questions being scored and vice versa.

No identifiable data were collected, ensuring full anonymity. Demographic information was collected to characterise the study population and assess the effect of expertise on the proposed indicators. Experts were asked to self-identify their area of expertise as either: ‘cetacean expert (including cetacean conservation and biology)’, ‘animal welfare expert (including animal welfare science, welfare/animal ethics)’, ‘cetacean expert with knowledge and/or focus on welfare’, ‘animal welfare expert with knowledge and/or focus on cetaceans’, ‘veterinarian’ or ‘other’.

Each questionnaire was split into two sections, each with similar questions: the first section related to the welfare of stranded cetaceans and the second to their survival likelihood. The first questionnaire used mainly unstructured, open-ended questions (Appendix 2), allowing participants to provide opinions and elaborate on thoughts regarding indicators of welfare and survival. Experts were asked to identify any observable and/or measurable indicators they felt could be used to assess the welfare state or likelihood of survival of stranded cetaceans. These indicators could be animal-based, such as behaviour, or resource-/management-based, such as weather conditions or human intervention. Participants could provide additional comments if desired. The authors conceptualisation of animal welfare state and likelihood of survival were not provided to ensure that the experts own understanding of these concepts were captured (Boys et al. 2022b; Chapter 2).

The indicators suggested were transcribed intelligent verbatim (i.e., spelling/grammar was corrected) and reviewed independently by myself using reflexive thematic analysis to generate common themes from the qualitative data (Braun and Clarke 2006, 2019). These themes were reviewed by myself and the supervisory team to finalise the major themes for welfare and survival likelihood (Appendix 4) that were used in the development of the second questionnaire (Appendix 3). A maximum of 20 major themes per question were presented to participants as 'categories' for scoring in the second round, maximising data collection whilst minimising questionnaire fatigue (Lavrakas 2008). These categories were identified based on being commonly proposed by participants, as well as being identified as the most relevant and important aspects for the chapter by myself and the supervisory team (Braun and Clarke 2012).

In the second questionnaire, participants were asked to score each of the categories in closed-ended questions with scalar (0–10) responses (Appendix 4) (Orsi et al. 2011) based on their value for assessing welfare or survival likelihood, where '0=Little/no value', '5=Some value' and '10=Great value'. Participants were also asked to score how easy/practical each indicator category would be to measure at strandings, where '0=Difficult to measure', '5=May be measurable depending on skills/equipment' and '10=Easy to measure'. They could also choose the option "Don't Know" if they felt they did not have sufficient knowledge to score a particular category. Their thoughts about any barriers to measuring the indicator categories were solicited using an open-ended question.

For categories reflecting animal-based indicators of cetacean welfare, participants were asked to suggest any affective (mental) experience/s that may be inferred from observation of the indicator. Some of the indicator categories generated through the reflexive thematic analysis of answers from questionnaire 1 comprised multiple individual indicators (Appendix 6 Table A6.3). For example, the category 'Abnormal movements and behaviours' included *arching*, *thrashing*, *straining*, *agitated movements,* and others. For such composite categories, the question of affective experience was asked of each of the individual indicators separately, e.g., what affective experience might be inferred from observation of arching. These were open questions, allowing participants to provide all suggestions they felt were relevant.

3.2.3 Analysis of data from questionnaire 2

The median scores collected in the second questionnaire were analysed for each category to quantify and rank the indicators, based on their perceived value and practicality for assessing stranded cetacean welfare or survival likelihood at stranding events. Higher median scores for categories reflected greater value for assessing, or more easy/practical measurement of, that indicator for welfare or survival likelihood. Responses of “Don’t know” were not included when calculating median scores.

While quantitative data were collected on continuous scales (Chyung et al. 2018), the responses were pooled into four groupings (score: “0–3.99”; “4–6.99”; “7–10”; “Don’t know”) to evaluate the level of consensus among participants for each theme. At least 70% of participants had to score a category within the same grouping for consensus to be reached (Sumsion 1998; Campos-Luna et al. 2019; Whittaker et al. 2021).

Qualitative data reflecting participants’ views on barriers to measuring welfare and survival likelihood indicators were investigated using reflexive thematic analysis to collate common themes (Braun and Clarke 2006, 2019). These themes are presented to provide context for the interpretation of experts’ views on the ability to measure the welfare/survival likelihood indicators.

The welfare categories provided were classified based on being welfare status or welfare alerting indicators. These categories were subsequently sorted into the three physical/functional domains and one situation-related (external conditions) domain of a modified version of the Five Domains Model for welfare assessment (Mellor et al. 2020). Additionally, the qualitative data generated on potential affective experiences were summarised; any term mentioned once for each indicator was included in the summary (Appendix 6 Table A6.3), even if not considered a commonly accepted affective experience. The most common suggestions identified were tallied based on the number of unique mentions for each indicator category.

Linear discriminant analysis (LDA) was conducted using package MASS (Venables and Ripley 2013) in R (V. 1.2.5033) to visualise the effect of participants’ self-identified expertise on the scores for value and ease/practicality of measuring welfare and survival likelihood indicator categories. When an expert responded “Don’t know” for a particular category, data imputation was applied by calculating the average score of the expertise group across that category. Orthogonal axes were generated to maximally separate the six expertise groups based on participant scores. Visual representations of the differences and similarities among expertise groups were provided using the first two axes of each LDA, prepared using the package ggplot2 (Wickham 2009).

3.3 Results

International experts were invited to participate (n = 168) in both questionnaires; the first questionnaire had a response rate of 40.5% (n = 68) and the second questionnaire a response rate of 37.5% (n = 63). Variation among expertise and regional representation was minimal between surveys (Table 3.1; Boys et al. 2022a; Chapter 2).

Table 3.1 Number of expert participants in each self-defined expertise category and their current region of work across two questionnaires.

Expertise	**Questionnaire 1**	**Questionnaire 2**	**Region**	**Questionnaire 1**	**Questionnaire 2**
Cetacean conservation and biology	26% (n = 18)	25% (n = 16)	Europe	40% (n = 27)	41% (n = 26)
Veterinary medicine	24% (n = 16)	32% (n = 20)	Oceania	25% (n = 17)	30% (n = 19)
Animal welfare science/ethics	16% (n = 11)	14% (n = 9)	North America	22% (n = 15)	16% (n = 10)
Cetacean biology with a focus on welfare	16% (n = 11)	19% (n = 12)	South America	6% (n = 4)	6% (n = 4)
Animal welfare with a focus on cetaceans	3% (n = 2)	5% (n = 3)	Asia	4% (n = 3)	2% (n = 1)
Other: strandings response/broader ecology	15% (n = 10)	5% (n = 3)	Central America	1% (n = 1)	3% (n = 2)
			Africa	1% (n = 1)	2% (n = 1)

3.3.1 *Developing indicators of stranded cetacean welfare*

3.3.1.1 *Perceived value of welfare indicators*

Forty-nine themes reflecting indicators for assessing stranded cetacean welfare were generated from questionnaire 1 responses (Appendix 6 Table A6.1). Twenty of these themes were provided in the second round for scoring as categories. Sixteen of the twenty indicator categories presented in questionnaire 2 were perceived to have ‘great value’ (median scores ≥7; Figure 3.1). Five categories achieved consensus as being of great value (scores ≥7) by at least 70% of the experts, these included one resource-based indicator (‘length of time stranded and number of re-strandings’), and four animal-based indicators (‘signs of physical trauma, injuries and wounds’; ‘signs of illness and disease’; ‘swimming ability and orientation when returned to water’; ‘animal’s level of response to stimuli/reflex’). The indicator perceived as most valuable for assessing welfare state, based on the percentage of experts scoring it ≥7, was ‘length of time stranded and number of re-strandings’ while the least valued indicator of the twenty presented was ‘vocalisation rate and type’.

3.3.1.2 *Perceived practicality of welfare indicators*

Fifteen welfare indicator categories had a median score of ≥7, suggesting that experts viewed them as easy/practical to measure at stranding events (Figure 3.2). Seven categories reached expert consensus as being easy/practical to measure (score ≥7; Figure 3.2). These included two resource-based indicators (‘weather, ambient temperature, sea and tidal conditions’ and ‘availability of resources including equipment’) and five animal-based indicators (‘bleeding/fluids/mucus from orifices’; ‘abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering’; ‘respiration rate and character/effort’; ‘signs of physical trauma, injuries and wounds’; and ‘animal’s skin condition such as sunburn, peeling, cracking or blistering’). The indicator considered easiest to measure based on the percentage of experts scoring it as ≥7 was ‘weather, ambient temperature, sea and tidal conditions’ while ‘measurement of blood parameters and serum/plasma chemistry’ was deemed most difficult.

Notably, of the most valuable welfare indicator categories, only one reached consensus as being easy/practical to measure: ‘signs of physical trauma, injuries and wounds’. However, of the other easily measurable welfare indicators (i.e., reaching consensus), all except one (‘weather, ambient temperature, sea, and tidal conditions’) were considered to also be valuable (≥ 7) by over 50% of the experts.

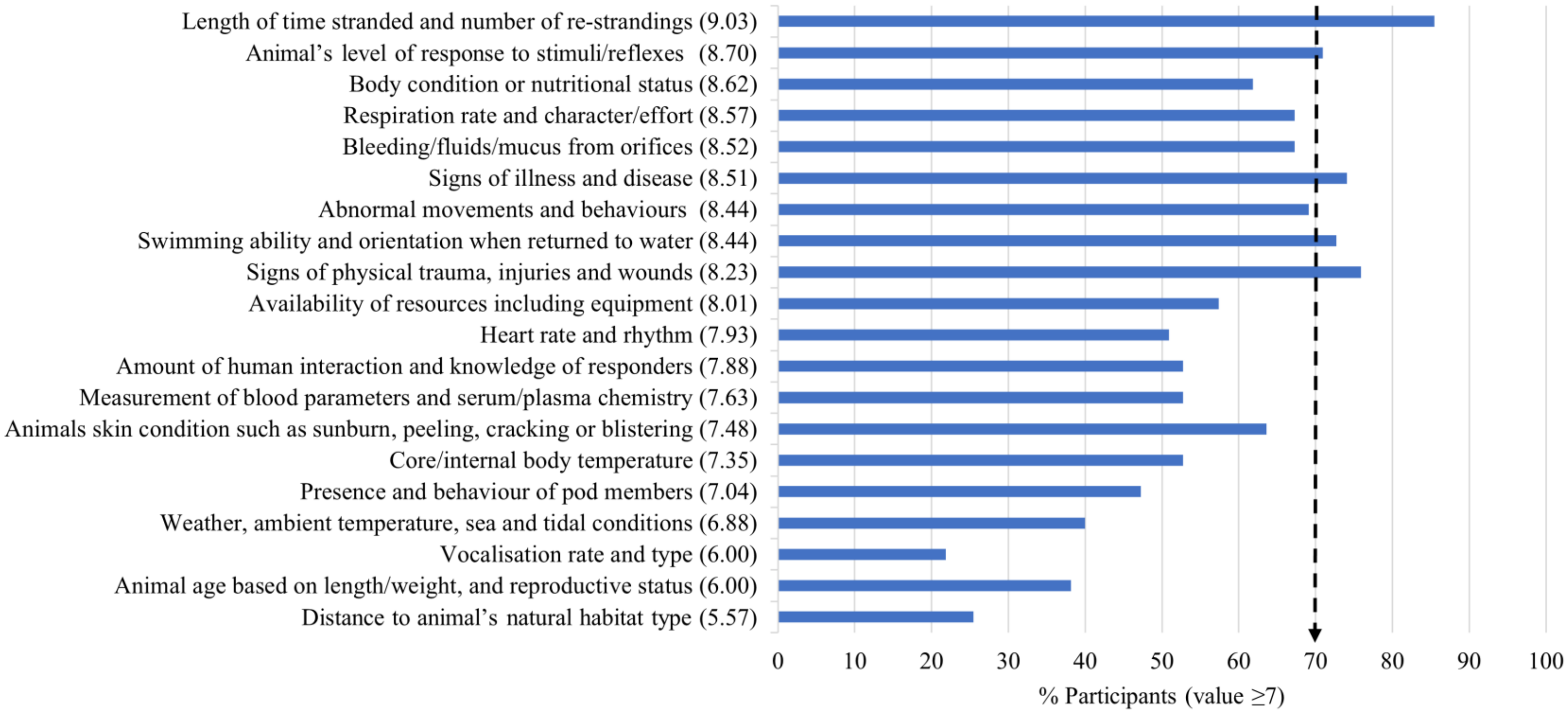

Figure 3.1 The perceived value of the 20 welfare indicator categories generated from reflexive thematic analysis of expert suggestions, ranked in order of the median score (in parentheses) on the y-axis, with percentage of experts scoring the theme ≥7/10 on the x-axis. The dashed arrow represents the consensus level i.e., 70% of experts scored the indicator as greatly valuable. The category labels have been simplified to fit on the figure, see Appendix 6 Table A6.1 for full labels.

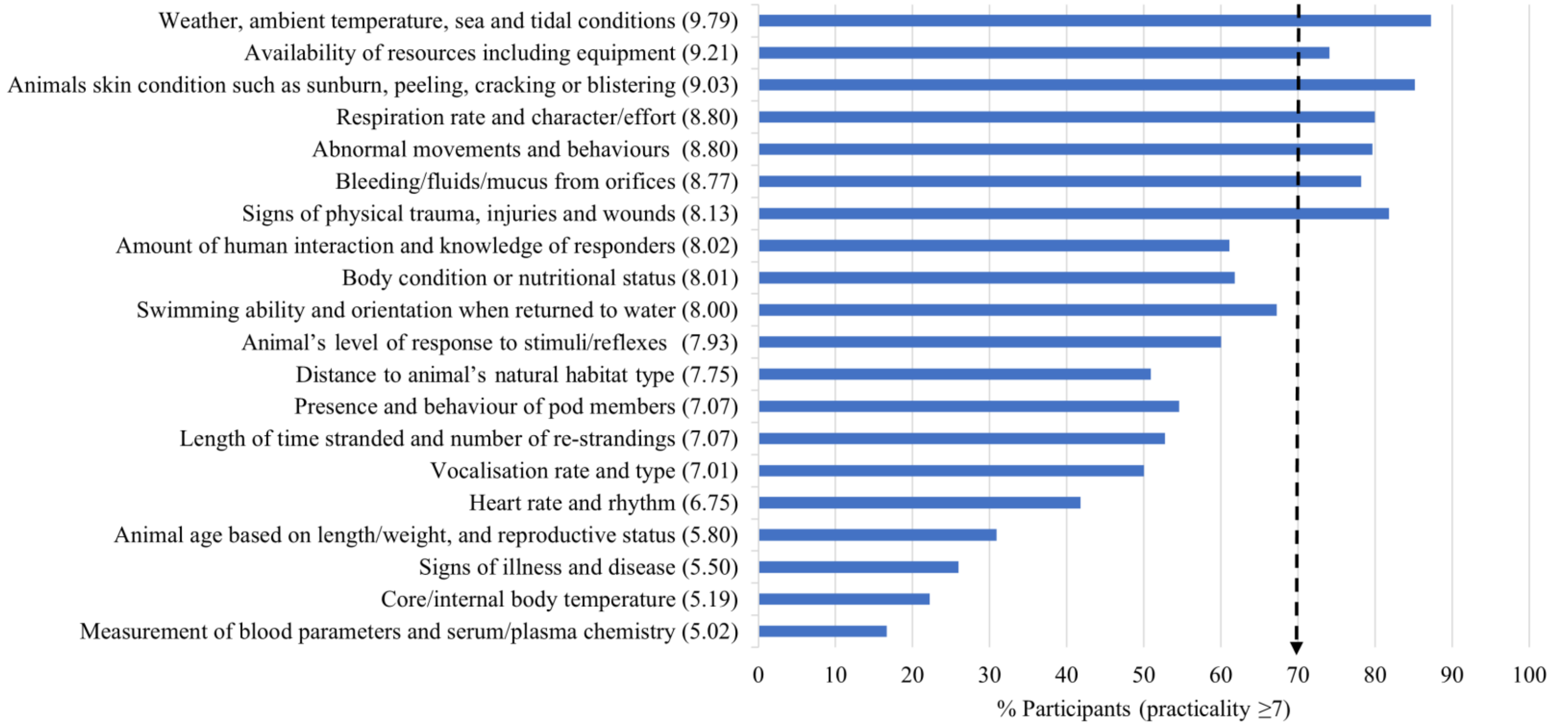

Figure 3.2 The perceived practicality of the 20 welfare indicator categories generated from reflexive thematic analysis of expert suggestions, ranked in order of the median score (in parentheses) on the y-axis, with percentage of experts scoring the theme ≥7/10 on the x-axis. The dashed arrow represents the consensus level i.e., 70% of experts scored the indicator as practical to measure. The category labels have been simplified to fit on the figure, see Appendix 6 Table A6.1 for full labels.

3.3.1.3 Barriers to measuring indicators of stranded cetacean welfare

Twenty-eight of the participants (44%) identified major barriers to measuring indicators of cetacean welfare state. From reflexive thematic analysis of qualitative responses, three major themes were interpreted:

- Skills/training/knowledge of responders
- Lack of data and ability to interpret parameters and assess changes from baseline
- Difficulties in assessing each indicator due to equipment/situation at stranding event

The main barrier regarding the measurement of welfare indicators highlighted by 20 experts (71%) who provided a response to the question was the availability of well-trained, experienced, and knowledgeable personnel. For example, one participant noted:

"Having […] properly trained users to make accurate measurements of certain things (vocalisations, heart rate, taking blood samples) and ability to obtain results during the stranding event to have any meaningful use for decision making."

It was also emphasised that for many parameters, both physiological and behavioural, baseline data against which to compare measures taken during a stranding are lacking, which limits the ability to identify welfare-relevant deviations. One participant noted:

"There is still a lot we do not know about cetaceans (e.g.: normal heart rates and blood parameters of different species in the wild) to form baseline 'normal' data for them that samples/data from stranded cetaceans can be compared to…"

Additionally, it was mentioned that the specialised equipment required and features of the stranding event (e.g., number of animals, size of animals, position/location when stranded) would affect which indicators could be measured *in situ*. One participant noted:

"Rectal temperature may not be safe or possible […]. Heart rate and rhythm easy enough on small cetaceans but requires ECG for large cetaceans. Point of care blood analysers may be used in field situations but some field situations are not conducive even for those instruments."

Indeed, one expert remarked that at mass stranding events assessing all indicators on all individuals would not be possible and prioritising key indicators would be important:

"[.....] Other things to consider in terms of measuring these indicators is that you can't possibly collect all these data on 100 whales, so the ability to triage is critical - i.e., if you only had the ability to evaluate one or two parameters, which would be the most significant? Prioritization is key at strandings."

3.3.1.4 Classification of welfare indicators using the Five Domains Model

The 20 indicator categories generated from reflexive thematic analysis of questionnaire 1 data, included 13 welfare status indicators and seven welfare alerting indicators. These categories included representative indicators fitting into all three of the physical/functional domains and one situation-related domain in the Five Domains Model framework for assessing animal welfare (Table 3.2). Four of the five indicators that reached expert consensus as being valuable were welfare status indicators, with three in Domain 3 and one in Domain 4 (Table 3.2). Five of the seven indicators that reached consensus as being practical to measure were welfare status indicators, with one in Domain 2, three in Domain 3 and one in Domain 4 (Table 3.2).

Table 3.2 The 20 welfare status and welfare alerting indicator categories generated from reflexive thematic analysis of expert suggestions, categorised according to the Five Domains Model for welfare assessment (Mellor et al. 2020). Symbols indicate categories that reached expert consensus for value* and practicality†.

Domain	**Indicator types**	
	Welfare status	**Welfare alerting**
1: Nutrition	Body condition or nutritional status	Animal age based on length/weight or reproductive status
2: Physical environment	Animal's skin condition such as sunburn, peeling, cracking, or blistering, desiccation† Core/internal body temperature	Length of time stranded and number of re-strandings* Availability of resources including equipment† Weather, ambient temperature, sea, and tidal conditions† Distance to animal's natural habitat type

3: Health	Signs of physical trauma, injuries, and wounds*†	
	Signs of illness and disease*	
	Respiration rate and character/effort†	
	Bleeding/fluids/mucus from orifices†	
	Measurement of blood parameters and serum/plasma chemistry	
	Heart rate and rhythm or function	
	Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness, or consciousness*	
4: Behavioural interactions	Swimming ability and orientation when returned to water*	Presence and behaviour of pod members
	Abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering†	Amount of human interaction and knowledge of responders
	Vocalisation rate and type	

3.3.1.5 Inferring affective experience from welfare status indicators

There were 26 individual indicators extracted from the 13 welfare status categories (Appendix 6 Table A6.3). Forty-three (68%) participants provided a response to at least one indicator for the question on affective experiences (median: 41, range: 33–43).

Most of the inferred affective experiences were negatively valenced, i.e., unpleasant experiences (Table 3.3). The most suggested affective experiences, based on the number of indicators that they were mentioned for, were “stress”, “distress”, “pain” and “fear”, with at least one of these suggested for every indicator. Additionally, “dizziness” and “lethargy” were suggested for several indicators, whilst other affective experiences were indicator specific, such as “breathlessness” which was mentioned only in relation to respiratory indicators (Appendix 6 Table A6.3). Furthermore, some of the affective experiences mentioned for ‘reduced respiration rate’, ‘abnormal swimming movements’, ‘fluke slapping’ and ‘vocalisation’ could be considered positively valenced, including “relaxed”, “resting”, “calm”, “excitement” “happy” and “safety” (Appendix 6 Table A6.3). In Table 3.3, only those suggestions that were provided at least twice for the particular indicator are reported (see Appendix 6 Table A6.3 for all suggestions provided by experts).

Instead of providing an affective experience, experts sometimes suggested potential underlying causes of the indicator being displayed. For example, for physiological indicators “agonal”, “adrenaline”, “pruritis”, “decompensating”, “hyperthermia”. For behavioural indicators “effort to escape” and “avoidance behaviour” (see Table 3.3 and Appendix 6 Table A6.3). These responses have been collated under the corresponding physical/functional (Domains 1 to 3) or situational (Domain 4) domain to distinguish them from commonly accepted affective experiences (Domain 5: Mental state). Additionally, two veterinarians indicated that they were not comfortable with providing a potential affective experience that may be inferred when observing a particular welfare status indicator. For example, one veterinarian stated:

“Personally I feel like great care must be taken when imposing our assumptions on the experience of an animal - I am quite reluctant to fill in any of the above as I do not believe we have the right to comment on many of those as to how the animal experiences the situation. I would even be reluctant to comment on how another human would experience those conditions as there is so much individual variability.”

Table 3.3 Collation of respondents' unique suggestions, mentioned at least twice, of potential affective experiences (Domain 5) and other states or conditions (aligned with Domains 1–4) (Mellor et al. 2020) of stranded cetaceans inferred when observing a particular welfare status indicator. Total number of mentions for that indicator is included in parentheses following each suggested term. *Represents catch-all term for a range of negative affective experiences and †may refer to a physiological stress response (Domain 3: Health) or a catch-all term for a range of negative affective experiences (Domain 5: Mental state). See Appendix 6 Table A6.3 for all unique suggestions.

Welfare status indicator	**D1: Nutrition**	**D2: Physical environment**	**D3: Health**	**D4: Behavioural interactions**	**D5: Mental state**
Elevated respiration rate		Hyperthermia (n = 3)	Stress† (n = 23); Disease (n = 4); Illness (n = 3); Shock (n = 3); Infection (n = 2)		Fear (n = 11); Pain (n = 10); Distress* (n = 6); Anxiety (n = 3); Feeling unwell/ill (n = 3); Discomfort (n = 2)
Reduced respiration rate			Stress† (n = 8); Illness (n = 3); Shock (n = 3); Dive reflex (n = 2)		Pain (n = 4); Exhaustion (n = 3); Fear (n = 3); Depression (n = 2); Tiredness (n = 2); Weakness (n = 2)
Abnormal respiratory character			Stress† (n = 20); Disease (n = 6); Respiratory disease (n = 6); Illness (n = 4); Shock (n = 3); Approach of death (n = 2)		Fear (n = 10); Pain (n = 10); Distress* (n = 7); Feeling unwell/ill (n = 3); Discomfort (n = 2); Exhaustion (n = 2); Weakness (n = 2)

Agitated movements		Stress† (n = 17)	Effort to escape (n = 5)	Fear (n = 13); Pain (n = 11); Distress* (n = 9); Discomfort (n = 5); Anxiety (n = 4); Frustration (n = 2); Negative (n = 2)
Arching		Stress† (n = 10); Illness (n = 2); Shock (n = 2); Death throes (n = 2)	Escape response (n = 5)	Pain (n = 19); Fear (n = 8); Distress (n = 6); Discomfort (n = 4); Negative (n = 2)
Thrashing		Stress† (n = 18); Shock (n = 2)	Effort to escape (n = 4)	Fear (n = 15); Pain (n = 14); Discomfort (n = 5); Distress* (n = 5); Panic (n = 3); Anxiety (n = 2)
Fluke slapping		Stress† (n = 16); Illness (n = 2)	Effort to escape (n = 5); Aggression (n = 2)	Fear (n = 12); Pain (n = 8); Distress* (n = 5); Anger (n = 4); Anxiety (n = 3); Discomfort (n = 2)
Tensing/straining		Stress† (n = 17); Disease (n = 2); Illness (n = 2)	Escape (n = 5)	Pain (n = 16); Fear (n = 10); Discomfort (n = 5); Distress* (n = 5)

Abnormal body posture	Gravity (n = 2)	Stress† (n = 9); Illness (n = 3); Disease (n = 2); Injury (n = 2)		Pain (n = 22); Fear (n = 7); Discomfort* (n = 6); Distress (n = 3); Feeling unwell/ill (n = 2); Negative (n = 2)
Fin movement		Stress† (n = 6)	Effort to escape (n = 7); Positive attempts to swim (n = 3)	Fear (n = 6); Distress* (n = 4); Pain (n = 4); Anxiety (n = 2); Discomfort (n = 2)
Head swinging		Stress† (n = 10); Disease (n = 3); Neurological disease or neurological condition (n = 3); Illness (n = 2)	Desire to escape (n = 5)	Fear (n = 8); Distress* (n = 7); Pain (n = 5); Discomfort (n = 3); Confusion (n = 2); Panic (n = 2)
Tremors/shivering	Body temperature abnormality (n = 13)	Stress† (n = 19); Illness (n = 5); Shock (n = 3); Disease (n = 2); Neurological disease or neurological condition (n = 2)		Pain (n = 11); Fear (n = 8); Distress* (n = 4); Discomfort (n = 2); Negative (n = 2)

Injury/Trauma/Wounds			Stress† (n = 6)	Pain (n = 28); Fear (n = 4); Discomfort (n = 3); Distress* (n = 3); Feeling unwell/ill health (n = 2)
Reduced stimuli/reflexes			Disease (n = 6); Stress† (n = 6); Consciousness (n = 4); Illness (n = 3); Injury (n = 2); Physiological compromise (n = 2); Shock (n = 2); Weak (n = 2)	Pain (n = 4); Feeling unwell/ill health (n = 3); Depression (n = 2); Lethargy (n = 2); Tiredness (n = 2); Weakness (n = 2)
Poor skin condition		Sun (n = 2); Sunburn (n = 2)	Disease (n = 7); Illness (n = 7); Stress† (n = 3); Hunger (n = 2)	Pain (n = 18); Discomfort (n = 6);
Poor body condition	Lack of food (n = 3); Age (n = 2); Malnutrition (n = 2)		Disease (n = 9); Illness (n = 6); Stress† (n = 5); Underlying health issue (n = 3); Injury (n = 2)	Hunger (n = 11); Pain (n = 6); Discomfort (n = 5); Weakness (n = 4); Sickness (n = 3); Distress* (n = 2); Feeling ill/unwell (n = 2)

Abnormal swimming movements			Stress† (n = 9); Injury (n = 7); Neurological illness/disease (n = 5); Disease (n = 3); Illness (n = 3); Neurological impairment (n = 2)	Pain (n = 14); Disorientation (n = 7); Distress* (n = 4); Confusion (n = 3); Fear (n = 3); Weakness (n = 3); Discomfort (n = 2)
Elevated stress hormones			Stress† (n = 28); Disease (n = 4)	Fear (n = 8); Pain (n = 6); Anxiety (n = 4); Distress* (n = 4)
Abnormal blood chemistry		Muscle damage (n = 2)	Stress† (n = 12); Disease (n = 10); Illness (n = 5); Underlying health issue (n = 4); Infection (n = 2)	Pain (n = 5); Feeling unwell/ ill health (n = 4); Distress* (n = 3); Nausea (n = 3); Discomfort (n = 2); Thirst (n = 2)
Abnormal haematology	Dehydration (n = 2)		Stress† (n = 13); Disease (n = 9); Illness (n = 6); Infection (n = 3); Trauma (n = 3); Underlying health issue (n = 3)	Pain (n = 5); Distress* (n = 4); Feeling unwell/ill health (n = 4); Nausea (n = 2); Sickness (n = 2)

Vocalisation: rate, character			Stress† (n = 18)	Communicate with conspecific (n = 5); Social isolation (n = 2)	Fear (n = 11); Pain (n = 7); Distress* (n = 5); Discomfort (n = 2); Feeling unwell/ill (n = 2)
Elevated body temperature		Hyperthermia (n = 2); Exposure (n = 2); Out of water (n = 2)	Stress† (n = 14); Disease (n = 7); Illness (n = 4); Infection (n = 3); Shock (n = 2)		Pain (n = 6); Discomfort (n = 5); Fear (n = 5); Distress* (n = 4); Feeling ill (n = 2); Overheating (n = 2)
Bleeding/fluids/mucus from orifices			Disease (n = 6); Illness (n = 6); Injury (n = 6); Internal injury (n = 6); Stress† (n = 4); Trauma (n = 3); Infection (n = 2)		Pain (n = 17); Distress* (n = 5); Feeling unwell/ill health (n = 3); Discomfort (n = 2); Fear (n = 2); Sickness (n = 2)
Elevated heart rate		Hyperthermia (n = 3)	Stress† (n = 26); Disease (n = 4); Illness (n = 3); Physiological compromise (n = 3); Underlying heart		Fear (n = 13); Pain (n = 13); Distress* (n = 5); Anxiety (n = 3)

		condition (n = 3); Injury (n = 2); Shock (n = 2)	
Abnormal heart rhythm		Stress† (n = 23); Disease (n = 6); Illness (n = 3); Physiological compromise (n = 3); Injury (n = 2); Shock (n = 2)	Pain (n = 7); Distress* (n = 6); Fear (n = 6); Feeling ill (n = 2)
Presence of disease or illness	Old (n = 2)	Stress† (n = 6); Disease (n = 3); Illness (n = 2); Sick (n = 2)	Pain (n = 15); Discomfort (n = 5); Distress* (n = 4); Weakness (n = 4); Feeling unwell/ill (n = 3); Malaise (n = 2); Suffering* (n = 2)

3.3.2 Developing indicators of stranded cetacean survival likelihood

3.3.2.1 Perceived value of survival likelihood indicators

Forty themes on assessing likelihood of survival were generated from reflexive thematic analysis of participant responses in questionnaire 1 (Appendix 6 Table A6.2). Twenty of the major themes were provided for scoring as categories in the second round. Seventeen of the 20 indicator categories presented in questionnaire 2 were perceived to have 'great value' (median scores ≥7; Figure 3.3) for assessing survival likelihood.

Five indicator categories achieved consensus as being of great value (scores ≥7) by at least 70% of the experts, including one resource-based indicator ('length of time stranded and number of re-strandings') and four animal-based indicators ('signs of physical trauma, injuries and wounds'; 'signs of illness and disease'; 'swimming ability and orientation when returned to water'; 'bleeding/fluids/mucus from orifices'; Figure 3.3). The most valued indicator category for survival likelihood, based on the percentage of experts scoring it ≥7, was 'length of time stranded and number of re-strandings' while the least valued indicator category was 'distance to animal's natural habitat type' (Figure 3.3).

3.3.2.2 Perceived practicality of survival likelihood indicators

Thirteen survival likelihood indicator categories were perceived to be easy/practical to measure at stranding events (median score ≥7; Figure 3.4). Seven indicator categories reached expert consensus (≥70%) as being easy/practical to measure. These included two resource-/management-based indicators ('weather, ambient temperature, sea and tidal conditions' and 'availability of resources including equipment') and five animal-based indicators ('bleeding/fluids/mucus from orifices'; 'abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering'; 'respiration rate and character/effort'; 'signs of physical trauma, injuries and wounds'; and 'animal's skin condition such as sunburn, peeling, cracking or blistering'). The category considered most practical for measurement, being scored ≥7 by the highest percentage of experts, was resource-based ('weather, ambient temperature, sea, and tidal conditions') but this indicator was only considered highly valuable by 46% of experts. The least practical to measure, based on the percentage of experts scoring ≥7, was 'species biology and response to stress'.

Two of the most valuable indicator categories reached consensus as being easy/practical to measure (‘signs of physical trauma, injuries and wounds’ and ‘bleeding/fluids/mucus from orifices’). However, of the other easy/practical to measure indicator categories (i.e., reaching consensus), all except one (‘weather, ambient temperature, sea, and tidal conditions’) were considered by the experts to be greatly valuable (≥7) indicators of survival likelihood by over 50% of the experts.

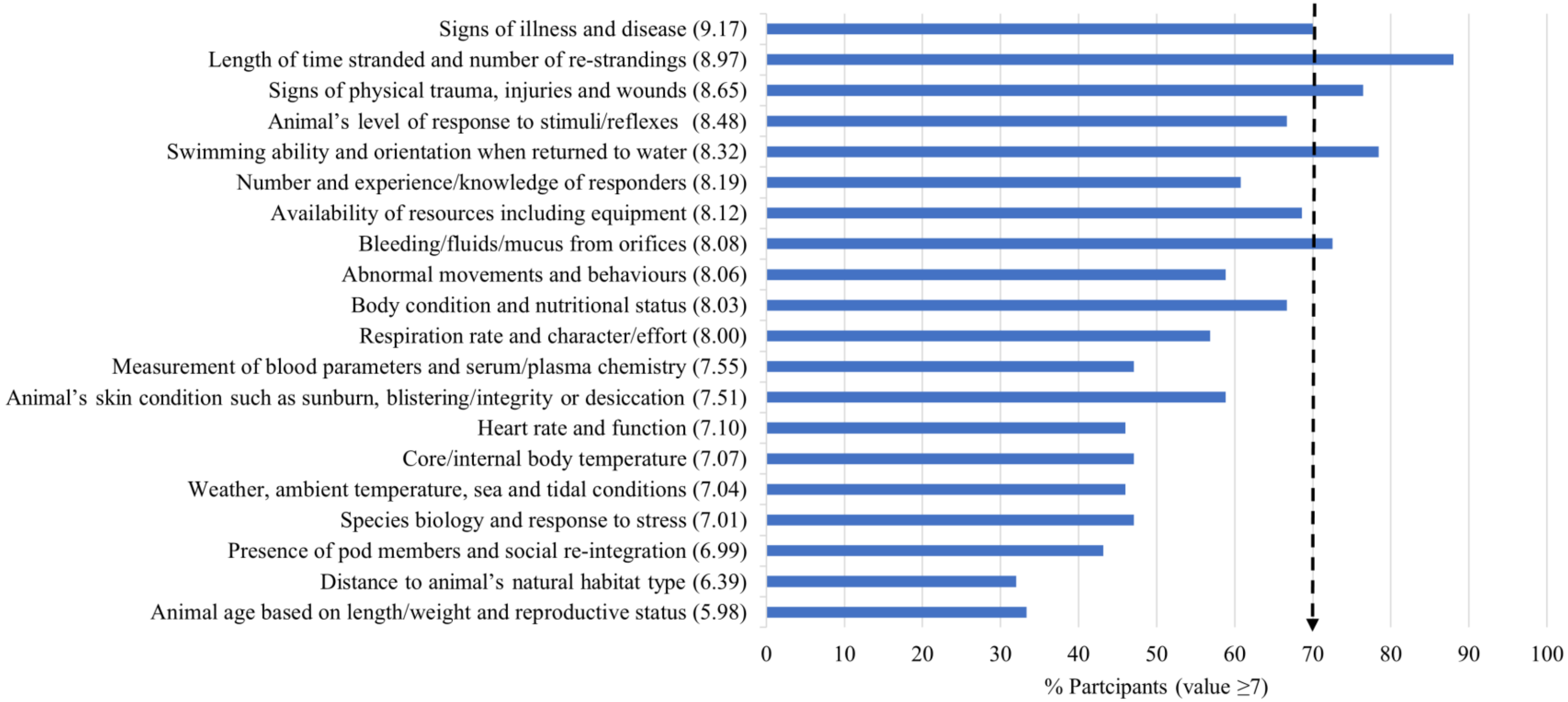

Figure 3.3 The perceived value of the 20 survival likelihood indicator categories generated from reflexive thematic analysis of expert suggestions, ranked in order of the median score (in parentheses) on the y-axis, with percentage of experts scoring the theme ≥7/10 on the x-axis. The dashed arrow represents the consensus level i.e., 70% of experts scored the indicator as highly valuable. The category labels have been simplified to fit on the figure, see Appendix 6 Table A6.2 for full labels.

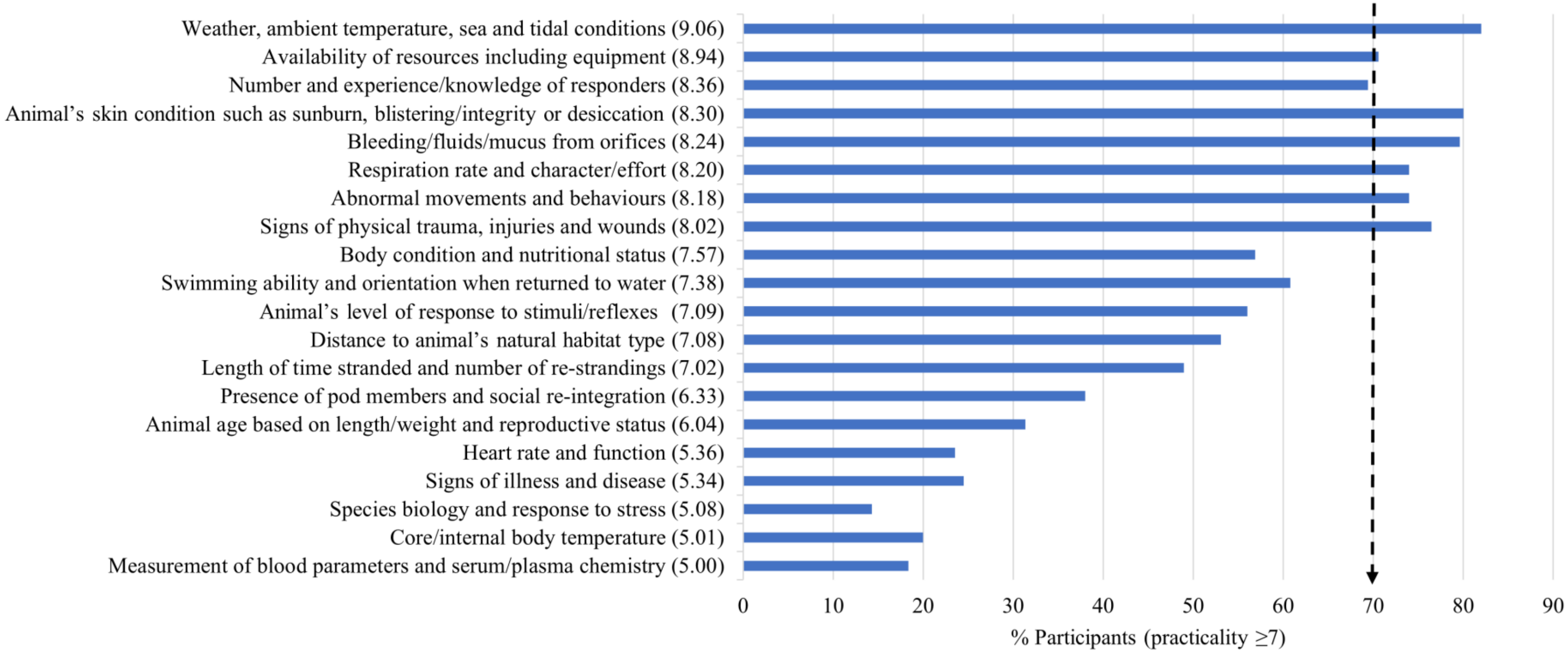

Figure 3.4 The perceived practicality of the 20 survival likelihood indicator categories generated from reflexive thematic analysis of expert suggestions, ranked in order of the median score (in parentheses) on the y-axis, with percentage of experts scoring the theme ≥7/10 on the x-axis. The dashed arrow represents the consensus level i.e., 70% of experts scored the indicator as practical to measure. The category labels have been simplified to fit on the figure, see Appendix 6 Table A6.2 for full labels.

3.3.2.3 Barriers to measuring survival likelihood indicators

Few participants (21%, n = 12) contributed major barriers to measuring the indicators of survival likelihood. Three major themes were interpreted from reflexive thematic analysis of these qualitative responses:

- Skills/training/knowledge of responders;
- Lack of data and ability to interpret parameters and assess changes from baseline;
- Difficulties in assessing each indicator due to equipment/situation at stranding event.

The main barrier regarding the measurement of survival likelihood indicators highlighted by six experts (50%) who provided a response to the question, was the availability of well-trained, experienced, and knowledgeable personnel. For example, one participant noted:

"[...] External signs should be easier to record and assess, especially when a remote expert can see photographs taken at the stranding - a barrier here is ensuring that the photographer takes photos that are useful and not just for social media use. Having the right people looking for indicators is imperative - they need to be trained and informed about cetaceans."

It was also noted that baseline data against which to compare measurements taken during a stranding are lacking. One participant noted:

"[…] having access to 'normal' baseline data for different species in the wild to compare with (e.g.: blood parameters, heart rates etc)."

The need for specialised equipment and complexities of undertaking measurements at stranding events were also highlighted by several participants:

"Any internal indicators can only really be taken with the right equipment - core temperature for example. Vets may carry thermometers but probably not a thermistor probe long enough to measure core temperature. […]"

"Blood parameters and serum chemistry can only be measured thoroughly in a lab, so cannot be assessed sufficiently on the beach. Using them as factors to determine survivability of an animal to be refloated, therefore, is very difficult, even impossible."

3.3.3 Potentially valuable and practical indicators of welfare and survival likelihood for future assessments

Thirty-seven themes (75.5%) generated from reflexive thematic analysis of questionnaire 1 responses were consistent for both welfare and survival likelihood (Appendix 6). In addition, 19 of the 20 indicator categories (90%) presented in questionnaire 2 for scoring were similar for welfare and survival likelihood. The indicator category that applied only to welfare was ‘vocalisation rate and type’, whilst the indicator category that applied only to survival likelihood was ‘species biology and response to stress’.

Four of the five (80%) indicator categories that reached consensus based on their perceived value were the same for welfare and survival likelihood (‘length of time stranded and number of re-strandings’, ‘signs of physical trauma, injuries, and wounds’, ‘signs of illness and disease’ and ‘swimming ability and orientation when returned to water’). Additionally, all seven indicator categories that reached consensus based on being easy/practical to measure were the same for both welfare and survival likelihood.

The indicator categories which were perceived to be greatly valuable (median scores ≥7) and easy/practical to observe and/or measure (median scores ≥7) for both welfare and survival are collated in Table 3.4.

Table 3.4 Indicator categories perceived by experts as valuable (median score ≥7) <u>and</u> measurable (median score ≥7) for <u>both</u> stranded cetacean welfare and survival likelihood. Type of indicator is provided to highlight those potentially providing direct welfare status information. For each, some basic recommendations for observation and/or measurement of the indicator using video and/or photographs are provided based on experience at strandings (Massey University, *unpub. data*) and previous work on cetacean welfare (Clegg et al. 2015) or strandings (Sharp et al. 2014).

Indicator	**Type of indicator**		**Method of observation/measurement**
Abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering	Status	Video	Continuously film cranio-laterally with entire animal body in frame if possible. Note what behaviours are occurring, how many times they occur (frequency) and for how long (duration). Note if other events e.g., human intervention, are occurring around animal simultaneously
Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness, or consciousness	Status	Video	When animal's eye open walk around, along length of animal to see if eye follows movement. If instructed by experts, gently touch around blowhole to see if blowhole tightens closed, gently touch at edge of corner of eye to see if there is a blink response
Animals skin condition such as sunburn, peeling, cracking, or blistering	Status	Photograph /video	Estimate the percentage of the body that has skin blistering and/or peeling, estimate depth of blisters based on layers of skin involved e.g., superficial sloughing

Bleeding/fluids/mucus from orifices	Status	Video	Regular observation of all accessible orifices (e.g., Mouth, blowhole, eyes) and note signs of blood, mucus or other fluids including appearance of colour and consistency
Body condition or nutritional status	Status	Photograph /video	Take photographs cranio-ventrally at head level towards flukes, observe body shape in epaxial section and thoracic wall e.g., for protrusion of ribs. Photograph cranio-laterally at head level to observe any concavity in the nuchal crest (area dorsal to blowhole)
Respiration rate and character/effort	Status	Video	Count the number of times the animal breathes during a 5 min period, observe whether the animal breathes out and then in, are they any noises when the animal breathes, does the animal make effort e.g., move each time it breathes?
Signs of physical trauma, injuries, and wounds	Status	Photograph /video	Look for any injuries, make note of how many an animal has, if they are bleeding: superficial or deep wounds, observe for any awkward looking positions e.g., pectoral fins that are up and out instead of close to body and down, curved peduncle position that does not change
Swimming ability and orientation when returned to water	Status	Video	After a period of acclimation in water is the animal able to remain upright alone, does it roll more to one side? If it is swimming, does it swim straight or in circles?

Amount of human interaction, number, and knowledge of responders	Alerting	Video	Count number of humans, what interactions are they having with the animal, what training they have
Availability of resources including equipment	Alerting	Photograph /video	What equipment is being used e.g., sheets, buckets, re-floating pontoons? Also discuss with local authorities, strandings network about available equipment
Length of time stranded and number of re-strandings	Alerting	Video	Gather information from field responders about when animal was first found stranded, how many times has it been re-floated? Film any re-floating procedures and subsequent behaviour including re-strandings

3.3.4 *Effect of participant expertise on perceived value and practicality of indicators*

The LDAs revealed overlap of expertise groups in the scoring of welfare and survival likelihood indicator categories in terms of both value and practicality. This suggests that self-reported expertise did not have a major effect on the scoring of indicator categories. Specific results from the LDAs are presented in Appendix 7.

3.4 Discussion

Management decisions at stranding events should be informed by both the likelihood that the animal will survive post-re-floating, and the impacts that both the stranding and human intervention have on the animals' welfare state (overall affective experience). However, empirical data to inform such assessments is currently lacking (IWC 2016a; Nicol et al. 2020). This chapter has provided face validity (alignment between indicators and welfare state/survival likelihood) to the first comprehensive list of indicators perceived by international, interdisciplinary experts to be valuable and practical to measure for assessments of stranded cetacean welfare and survival likelihood. These indicators should now be further evaluated at cetacean stranding events to confirm their feasibility and their predictive value for survival likelihood. Furthermore, this chapter has provided information on the potential affective states that cetaceans may experience during a stranding event, based on expert opinion. Given the paucity of empirical data available to assess stranded cetacean welfare and survival likelihood, this represents an important step in the development of a systematic assessment framework to support appropriate, scientifically-informed decision-making.

Notably, the indicator categories arising from expert opinions highlight the inextricable link between welfare and survival likelihood for stranded cetaceans, with many of the same indicators suggested for both concepts. This emphasises that improvements in knowledge and ability to assess such indicators will advance evaluation of both welfare and survival likelihood of stranded cetaceans. However, the variable affective experience suggestions provided by experts for welfare status indicators, highlight the importance of undertaking investigations into how indicators correlate among differing variables (Watters et al. 2021). For example, further work correlating behavioural expression with factors such as physical state, time stranded, types of intervention and actual survivorship, should be considered research priorities.

3.4.1 *Using expert opinion to develop valuable and measurable indicators of stranded cetacean welfare and survival likelihood*

Indicators that emerged as both valuable (how closely each indicator aligned with welfare state or survival likelihood) and practical (how feasible the indicator is to measure) for assessments, based on the median scores and achieving consensus, were largely similar for welfare and survival. It is useful that these experts report that the same indicators can be used to assess both welfare state and likelihood of survival, since this will allow for the development of an assessment framework that considers both concepts concurrently. Consistent with this, the same group of experts regarded the concepts of welfare and survival likelihood in the context of strandings to overlap and had similar concerns about issues that may affect both welfare and survival likelihood of stranded cetaceans (Boys et al. 2022b; Chapter 2). In addition, it is crucial that both immediate welfare impacts and likelihood of survival be considered when making decisions about whether individuals should be re-floated, palliated, or euthanised (Boys et al. 2022c, b; Chapters 2 and 6).

The experts ranked indicators classified as both animal-based and resource-/management-based as greatly valuable and practical to measure for evaluating the welfare and survival likelihood of stranded cetaceans. Importantly, many of the indicators relate to the concepts and concerns for stranded cetacean welfare and survival likelihood that were highlighted by the same group of experts (Boys et al. 2022b; Chapter 2). The animal-based indices are direct indicators of a cetacean's physical state or external situation and therefore more directly reflect aspects of welfare and survival likelihood status. Several animal-based indicators scored as valuable and practical to measure, related to various aspects of survival likelihood and animal welfare, as conceptualised using the Five Domains model for animal welfare assessment: nutrition, physical environment, health, and behavioural interactions (Mellor et al. 2020). The resource-/management-based indicators, which provide important contextual information, related to the length of time stranded, weather conditions and human intervention, in terms of available resources and the knowledge of responders.

The fact that the representative indicators suggested by experts fit in all four domains of the Five Domains Model (Mellor et al. 2020), emphasises its potential to be used to develop a structured assessment framework specific to stranded cetaceans. Some indicators may overlap among domains; for example, skin conditions such as blistering, which was placed into the physical environment (D2) could also be considered in health (D3). Such overlap in measurable indicators should ensure that redundancy is included by reducing the possibility of overlooking an indicator, since it will likely be identified elsewhere (Clegg et al. 2015).

The most valuable indicators for welfare which reached consensus included four welfare status indicators: 'physical trauma, injuries and wounds', 'animal's level of responsiveness' and 'illness/disease' in the health domain (D3), and 'swimming ability' in the behavioural interactions domain (D4). The fifth indicator that reached consensus was welfare-alerting and resource-/management-based: 'length of time stranded' in the physical environment domain (D2). Importantly, four of these indicators were also considered to be of great value and reached consensus for survival likelihood. The indicator that did not reach consensus for survival likelihood was 'animal's level of responsiveness', though this was still considered to be of great value (median score: 8.5). Additionally, for survival likelihood another animal-based indicator 'bleeding/fluids/mucus from orifices' was of great value and reached consensus. Notably, this indicator was also considered to be greatly valuable for welfare (median score: 8.5), being a welfare status indicator in the health domain (D3).

Of the welfare indicators that reached consensus as being greatly valuable, only one was considered to also be practical to measure based on consensus ('physical trauma, injuries, wounds'). Likewise, for the valuable survival likelihood indicators that reached consensus, only two were considered to be practical to measure based on consensus: 'physical trauma, injuries, wounds' and 'bleeding/fluids/mucus from orifices'. However, when considering the median scores of the other valuable indicators, all but one ('illness/disease') were considered practical to measure (median score ≥7). This suggests that most of the valuable indicators would be assessable at stranding events.

Those indicators that were considered practical to measure based on consensus were the same for both welfare and survival likelihood. These included five animal-based indicators ('animal's skin condition', 'abnormal behaviour', 'respiration rate', 'bleeding/fluid/mucus from orifices' and 'physical trauma, injuries, wounds') and two resource-/management-based indicators ('weather' and 'availability of resources'). Notably, all these practical indicators, except 'weather', were also considered greatly valuable based on their median scores (≥7). In this case, weather was likely not considered to be valuable since it is not directly related to welfare state or survival likelihood. However, it may still provide additional risk-related information, since concerns likely to have negative effects on stranded cetacean welfare and survival likelihood included hyperthermia and sunburn (Boys et al. 2022b; Chapter 2), which are more likely to occur on hot and/or sunny days (Geraci and Lounsbury 2005).

Notably, a further two indicators did not reach consensus for value or practical measurement but based on median scores (≥7) were still considered by experts as both greatly valuable and practical to measure for both welfare and survival likelihood. These were the animal-based indicator ‘animal body condition’ which would represent welfare status in the domain nutrition (D1) and the resource-/management-based indicator ‘human interaction, number and knowledge of responders’ which would be considered as welfare alerting in the domain behavioural interactions (D4).

Despite only a third of experts reporting animal welfare knowledge, the complement of animal-based indicators recommended by the experts facilitates holistic assessment of animal welfare state and survival likelihood. Consistent application of the indicators considered to be both valuable and practical would ensure scientifically-informed decision-making at stranding events. Results of this chapter tentatively suggest that the indicator categories provided in Table 3.4, may be potential candidates for assessment of both welfare and survival likelihood at stranding events, based on being considered valuable and practical by experts (median scores ≥7). Additionally, these indicators are likely assessable via video and therefore could be used by remote experts in an evaluation (Table 3.4); a factor emphasised to be important by experts in this chapter since there are often limited trained/knowledgeable personnel at stranding events.

Those indicators relating to an animal’s physical state (i.e., aligned to Domains 1 to 3) could provide information about why an animal may have stranded and how it will likely cope with prolonged physiological stress. Poor body condition, physical trauma/injury and bleeding/fluid from orifices are likely linked to negatively valenced welfare states (Schwacke et al. 2014; Clegg et al. 2015; Nicol et al. 2020) and can affect the outcome of strandings due to the detrimental effect on survival (Townsend 1999; Geraci and Lounsbury 2005; Fernandez et al. 2017). Objective assessment of these indicators may be limited where there are incomplete data available, such as for visual assessment of body condition (Joblon et al. 2014), and difficulties in diagnosing internal injuries (Ketten and Montie 2008). This lack of data and difficulties in evaluating some indicators were also highlighted by the experts as barriers to assessments. Despite these difficulties, some of these suggested indicators may correlate with certain management decisions. For example, haemorrhaging from orifices is considered an indication of significant internal injury, and a decision of euthanasia is often implied due to the likely compromised welfare and low survival likelihood of the animal (Whaley and Borkowski 2009; Harms et al. 2018; Boys et al. 2022c; Chapter 6).

Indicators were also generated that provide suggestion of how being out of the water is likely affecting an animal in terms of its skin condition and, respiratory rate and character/effort. Assessment of skin condition could provide information on the animals physiological state, and skin blistering is suggested for use in the decision-making process for re-floatation versus euthanasia due to the likely impact upon both welfare and survival likelihood (Barnett et al. 2013; IWC 2014; Boys et al. 2022c; Chapter 6). Respiration rate and character will vary depending on the state of the animal; it is generally understood that high respiratory rates (>6 breaths/min) in delphinids are suggestive of physiological stress (Mazzariol et al. 2015; Gulland et al. 2018). Other respiratory abnormalities such as a delay of a few seconds between expiration and inspiration, and prolonged apnoea are indicative of shock (Mazzariol et al. 2015). Importantly, respiratory impairment is survival-critical, thus impacting upon an animals ability to survive, but is also likely to induce the negatively valenced welfare state of breathlessness aligned to a health condition in a survival-related domain (D3) (Lansing et al. 2009; Beausoleil and Mellor 2015b).

Behavioural indicators likely reflect how the animal's ability to exercise agency, or choice, is impacted by its (largely unnatural) situation and can be used to infer how it is experiencing its current situation. Unfortunately, there have been no ethological studies undertaken on stranded cetaceans, therefore assessing abnormal movements and what they may reflect in these animals is currently limited. Nevertheless, some behaviours have been noted previously as informing re-float decisions based on animal disposition (Wiley et al. 2001; Sampson et al. 2012; Sharp et al. 2016). For example, arching is assumed to be a sign of significant physiological stress (Townsend et al. 2018) and requires animals undergoing health assessments to be released immediately if observed, due to the negative impact on welfare and potential detrimental effect on survival

(Townsend et al. 2018; Barratclough et al. 2019). Another indicator that was generated and is used in capture-release health assessments is animal responsiveness. In these assessments animals are required to be alert and responsive before human intervention can be undertaken (Townsend et al. 2018). Animals that begin alert but have progressively reduced reflexes and dull eyes are likely to be deteriorating (Mazzariol et al. 2015; Nollens et al. 2018; Townsend et al. 2018), and stranded animals displaying a loss of reflexes should be considered candidates for euthanasia due to their welfare compromise and low survival likelihood (Harms et al. 2018; Boys et al. 2022c, in review; Chapters 5 and 6). Finally, swimming ability was also suggested; however, this can only be assessed once an animal is re-floated. Therefore, it should be considered as part of a final assessment to ensure that a re-floated animal is ready to be released, rather than as an indicator of animal viability for management decisions of re-floatation versus euthanasia (Gales et al. 2008b).

Notably, as was emphasised by experts in the barriers provided, there is limited baseline information for stranded cetaceans against which to compare physiological or behavioural deviations and identify relevant welfare and/or survival compromise. Therefore, further data collection and correlation among indicators and additional strandings context will be required to ensure rigorous evaluation (Watters et al. 2021). Importantly, experts also highlighted the need for trained personnel to accurately interpret behavioural and physiological parameters and evaluate these in the context of each stranding situation; unfortunately, this is currently limited by the variable availability of knowledgeable, trained personnel at many stranding events (Gales et al. 2008b; Boys et al. 2022b; Chapter 2).

The three resource-/management-based indicators considered valuable and practical to assess both welfare and survival likelihood included the length of time stranded/number of re-strandings, and features related to human intervention in terms of knowledge and available resources, such as equipment. These indicators provide relevant information of the potential risks of each stranding situation to animal welfare and survival likelihood (Spangenberg and Keeling 2016; Harvey et al. 2021). For example, the length of time stranded and number of re-strandings will affect the level of compounding damage that a stranded cetacean undergoes, since prolonged and/or multiple strandings likely cause sustained physiological stress responses (Fernandez et al. 2017; Câmara et al. 2020).

Therefore, longer, or numerous strandings are expected to increase the duration and intensity of negative welfare states and detrimentally impact survival likelihood.

Inappropriate human intervention related to responder lack of knowledge and/or unsuitable equipment can lead to additional animal injury and/or increased mortality (Simeone and Moore 2018b), adversely affecting both welfare and survival likelihood. In contrast, appropriate intervention with suitable equipment may minimise harm to animals caused by stranding and improve survival likelihood by reducing the amount of time stranded (Fernandez et al. 2017). However, the impact upon animal welfare is more complex to understand, since cetaceans, as wild animals unaccustomed to close human contact, may experience any form of human interaction as a threatening encounter, negatively impacting welfare (Mellor et al. 2020). Nevertheless, humans may also reduce the potential for significant welfare compromise caused by stranding associated factors, such as hyperthermia or sunburn, by providing shade and cooling water (Geraci and Lounsbury 2005).

Notably, due to the substantial overlap among indicators generated as valuable and practical for assessing both stranded cetacean welfare and survival likelihood, the application of these in an assessment framework would enable an integrated approach towards considering both concepts concurrently. This would ensure that decision-making at stranding events is scientifically-informed based on animal status and should ensure the best welfare and conservation outcomes for individual stranded cetaceans. However, the current lack of data collected at live stranding events hinders indicator evaluation and correlation, limiting the application of such an assessment framework. It is recommended that future studies prioritise data collection at stranding events to identify observable and/or measurable indicators, evaluate their feasibility for use in assessments and validate their functional impact to inform intervention decisions (Lesimple 2020). Such systematic data collection would also provide a baseline against which to examine for abnormalities. Improved data collection would enable an understanding of which indicators could be assessed by experts remotely via video recordings and/or photographs. Once such investigations are undertaken, extended work with experts should assess the reliability and validity of each indicator (Phythian et al. 2011; Pearson et al. 2021) for assessing stranded cetaceans. Improved understanding of indicators may also enable robust examination of some indices by lay-persons, which would be particularly beneficial at mass stranding events where resources tend to be further limited (Ogle 2017). These indicators, and the affective states inferred from them, could then be applied to develop an assessment framework to ensure holistic evaluation of stranded cetaceans.

3.4.2 Inferring affective experience from animal-based welfare indicators

In addition to providing face validity to indicators for assessing stranded cetacean welfare state, this chapter provides an initial understanding of potential affective states that experts postulated stranded cetaceans may experience based on impacts in each physical/functional and situation-related domain. These would be included in the fifth domain of the Five Domains Model (Mellor et al. 2020). The results generally showed consensus among experts about the valence of affective states inferred by the indicators, with almost all indicators being interpreted as reflecting negative experiences such as “stress”, “distress”, “pain”, and “fear”. This is likely due to the fact that strandings are understood to be atypical situations where physical disruptions and physiological instabilities can occur (Cowan and Curry 2008; Fernandez et al. 2017; Câmara et al. 2020) which will likely lead to negative mental/affective states. Additionally, it is likely that experts explicitly linked the welfare indicators to survival and end-of-life decision-making which typically focuses on alleviating suffering.

However, several terms with positive connotations (“relaxed”, “resting”, “calm”, “excitement”, “happy” and “safety”) were offered by experts for the indicators ‘reduced respiration rate’, ‘abnormal swimming movements’, ‘fluke slapping’ and ‘vocalisation’, respectively. Furthermore, both negatively and positively valenced affects were suggested by experts for the indicator vocalisation. This could have important implications for decision-making if a vocalisation is considered an indication of “happy” or “excitement” due to human interaction rather than a distress call. Notably, for other behavioural indicators there was no clear expert consensus in terms of specific affects, other than generally being negative, likely due to the context of stranding. Increased data collection on a suite of behavioural and physiological indicators should be undertaken at strandings, to allow for correlations to be investigated with additional stranding-related factors such as physical state, time stranded and actual survival. This will ensure valid evaluation of such indicators and appropriate inferences to inform strandings management (Lesimple 2020; Watters et al. 2021).

The same group of experts emphasised an integrated approach for characterising welfare and evaluating key welfare concerns for stranded cetaceans, including biological function, health, behaviour, and affective state (Boys et al. 2022b; Chapter 2). Despite this, some experts did not provide affective experiences, and instead gave descriptions of what an indicator may mean such as "Animal may be slipping away" or related to a possible medical explanation such as "neurological disease or condition" or "hit by boat" (see Table 3.3 and Appendix 6 Table A6.3). This suggests that although experts understand animal welfare to be a property of the individual cetacean (Boys et al. 2022b; Chapter 2), some experts are not comfortable inferring a subjective mental experience that the cetacean may be enduring. This was explicitly noted by at least two veterinarians and is a legitimate concern as there is much scientific research required to provide support for such inferences (Beausoleil and Mellor 2017; Mellor 2017).

Importantly, the variation in understanding of what indicators reflect, could influence the evaluation of animal welfare at stranding events, particularly in relation to the level of importance given to different outcomes (Beausoleil et al. 2018). For example, assessments that focus solely on evaluations of biological function without cautiously interpreting the results in terms of affective state, may suggest that animals would survive and result in re-floatation, but this does not mean these animals are in a good welfare state or have a life worth living (Paquet and Darimon 2010). Crucially, poor welfare state can have conservation implications by impacting fitness parameters (Ashley and Holcombe 2011; Germain et al. 2017) and long-term survival (Armstrong et al. 1999). According to contemporary concepts of animal welfare, including those generated by this group of experts (Boys et al. 2022b; Chapter 2), 'fitness' should be understood in terms of how it relates to impacts upon the animal's affective state. Therefore, the potential affective experiences of cetaceans must be considered from objective assessment of a range of indicators, to ensure that holistic approaches to welfare and survival are integrated in the decision-making process (Beausoleil et al. 2018; Clegg et al. 2021) considering both during and post stranding.

3.4.3 Chapter considerations

Experts in this chapter were also asked to characterise the welfare of stranded cetaceans (Boys et al. 2022b; Chapter 2), this characterisation can be used to infer the validity of the welfare indicators presented here. The same group of experts conceptualised stranded cetacean welfare according to contemporary animal welfare science (Boys et al. 2022b; Chapter 2), which encompasses physical, behavioural and situation-related factors and how these impact upon affective state. Therefore, it is unsurprising that many welfare and survival indicators aligned. However, if the construct of welfare was understood by participants from differing animal welfare orientations, then these conceptions could have limited the scope of indicators to be considered in an assessment and may have favoured others; this might limit the ability to adequately address welfare concerns and may conflict the conclusions of an assessment (Fraser et al. 1997). For example, those emphasising the biological function orientation are more likely to focus on issues affecting health/function (e.g., respiratory disease), but may discount other indicators, such as separation from conspecifics, which do not immediately impact health/function. For social species of stranded cetaceans this could lead to healthy animals being re-floated alone leading to unnatural social isolation which may impact future survival (Ellis et al. 2017). In contrast, those whose conceptualisation of welfare aligns with the natural living concept are more likely to focus on the animal's ability to perform their natural behaviours in terms of their needs and motivation. This is particularly relevant in captive or managed environments e.g., zoos (Sherwen et al. 2018), but in the case of stranded cetaceans is limited in its utility since the animals are in an abnormal environment unable to perform natural behaviours. Therefore, it is important to understand how welfare has been conceptualised before undertaking an assessment to ensure that the interpretation of outcomes is valid and reliable for the construct being measured i.e., to ensure that face validity is effectively characterised (Fraser et al. 1997). Face validity of the welfare indicators presented here can be inferred from the conceptualisation of stranded cetacean welfare which was characterised by the same group of experts (Boys et al. 2022b; Chapter 2).

A reflexive thematic analysis approach using verbatim wording from experts was used to generate the categories scored in this chapter. This allowed for conclusions to be drawn from the data rather than approaching it with pre-conceived ideas (Braun and Clarke 2006, 2012). However, I acknowledge that I had a role in co-generating the categories presented for scoring, and therefore the data created cannot be considered 'objective' (Yin 2016; Nowell et al. 2017). I am a marine biologist focused on cetacean strandings, and therefore have personal experiences and opinions relating to the categories explored. Throughout the questionnaire, experts were provided with opportunities to comment and none were received, suggesting that the experts agreed with the categories presented for scoring, providing some 'ground-truthing' to the co-generated data (O'Cathain and Thomas 2004).

Participants that were involved in the generation of themes in questionnaire 1 did not have to complete questionnaire 2, and vice versa. This may mean that some experts that responded only to questionnaire 2 may have suggested additional indicators that were not presented for scoring. However, throughout questionnaire 2 experts were able to provide comments and none were received to suggest experts felt any important categories were missing.

Participants of variable expertise (cetacean biologists, animal welfare scientists and veterinarians) responded to the questionnaires, enabling both welfare and conservation focussed indicators to be generated. This is important as heterogeneity is understood to lead to improved results when applying group decision-making (Boulkedid et al. 2011). Notably, the overlap in the LDAs indicated there were no major differences among expertise in terms of indicator value or practicality scoring (Appendix 7). This suggests that overall, there was consensus among expertise on those indicators that should be further investigated as part of the development of a framework to assess stranded cetacean welfare and survival likelihood.

3.5 Conclusion

Using expert opinion, this chapter generated a range of animal-based and resource-/management-based indicators specific to stranded cetaceans that were considered valuable and practical to measure. The complement of indicators generated and ranked by this interdisciplinary, international group of experts reflect a holistic approach to assessing both welfare and survival likelihood. Importantly, the generated indicators emphasised the inextricable link between welfare and survival likelihood for stranded cetaceans, demonstrating that welfare science can be integrated alongside conservation biology at cetacean strandings events. These indicators should be investigated at future stranding events to assess their feasibility, and to enable an assessment of their reliability and validity to inform decision-making. In this way stranded cetacean state can be unambiguously assessed, and measurable objectives established for conservation goals that incorporate animal welfare. In the following chapter the feasibility of these identified indicators is investigated.

Chapter 4 Evaluating potential cetacean welfare indicators from video of live stranded long-finned pilot whales (*Globicephala melas edwardii*)

Live long-finned pilot whale (*Globicephala melas edwardii*) undergoing human intervention during a mass stranding event.
Photo credit: Rebecca M. Boys.

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Abstract

Despite the known benefits of considering welfare within wildlife conservation and management, there remains a lack of data to inform such evaluations. To assess animal welfare, relevant information must be captured scientifically and systematically. A key first step is identifying potential indicators of welfare and the practicality of their measurement. The feasibility of evaluating potential welfare indicators from opportunistically gathered video footage was assessed using four stranded odontocete species (n = 53) at 14 stranding events around New Zealand. The first stranded cetacean ethogram was compiled, including 30 different behaviours, 20 of which were observed across multiple species. Additionally, thirteen types of human intervention were classified. A subset of 49 live stranded long-finned pilot whales (*Globicephala melas edwardii*) were assessed to determine indicator prevalence and to quantify behaviours. Four 'welfare status' and six 'welfare alerting' non-behavioural indicators could be consistently evaluated from the footage. Additionally, two composite behavioural indicators were feasible. Three human intervention types (present, watering, and touching) and five animal behaviours (tail flutter, dorsal fin flutter, head lift, tail lift, head side-to-side) were prevalent (>40% of individuals). This chapter provides the first systematically collected data on potential welfare indicators evaluated at cetacean strandings and highlights the potential for non-invasive, remote assessments via video footage. The chapter represents the initial step towards developing a systematic, holistic welfare assessment framework for cetacean stranding events.

Keywords: Animal welfare assessment; Behaviour; Cetacean; Human intervention; Management; Marine mammal; Stranding; Wildlife

4.1 Introduction

The welfare of free-ranging animals is increasingly recognised as important to conservation (Paquet and Darimon 2010; Butterworth 2017; Scholtz 2017). In addition, there is growing acknowledgment that human activities may directly and indirectly compromise the welfare of wild animals (Fraser and MacRae 2011). However, conservation of wildlife populations is often a focus of government regulations, policies and biodiversity plans and the welfare of individual animals comprising such populations is often overlooked. This is despite the fact that animal survival, and thus conservation success, is inextricably linked to welfare (Paquet and Darimon 2010; Beausoleil et al. 2018).

Although the need to assess wild animal welfare has been highlighted (Fraser 2010; Menkhorst et al. 2016; Hampton and Hyndman 2019; Clegg et al. 2021), there are limited systematic, scientific protocols for such assessments (Harvey et al. 2021). Furthermore, detailed behavioural and physiological data from species in the wild are often lacking (Hill and Broom 2009), hindering development of welfare assessments for wild populations (Harvey et al. 2020). Thus, a first step to progressing systematic and holistic welfare assessment for free-ranging wild animals is developing methods to capture relevant data. Such data need to be species/taxon- and context-specific and should address known or suspected welfare concerns (Harvey et al. 2020; Watters et al. 2021). Furthermore, to provide information about the welfare state of the animal, science-based indicators that can be observed and/or measured must be identified (Richmond et al. 2017; Harvey et al. 2020; Harley et al. 2021; Whittaker et al. 2021).

In the context of free-ranging cetaceans, data on stress hormones (Siebert 2011; Teerlink et al. 2018; Burgess et al. 2018), body condition (Bradford et al. 2012; Hart et al. 2017; Christiansen et al. 2020), skin disease (Van Bressem et al. 2009; Hart et al. 2012; Clegg et al. 2015) and the impacts of anthropogenic activities on behaviour (Stockin et al. 2008; Meissner et al. 2015; Bas et al. 2017) have been collected. However, few studies interpret their findings in terms of welfare or discuss possible welfare implications (Clegg et al. 2021). During live strandings, cetaceans are subject to both natural (Cowan and Curry 2008; Fernandez et al. 2017) and anthropogenic stressors (Geraci and Lounsbury 2005) that may affect their welfare and survival likelihood (Boys et al. 2022b; Chapter 2). Unfortunately, thus far such data on various behavioural and physiological indicators have not been gathered.

Major knowledge gaps concerning the welfare of stranded cetaceans were identified by international experts to be interpreting behavioural and physiological parameters, diagnosing internal injuries and making end-of-life decisions (Boys et al. 2022b; Chapter 2). Furthermore, these experts stated that major barriers to assessing the welfare of stranded cetaceans related to the limited relevant data collection at strandings and the lack of experts available onsite to interpret parameters and assist in decision-making (Boys et al. 2022b; Chapter 2). Notably, the characterisation of stranded cetacean welfare by those experts aligned with contemporary animal welfare science, which interprets interrelated aspects of health, biological function and behaviour in terms of their impact on animal mental state (Boissy et al. 2007; Mellor 2016). Welfare assessments guided by such characterisation are often facilitated via use of the Five Domains Model framework for assessing animal welfare (Mellor et al. 2020). In such a framework the indicators in domains 1–4 are observed and/or measured, and their cumulative impacts are used to cautiously infer the animal's potential affective state (mental state) in the fifth domain (Mellor and Beausoleil 2015; Beausoleil and Mellor 2017; Beausoleil et al. 2018).

Subsequently, these same experts proposed a range of potential welfare indicators for stranded cetaceans (Boys et al. 2022d; Chapter 3). The potential indicators could be grouped into three physical/functional (nutrition, physical environment, health) and one situation-related domain (behavioural interactions) of the Five Domains Model (Mellor et al. 2020). The proposed indicators included animal-based parameters, reflecting some aspect of the physical (e.g., body condition), physiological (e.g., respiration rate) or behavioural state of the animal (e.g., vocalisation). Other indicators were resource-/management-based parameters, reflecting aspects of the stranded cetacean's environment (e.g., substrate, duration stranded) or management (e.g., human interaction) that may influence its welfare (Fraser 2008; Hemsworth et al. 2015). Resource-/management-based indicators provide welfare-relevant information but do not provide direct evidence of welfare state and are thus characterised as 'welfare alerting' (Harvey et al. 2020). Only animal-based indicators can provide direct information about the animal's 'welfare status' and are often preferred in welfare assessments. However, some animal-based indicators may only be 'welfare alerting' in that they can indicate a predisposition for welfare impacts that relate to the animal itself rather than its environment, for example an animal that is neonatal or unweaned. Welfare alerting indicators are generally more feasible and reliable to assess across time and different observers and are often non-invasive, thus are commonly applied in welfare assessments.

To successfully apply indicators in a welfare assessment framework (WAF), the feasibility of measuring the indicators, methods of measurement and validity for inferring welfare states (i.e., mental states) from observable indicators must be evaluated (Kaurivi et al. 2019; Lesimple 2020; Harvey et al. 2021). In this chapter, the feasibility of assessing animal-based and resource-/management-based indicators proposed by experts at live cetacean stranding events was examined (Boys et al. 2022d; Chapter 3). Furthermore, since experts highlighted the need for assessments to be undertaken by remote, skilled personnel (Boys et al. 2022b; Chapter 2), indicators were evaluated based on whether they could be observed and/or measured using video footage gathered at live strandings.

Specifically, this chapter evaluates the use of video footage to (1) identify potential animal and resource-/management-based welfare indicators that could be feasibly measured, (2) examine why certain proposed welfare indicators cannot be identified and/or feasibly measured, and (3) assess whether indicators observed from pilot whales can be quantitatively evaluated via video. There are currently no ethograms available for stranded cetaceans and there is limited detail on the types of human intervention employed at stranding events. Therefore, this chapter sought to identify, and characterise all stranded cetacean behaviours (animal-based indicators) displayed and to provide the first description of types of human intervention (resource-/management-based indicators), that occurred at these same stranding events. Additionally, this chapter examined whether features of the stranding circumstances affected the prevalence, frequency or duration of behaviours displayed by stranded pilot whales.

4.2 Methods

4.2.1 In-field data collection

Due to the stochastic nature of strandings, video footage was collected opportunistically at 14 live stranding events between August 2010 and March 2022 around New Zealand

(Appendix 8 Table A8.1). Filming occurred with 53 live stranded cetaceans involving four species of odontocete: long-finned pilot whale (*Globicephala melas edwardii*), pygmy killer whale (*Feresa attenuata*), Cuvier's beaked whale (*Ziphus cavirostris*) and Gray's beaked whale (*Mesoplodon grayi*). Most stranding events (11 events, 49 individuals) involved long-finned pilot whales, herein referred to as pilot whales. Accordingly, analyses presented here focus only on pilot whales. Additional data from other species examined are included in the initial ground-truthing to identify and characterise all animal behavioural and human intervention indicators.

Camera set-up varied based on the opportunistic nature of events and equipment availability (Appendix 8 Table A8.1). When I was able to attend a stranding, two GoPro Hero 7 Black video cameras (GoPro Inc.) were mounted on wooden stakes anchored into the ground at 1–2 m from the focal animal. Each camera was mounted at a height of 50–100 cm and positioned cranio-laterally and angled caudally (0–45°) towards the tail flukes for each focal individual. These recordings were made at 720p and 60 fps with wide angle view, allowing for the focal animal's entire body to be observed bilaterally. Where I was unable to access the animals prior to re-floatation, footage was acquired from strandings personnel, including Department of Conservation (DOC) rangers (the government agency responsible for the management of stranding events), marine mammal medics and the public using camera phones, GoPro cameras, or other similar video cameras. In such circumstances, the videographer stood 1–2 m from the animal, and when possible, positioned themselves cranio-laterally to the focal individual's head, angling the camera caudally towards the tail flukes. Where possible, the videographer alternated position around the animal to enable the entire body to be observed bilaterally. In other cases, individuals were filmed from a lateral position, capturing the entire body on one side. Filming duration was dependent upon battery availability, time of day and the strandings response procedures in progress.

4.2.2 Selection of potential welfare indicators

Based on the opinions of an international panel of experts in cetacean biology, veterinary medicine, and/or animal welfare (Boys et al. 2022d; Chapter 3), a list of theoretically observable/measurable parameters that could be used as potential welfare indicators for stranded cetaceans was developed. The list also included parameters that were deemed observable/measurable from initial viewing of the video footage collected during the stranding events (Appendix 8 Table A8.1). The indicators and composite behavioural parameters (category including many different behaviours, each of which would be considered an indicator) were organised into the three physical/functional domains (nutrition, physical environment, health) and the situation-related domain (behavioural interactions) of the Five Domains model for welfare assessment (Mellor et al. 2020; Table 4.1). Within each domain, indicators were further split into animal-based indicators that may directly reflect animal state ('welfare status'), and 'welfare alerting' indicators (both animal- and resource-/management-based), which provide relevant information about the animal or its environment that may affect its state (Harvey et al. 2020; Table 4.1).

Table 4.1 Proposed animal welfare indicators, or composite indicators*, organised into the three physical/functional domains and one situation-related domain of the Five Domains Model for welfare assessment (Mellor et al. 2020). Within each domain, indicators are organised according to the type of information they provide about the animal's state. See text for details of each indicator and how it was measured or scored.

Domain	**Indicators**	
	Welfare status	**Welfare alerting**
1: Nutrition	Body condition	Animal age class
2: Physical environment	Skin condition/blistering	Initial strand vs Re-strand Dry-strand vs In-water strand Availability of equipment Substrate type *Weather, sea, and tidal conditions
3: Health	Signs of trauma, injuries Signs of skin illness and disease Respiration rate and character/effort Heart rate Bleeding/fluids/mucus from orifices	

4: Behavioural interactions	Body posture *Movements and behaviours Animal vocalisation	Presence and status of pod members *Type and duration of human interaction

4.2.3 Data scoring

Each video file, for all species, was examined manually at 0.8x speed at least twice to identify all observable indicators for each focal individual. A subset of videos was examined by two independent observers to ensure consistency in indicator classification. For each animal, information was collated about which indicators could be assessed (Table 4.1) and, for those indicators that can vary bilaterally, whether they could only be assessed on the left, right or both sides. The reasons that particular indicators could not be observed and/or measured for each individual cetacean were also noted. Since 92.5% (n = 49) of individual focal stranded cetaceans were pilot whales (Appendix 8 Table A8.1), only data related to that species was subsequently analysed and presented here. To be considered feasible, an indicator had to be fully assessable (across the whole body) and prevalent, being observed in at least 40% of the pilot whales.

Domain 1: Nutrition

Body condition was assessed visually based on the concavity of the epaxial musculature and nuchal crest following Joblon et al. (2014). The 4-point body condition score was assessed as (1) Emaciated: severe concavity of epaxial musculature, visibility of ribs and deep depression of nuchal crest; (2) Thin: mild to moderate concavity of epaxial musculature, no visible ribs and moderate depression of nuchal crest; (3) Normal: no concavity of epaxial musculature, no visible ribs and mild to no depression of nuchal crest; (4) Robust: convexity of epaxial musculature and slight convexity of nuchal crest (Figure 4.1).

The age class of the animal was qualitatively assessed based on approximate length relative to known adult length for the species (Betty et al. 2022). Animals were assigned to one of three categories: adult, juvenile or calf. As sex of all animals could not be assessed, adults were assigned to those animals of more than ~432cm (Betty et al. 2022). Juveniles were estimated to be over one third of the length of an adult, whilst calves were determined as being less than one third of adult length and/or with foetal folds still visible.

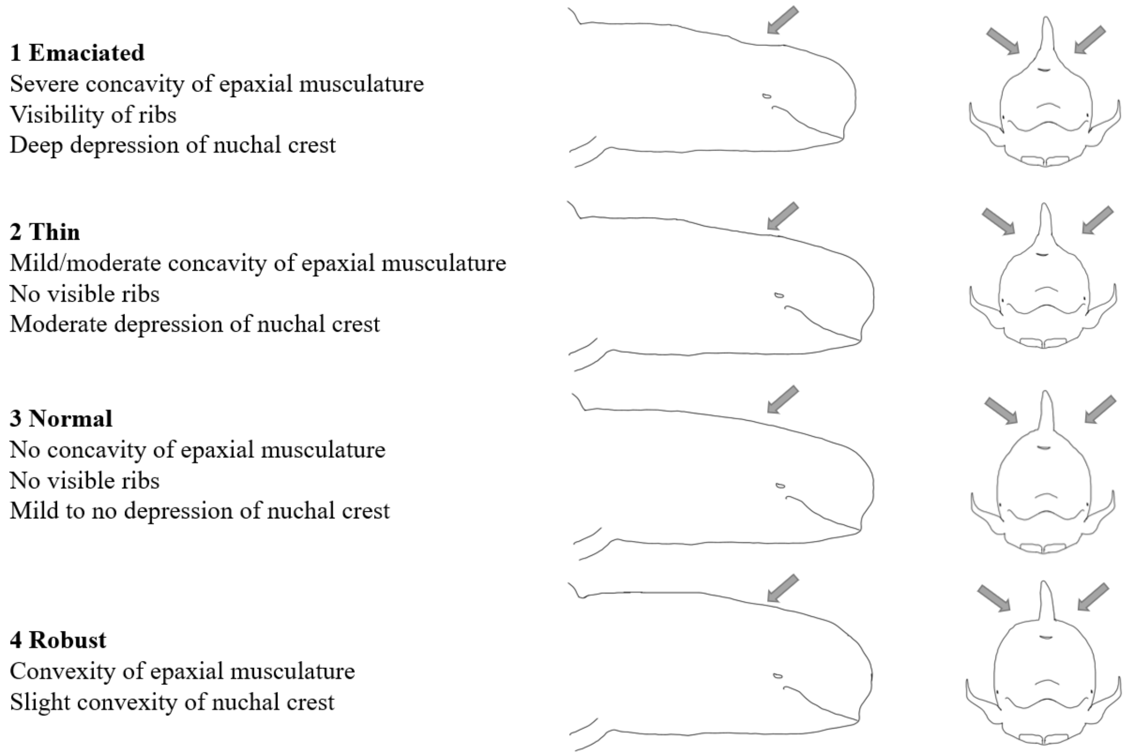

Figure 4.1 Four-point visual body condition scoring system developed for long-finned pilot whales (*Globicephala melas edwardii*).

Domain 2: Physical environment

The severity of any skin blistering was qualitatively scored following Groch et al. (2018) based on the presence of superficial dermal necrosis (Level 1); developed cutaneous bullae (Level 2) or; developed dermo-epidermal clefting with ulceration (Level 3; Figure 4.2).

Figure 4.2 Level of skin blistering observed in individual focal animals, (1) dermal necrosis and (2) bullae development on two individuals (top), (2) bullae development and (3) recent dermo-epidermal clefting with ulceration (middle), (3) dermo-epidermal clefting with ulceration two days following initial stranding (bottom). Photo credits: Kyle Mulinder (top and middle) and Project Jonah NZ (bottom).

When available, information was collected from stranding response forms about the focal animal's stranding circumstance, specifically, if this was an initial stranding or whether the animal had previously been re-floated and then subsequently re-stranded. Whether the animal was dry stranded (i.e., on sand only, with no water around the whole body) or in-water stranded (i.e., whole body surrounded by shallow water but not floating) was determined from the video footage. For animals that were filmed over a prolonged period, the animal was classified as dry stranded or in-water stranded based on the conditions present for the longest period during the filming.

The availability of basic strandings response equipment was assessed based on what was in view on the video footage of the focal individual. This included sheets for coverage of the animals, buckets for pouring water over the animal, spades for digging and re-floatation mats. Substrate type was assessed from the video footage based on whether the focal animal was stranded on (1) mud flats, (2) sandy beach, (3) pebble beach or (4) rocky shore. Substrate information was used to provide additional context to potential welfare concerns such as external injuries.

Weather and sea swell were assessed based on what could be viewed on the video. Weather conditions were categorised as (1) sunny, (2) overcast or (3) precipitation. For animals filmed in prolonged stranding events, the weather conditions were classed as those most prevalent during filming. Due to the potential impact of swell height on the ability to attempt re-floatation, sea conditions were qualitatively assessed based on approximate swell height as (1) minimal to small swell, ankle to waist high waves; (2) medium swell, waist to shoulder high waves or (3) large swell, head high and larger waves. Tidal conditions were assessed based on whether the tide was low or high, and flooding or ebbing, based on tidal charts (NIWA 2019) for the specific stranding date, time and location.

Domain 3: Health

Externally visible injuries were qualitatively assessed as being superficial or penetrating wounds and classified by the location on the body. Skin illness/disease was scored based on the perceived appearance of characterised cutaneous manifestations known to occur due to specific infections/diseases (Van Bressem et al. 2007, 2008, 2009; Hart et al. 2012; Kautek et al. 2019), including “tattoo”, “rounded cutaneous”, “whitish velvety” and “whitish to slightly pink verrucous” skin lesions following Van Bressem et al. (2007). Skin illness/disease lesions were assessed based on being present/absent and the area of the body involved (Van Bressem et al. 2007).

Respiration rate was assessed based on the visible opening and closing of the blowhole, and the audible sound of the focal animal exhaling. Respiration rate was quantitatively assessed, with each audible and visible open/close of the blowhole considered to be a single respiration (Kremers et al. 2016). Respiration character/effort was qualitatively assessed by examining whether inhalation and closure of the blowhole occurred immediately following exhalation, or whether there was a period (measured in seconds) between exhalation and inhalation (Mazzariol et al. 2015; Martins et al. 2020). Additionally, unusual respiration was noted through qualitative assessment of the blowhole opening and closing and audible exhalation, such as whether the animal exhaled twice before inhaling or displayed chuffing (Mazzariol et al. 2015; Fire et al. 2020).

Heart rate was quantified when possible as a recorded count of rhythmic movement of skin (Al-Naji et al. 2019) on the ventrum, medial to the left pectoral fin. However, heart rate was only observable in animals in lateral recumbency as movement in the area close to the ventral surface of the left pectoral fin must be visible. Each of the animal's observable orifices were examined throughout the video duration to assess for any blood, mucus or other fluids being expelled. Any such excretions were noted qualitatively based on frequency and the orifice of origin.

Domain 4: Behavioural interactions

Body posture was assessed based on the animal's recumbency position: (1) ventral (lying on the ventrum), (2) lateral (lying on one side of the body) or (3) dorsal (lying on the dorsal surface of the body). Animals could be scored in multiple positions during a video; for example, they may have been moved from a lateral to a ventral position as part of standard stranding response procedures (Geraci and Lounsbury 2005). Additionally, body posture was assessed based on whether the animal exhibited spinal curvature, most often observed in the peduncle. This feature was assessed based on continuous presence/absence throughout the observation period and was categorised as (1) lateral curvature: body or peduncle is curved laterally to the left or right (Figure 4.3), (2) dorsal curvature: peduncle is curved dorsally or (3) ventral curvature: peduncle is curved ventrally.

Animal movements were assessed based on the type of behaviour, its prevalence, frequency, and relative duration (see section 4.2.3.1). Additionally, audible vocalisations were assessed based on presence/absence and duration, as part of the behavioural analysis (see section 4.2.3.1). Since it was not possible to confirm whether audible vocalisations were from the focal animal or another animal in the immediate vicinity during mass strandings, the social circumstances of the focal animal was noted when vocalisations were recorded.

Figure 4.3 Example of spinal curvature as left lateral curvature of the peduncle in a stranded long-finned pilot whale. Photo credit: Kyle Mulinder

Some video footage provided observation of additional stranded animals, and further information on the stranding event was gathered from DOC stranding reports. This enabled evaluation of whether the pod members of the focal stranded animal were present/absent, and when present, whether pod members were (1) alive or dead, and (2) stranded or floating. Human intervention was considered to occur when a human interacted with a focal animal (see section 4.2.3.2). Intervention was assessed based on the presence/absence and type of interaction occurring.

4.2.3.1 Development of ethogram

Video footage was examined using Program BORIS v7.9.6 (Friard and Gamba 2016) to develop a comprehensive ethogram which represents all behaviours observed for the four species of stranded cetaceans, including unusual and rare occurrences (Martin and Bateson 2009). The preliminary ethogram was based on five behaviours detailed in the literature relating to decision-making on the re-floatation of stranded odontocetes: body posture, arching, thrashing, trembling, and vocalisation (Townsend 1999; Geraci and Lounsbury 2005; Sampson et al. 2012; Sharp et al. 2014). However, these specific behaviours have not previously been described in detail and their occurrence was not quantified in those studies. Thus, to begin, those behaviours were identified and defined for the two stranded pygmy killer whales due to the length of the video footage available (5 h; Appendix 8 Table A8.1). The footage was then re-examined to characterise all other behaviours expressed by the pygmy killer whales, until no new behaviours were noted. This updated ethogram (n = 19 behaviours and one physiological parameter) was then applied to footage of the other species and stranding events, with new behaviours identified and characterised if there was no prior observation. Additionally, two physiological parameters (respiratory rate and heart rate) were included in the ethogram as their frequency and duration could be calculated from video footage.

4.2.3.2 Human intervention

Video footage was also examined to identify and characterise types of human intervention for inclusion in the ethogram. I examined footage for each focal cetacean manually at 0.8x speed at least twice to identify and ensure intra-observer reliability of characterisation. Additionally, the same two independent observers examined a subset of videos to ensure consistency in characterisation of intervention types.

Human intervention occurring at live stranding events includes up-righting animals, covering them in wet sheets and pouring water over the body to reduce risk of hyperthermia and sunburn (Geraci and Lounsbury 2005). However, previous studies have not provided detailed characterisation of the types of human intervention occurring with live stranded cetaceans. In this chapter, a human intervention was considered to occur when a human was observed on the video footage within 1–2 m of the focal cetacean. Again, the video footage of the pygmy killer whales was examined to characterise all types of human intervention, until no new interventions were observed. This ethogram of human intervention was then applied to all other stranding events. New intervention types were identified and characterised if there was no prior observation.

4.2.4 Analysis of pilot whale data

All behavioural and physiological parameters and human interventions identified in the ethogram for the 49 pilot whales were characterised and coded per second using BORIS v7.9.6 (Friard and Gamba 2016). The prevalence, frequency and relative duration of behavioural and physiological parameters and human interventions were calculated from the quantitative scores, standardised by each video's duration to remove any time bias. Behavioural parameters and human interventions were classified as point/event behaviours when they had very short and non-variable duration, or as behavioural states when their duration varied. Prevalence of each behaviour and type of human intervention was determined as the percentage of individual pilot whales displaying the parameter or being exposed to the intervention at least once during the observation period. The frequency of point/event behaviours was calculated as the mean rate per minute including only the individuals displaying that particular behaviour, and variability was calculated as standard error of the mean (SEM). The average relative duration of each state behaviour or human intervention was calculated as a percentage of the observation period including only those individuals that displayed the behaviour, or were exposed to the intervention, with variability presented as the range of relative durations.

This chapter further examined whether features of the stranding circumstance of the individual pilot whale affected the prevalence, frequency, or duration of expression of prevalent behavioural and physiological indicators. The effect of stranding number (initial vs re-strand) and circumstance (dry vs in-water) was examined on the prevalence of behaviours and physiological parameters using a Z-test for proportions, and on the frequency of point/event behaviours and physiological parameters and the relative duration of state behaviours using a Mann Whitney U test. To ensure valid statistical inferences, only prevalent parameters (observed in >40% individuals) were included in the analyses. The effects of these features on animals' durations in different postural positions were not evaluated as they were likely affected by human intervention rather than varying according to the focal animal's state.

4.3 Results

A total of 427.2 min (7.1 h) of video footage was collected from 11 mass and three single stranding events, with observations of 53 focal individuals of four species

(Appendix 8 Table A8.1). The duration of focal individual observations ranged from 10 s to 212.9 min (3.6 h; mean: 483.6 s; 8.1 min).

4.3.1 Feasibility of welfare indicators for stranded pilot whales

There were 49 video clips of individual pilot whales for a total of 93.5 mins (1.6 h), with a mean length of 114.5 s (1.9 min). Sixteen pilot whales (32.7%) were observable on both sides of the body, whilst 16 (32.7%) were observable on the left side only and 17 (34.7%) on the right side only. Table 4.2 shows the associated results of the 17 non-behavioural welfare indicators that were assessed. Of these, four welfare status indicators were feasible to assess from video footage of more than 40% of the stranded pilot whales. The welfare status indicators that could not be consistently assessed were heart rate, skin blistering, trauma/injuries, and skin disease. A further six welfare alerting indicators were also feasible to assess in at least 40% of pilot whales via video footage, whilst the other three indicators required data to be gathered from DOC stranding response forms.

Table 4.2 Non-behavioural welfare indicators assessed for 49 live stranded long-finned pilot whales across 11 stranding events between August 2010 and March 2022 on the New Zealand coast. Number of animals for which the indicator was feasible to assess across the whole body and percentage of animals for each parameter.

Domain	Welfare status indicator (no. feasible)	Percentage of 49 individuals (n)	Welfare alerting indicator (no. feasible)	Percentage of 49 individuals (n)
1: Nutrition				
	Body condition (29)		**Animal age class (49)**	
	Thin	14.3 (7)	Adult	79.6 (39)
	Normal	85.7 (42)	Juvenile	10.2 (5)
			Calf	10.2 (5)
2: Physical environment				
	Skin blistering (8)		**Substrate type (49)**	
	Superficial dermal necrosis	18.4 (9)	Sand beach	100 (49)
	Cutaneous bullae	18.4 (9)	**Stranding circumstance (49)**	
	Dermo-epidermal clefting/ulceration	20.4 (10)	Initial strand	40.8 (20)

		Re-strand	59.2 (29)
		Dry strand	63.3 (31)
		In-water strand	36.7 (18)
		Equipment (49)	
		Sheets covering animal	40.8 (20)
		Buckets pouring water	65.3 (32)
		Spades	20.4 (10)
		Weather (49)	
		Sun	34.7 (17)
		Overcast	65.3 (32)
		Sea condition (24)	
		Minimal/small swell	44.9 (22)
		Medium swell	2.0 (1)
		Tide (49)	
		High	20.4 (10)

			Low	55 (27)
			Incoming	22.4 (11)
			Receding	2.0 (1)
3: Health				
	Trauma/injuries (8)			
	Superficial wounds	8.2 (4)		
	Penetrating wounds	2.0 (1)		
	Skin illness/disease (8)			
	Present	2.0 (1)		
	Respiration (33)			
	Unusual respiratory character	8.2 (4)		
	Heart rate (3)			
	Bleeding/fluid/mucus from orifice (47)			
	Mucus from mouth	4.1 (2)		
	Mucus from blowhole	4.1 (2)		

	Dark green fluid from anus	6.1 (3)		
4: Behavioural interactions				
	Curvature of peduncle (49)		**Pod members (49)**	
	Left	12.2 (6)	Present	95.9 (47)
	Right	8.2 (4)	**Status pod members (49)**	
			All alive	4.1 (2)
			All dead	2.0 (1)
			Alive and dead	89.8 (44)
			Stranded	93.9 (46)

Domain 1: Nutrition

Body condition was feasible to fully assess in 29 (59.1%) stranded pilot whales. For the remaining animals, sheets covered the epaxial musculature (n = 20), thus the main visual assessment was based on the concavity of the nuchal crest. Most individuals (85.7%, n = 42) were in normal body condition and were adults (79.6%, n = 39).

Domain 2: Physical environment

Due to animals being covered in sheets just eight (16.3%) animals could be assessed across all body regions bilaterally. A further 21 (42.9%) could be assessed across all body regions on one side (10 on the left and 11 on the right). Of these, skin blistering was observed in 72.4% (n = 21). Skin blistering around the cranial region (including mandibles, melon, and blowhole; see Figure 4.2) could be assessed in all animals – an additional seven animals had blistering present in this cranial region. The level of blistering varied among the 28 affected pilot whales, ranging from superficial dermal necrosis to dermo-epidermal clefting with ulceration (Table 4.2).

The stranding circumstance of being in-water or dry stranded was feasible to assess in 100% of cases (Table 4.2), with most animals observed whilst dry stranded. Further information gathered from DOC stranding reports indicated that, at the time of filming, more than half the animals had re-stranded.

The availability of basic stranding response equipment could be assessed in all cases, with sheets, buckets and spades used for digging around some focal animals clearly visible, although no focal animals were observed on re-floatation mats. The substrate at the stranding location was identified to be sandy in 100% of cases, though in three cases shells were present.

The weather was feasible to assess in all videos. For most animals (65.3%, n = 32) the weather was overcast, whilst for the remainder it was sunny. Over half of the pilot whales were observed at low tide, with the tidal conditions varying for the rest. The distant low tide mark meant that the sea condition could not be assessed for 26 animals, whilst most of the remainder were observed with minimal swell (n = 22).

Domain 3: Health

Injuries and wounds across the head and flukes were feasible to assess in all animals, whilst eight (16.3%) could be assessed across all body regions bilaterally, and 21

(42.9%) on one side. Injuries and wounds were rare and mainly involved superficial lacerations (Table 4.2); these injuries in two animals were likely related to the substrate containing shells. Similarly, skin lesions indicative of illness/disease were not feasible to assess for the 20 animals covered by sheets and a further 21 could only be assessed on one side. One of the 29 animals that was feasible to assess was observed to have tattoo-like lesions on the cranial region (Figure 4.4).

All respiratory events would have been observable via the video footage if they had occurred. However, due to the short length of some videos, respiration was only observed in 67.3% (n = 33) of the animals. In four of these animals an unusual respiratory character was noted; one animal displayed double chuffing, with short forceful exhalations occurring twice prior to inhalation for almost every respiratory event. Three animals displayed extended time between exhalation and inhalation. Indeed, in one animal the blowhole remained open for 6 secs post exhalation and prior to inhalation. Heart rate was only feasible to assess in three animals since the other individuals in the necessary position (lateral or dorsal recumbency) were in water (n = 9) or were filmed at an angle not conducive to observing the ventrum (n = 1).

Bleeding/fluid/mucus from orifices was readily assessable in the case of the blowhole and mouth (95.9%, n = 47) of the animals. Mucus excretion was observed to occur in four animals, two from the mouth and two from the blowhole (Figure 4.4). The genital and anal orifices were less observable due to most animals being in ventral recumbency (71.4%, n = 35). However, three animals were observed to defecate dark green liquid (Figure A8.1).

Figure 4.4 Left: Observation of mucus from the blowhole and mouth of two live stranded long-finned pilot whales. Area considered the cranial region is defined within the white pentagon. Right: Tattoo-like lesions (within white oval) observed on the cranial region of one individual. Photo credits: Kyle Mulinder (Left) and Project Jonah NZ (Right).

Domain 4: Behavioural interactions

Body posture was feasible to assess in 100% of the pilot whales, with most animals in ventral or lateral recumbency only throughout filming (Table 4.3). Nine (18.4%) were observed in both ventral and lateral recumbency, with an additional animal observed in ventral, lateral and dorsal recumbency over 1.5 mins. Spinal curvature (Figure 4.3) was feasible to assess in all cetaceans and was noted in ten individuals (20.4%; Table 4.2). Notably, four pilot whales had their pectoral fins oriented laterally and superior to the dorsal plane (Appendix 8 Figure A8.2), and all were undergoing human intervention when filmed. Behavioural events (Appendix 8 Table A8.2) were observed in 100% of individuals; detailed results are presented in section 4.3.2. Audible vocalisations from animals were only detected at mass strandings; these were identified from video of five focal animals (10.2%; Table 4.3), three of which were identified as calves and two were adults in the presence of calves.

Nearly all (95.9%, n = 47) of the focal individuals formed part of mass strandings and therefore, stranded conspecifics were also present. In most cases (89.8%, n = 44), pod members were a mixture of alive and dead stranded (Table 4.2). Human interactions with focal animals were observed in 100% of events and included non-invasive (presence only) and invasive interactions (e.g., up-righting animals). Detailed information on the observed human interactions is provided in section 4.3.3.

4.3.2 The stranded odontocete ethogram

Thirty behaviours were identified and described for the four odontocete species when stranded. These included six point and 24 state behaviours (Appendix 8 Table A8.2). Aside from recumbency posture, behavioural parameters were not mutually exclusive, in that multiple behaviours could be displayed by an individual simultaneously.

4.3.2.1 Quantifying behavioural observations: Pilot whales

Table 4.3 shows how feasible each of the behavioural indicators were and provides the prevalence, frequency and duration of the behavioural and physiological parameters assessed. Notably, almost all the behavioural indicators (93.3%, n = 28), would have been feasible to assess if they had occurred. Eye open left and right were not consistently feasible due to light conditions and pec joint movement was not feasible in covered animals.

Most pilot whales (71.4%, n = 35) were observed in ventral recumbency throughout filming. When this recumbency was noted, it lasted for an average of 88.5% of the observation period. A further 10 individuals were moved into ventral recumbency as part of human intervention during filming. Remaining individuals were filmed in lateral recumbency (28.6%, n = 14) which on average lasted for 60.7% of the observation.

Five behaviours were prevalent, being displayed by over 40% of the pilot whales: tail flutter (69.4%, n = 34), dorsal fin flutter (55.1%, n = 27), head lift (51%, n = 25), tail lift (46.9%, n = 23) and head side-to-side (42.9%, n = 21). The only behaviour observed in other species but not recorded in pilot whales was head arch. In contrast, nine behaviours were recorded only in pilot whales (Appendix 8 Table A8.2), though all with low prevalence (Table 4.3).

When observed, individuals spent on average more than half the monitored time displaying right pectoral fin flutter (57.7%) and tail flutter (54.6%). The mean percentage of the observation period spent displaying dorsal fin flutter in those that did, was 41.4%. Although prevalent, head lifting occurred on average for only 12.3% of the observation period, whereas tail lift and head side-to-side, also both prevalent, occurred for nearly a quarter of the observation period. All point behaviours had low prevalence and low rate of occurrence.

Respiration was recorded at a mean rate of 4.4 breaths/min (SEM ±0.4). Notably, inspiration occurred simultaneously with head lifting in nearly 45% of occurrences. The mean heart rate recorded was 48.8 beats/min (SEM ±11.6).

Table 4.3 Observed prevalence (% of individuals displaying or for which the indicator was feasible), mean frequency (rate/min) or mean relative duration (% of observation period and range) for only long-finned pilot whales that displayed the behaviour, from a total of 49 individuals across 11 stranding events between August 2010 and March 2022. See Appendix 8 Table A8.2 for descriptions of behaviours.

Behaviour	**Prevalence**	**Frequency**	**Relative duration**

State behaviours			
Ventral recumbency	91.8		88.5 (7.7–100.0)
Lateral recumbency	28.6		60.7 (4.4–99.8)
Dorsal recumbency	2.0		3.4 (3.4–3.4)
Tail flutter	69.4		54.6 (4.6–99.9)
Dorsal fin flutter	55.1		41.4 (6.1–97.3)
Head lift	51.0		12.3 (2.3–32.6)
Tail lift	46.9		23.9 (0.6–72.9)
Head side-to-side	42.9		22.2 (1.1–81.5)
Pec fin flutter R	24.5		57.7 (3.8–98.6)
Pec fin flutter L	22.4		34.8 (4.3–34.75)
Pec joint moves	20.4		22.5 (0.5–78.3)
Tail hover	18.4		22.0 (0.2–55.2)
Tail side-to-side	16.3		15.8 (0.3–46.3)
Body tremble	12.2		24.3 (0.2–84.2)
Vocalisation	10.2		20.7 (5.1–60.2)
Body rocking	10.2		10.4 (5.2–23.2)
Eye open L	10.2		35.4 (2.4–73.7)
Eye open R	8.2		22.1 (2.5–63.8)
Body tenses	6.1		11.2 (5.1–20)
Tail arch	4.1		15.8 (12.4–19.1)
Tail fluke slapping	4.1		28.3 (19.9–36.7)
Whole body arching/ thrashing	4.1		5.4 (2.4–8.4)
Mouth open	2.0		17.2 (17.2–17.2)
Point behaviours			
Blowhole twitch	22.4	4.7 ± 1.7	
Nuchal pad twitch	10.2	6.2 ± 2.9	

Open-close blowhole	6.1	3.0 ± 1.6
Water from blowhole	4.1	2.1 ± 1.4
Head-pec fin jerk/flinch	2.0	2.6 ± 0.0
Movement in lower jaw	2.0	6.9 ± 0.0
Physiological parameters		
Respiration	67.3	4.4 ± 0.4
Heartbeat	6.1	48.8 ± 11.6

4.3.2.2 Differences in stranding circumstances: Initial vs re-strand

Of the 49 pilot whales observed, 29 (59.2%) were filmed during a re-stranding, whilst the remainder (40.8%, n = 20) were filmed during their initial stranding event. Of the re-stranded animals 20 were dry and nine were in-water stranded when observed. Similarly, of the 20 initial stranded animals, 11 were dry and nine were in-water stranded when observed.

Body tremble, mouth open and movement in lower jaw were only displayed by animals that were stranded for the first time, while head-pec fin jerk was only observed in re-stranded animals, however the prevalence of all these behaviours was very low (Table 4.4).

There was evidence of a statistical difference in the prevalence of only one prevalent behaviour, dorsal fin flutter ($z = 2.33$, $P = 0.03$); a greater proportion of initially stranded animals than re-stranded animals displayed this behaviour (Table 4.4). No evidence of statistical differences was found in the duration of any of the prevalent behaviours, nor in the rate of respiration ($P > 0.05$; Table 4.4).

4.3.2.3 Differences in stranding circumstances: Dry vs in-water

Eighteen pilot whales (36.7%) were observed stranded in water, while 31 (63.3%) were recorded as dry stranded. Body rocking and tail fluke slapping were only observed in individuals that were dry stranded, whilst tail side-to-side, tail arch, whole body arching/thrashing, mouth open, head-pec fin jerk and movement in lower jaw were only displayed by animals stranded in water (Table 4.5).

Four of the prevalent behaviours were displayed in a significantly greater proportion of animals stranded in-water than dry stranded: dorsal fin flutter ($z = -3.03$, $P = 0.00$), head lift ($z = -2.26$, $P = 0.03$), tail lift ($z = -3.29$, $P = 0.00$) and head side to side ($z = -2.57$, $P = 0.02$; Table 4.5). However, no evidence of statistical differences were observed in the duration of prevalent behaviours, nor in the rate of respiration ($P > 0.05$; Table 4.5).

Table 4.4 Observed prevalence (% of individuals displaying behaviour), mean frequency (rate/minute) ± SEM of point behaviours or mean relative duration (% of monitored time and range) of state behaviours for only long-finned pilot whales that displayed the behaviour, from a total of 20 initial stranded and 29 re-stranded individuals across 11 stranding events on the New Zealand coast between 2010 and March 2022. †Only prevalent behaviours could be tested for statistical difference; * significant difference (α = 0.05) in prevalence between stranding circumstances.

	Prevalence		Frequency		Relative duration	
Behaviour	**Initial strand**	**Re-strand**	**Initial strand**	**Re-strand**	**Initial strand**	**Re-strand**
State behaviours						
Ventral recumbency	90.0	93.1			85.9 (17.5–100.0)	90.3 (7.7–99.9)
Lateral recumbency	40.0	20.7			54.9 (4.4–99.8)	68.4 (7.2–97.4)
Dorsal recumbency	0.0	3.4			0.0 (0.0–0.0)	3.4 (3.4–3.4)
Tail flutter†	75.0	65.5			49.3 (4.6–99.9)	58.8 (12.9–98.1)
Dorsal fin flutter†	75.0	41.4			38.0 (6.1–95.6)	45.6 (13.0–97.3)
Head lift†	65.0	41.4			12.2 (2.6–32.4)	12.4 (2.3–32.6)
Tail lift†	45.0	48.3			27.4 (0.6–72.9)	21.6 (2.3–54.1)
Head side-to-side†	60.0	31.0			22.6 (5.5–81.5)	21.7 (1.1–47.4)

Pec fin flutter R	35.0	17.2	55.2 (3.8–98.6)	61.2 (30.0–93.7)
Pec fin flutter L	30.0	17.2	22.7 (4.3–69.2)	49.2 (12.2–87.0)
Pec joint moves	25.0	17.2	10.6 (0.5–30.0)	34.5 (11.3–78.3)
Tail hover	20.0	17.2	20.0 (0.2–55.2)	23.6 (2.2–55.1)
Tail side-to-side	15.0	17.2	31.1 (11.7–46.3)	6.7 (0.3–11.8)
Body tremble	30.0	0.0	24.3 (0.2–84.2)	0.0 (0.0–0.0)
Vocalisation	10.0	10.3	33.5 (6.7–60.2)	12.2 (5.1–24.4)
Body rocking	15.0	6.9	11.7 (5.2–23.2)	8.6 (5.9–11.3)
Eye open l	15.0	6.9	37.5 (14.2–73.7)	32.2 (2.4–61.9)
Eye open r	10.0	6.9	33.2 (2.5–63.8)	11.1 (2.9–19.3)
Body tenses	10.0	3.4	14.2 (8.4–20.0)	5.1 (5.1–5.1)
Tail arch	5.0	3.4	19.1 (19.1–19.1)	12.4 (12.4–12.4)
Tail fluke slapping	5.0	3.4	19.9 (19.9–19.9)	36.7 (36.7–36.7)
Whole body arching/ thrashing	5.0	3.4	8.4 (8.4–8.4)	2.4 (2.4–2.4)
Mouth open	5.0	0.0	17.2 (17.2–17.2)	0.0 (0.0–0.0)

Point behaviours				
Blowhole twitch	25.0	20.7	6.2 ± 3.0	5.3 ± 1.9
Nuchal pad twitch	10.0	10.3	1.9 ± 0.7	9.6 ± 4.0
Open-close blowhole	10.0	3.4	2.8 ± 1.2	5.9 ± 0.0
Water from blowhole	5.0	3.4	3.6 ± 0.0	0.7 ± 0.0
Head-pec fin jerk/flinch	0.0	3.4	0.0 ± 0.0	2.6 ± 0.0
Movement in lower jaw	5.0	0.0	6.9 ± 0.0	0.0 ± 0.0
Physiological parameters				
Respiration rate	65.0	69.0	3.8 ± 0.7	4.6 ± 0.6
Heartbeat	10.0	3.4	33.8 and 71.5	41.1

Table 4.5 Observed prevalence (% of individuals displaying behaviour), mean frequency (rate/minute) ± SEM of point behaviours or mean relative duration (% of monitored time and range) of state behaviours for only long-finned pilot whales that displayed the behaviour, from a total of 31 dry and 18 in-water stranded individuals across 11 stranding events on the New Zealand coast between 2010 and March 2022. †Only prevalent behaviours could be tested for statistical difference; * significant difference (α = 0.05) in prevalence between stranding circumstances.

	Prevalence		Frequency		Relative duration	
Behaviour	**Dry**	**In-water**	**Dry**	**In-water**	**Dry**	**In-water**
State behaviours						
Ventral recumbency	90.3	94.4			97.7 (81.9–100.0)	73.3 (7.7–99.9)
Lateral recumbency	16.1	50.0			63.7 (4.4–99.8)	59.1 (7.2–97.3)
Dorsal recumbency	0.0	5.6			0.0 (0.0–0.0)	3.4 (3.4–3.4)
Tail flutter†	67.7	72.2			58.1 (4.6–99.9)	49.0 (13.0–92.4)
Dorsal fin flutter†	38.7	83.3			36.6 (6.1–87.6)	45.2 (12.3–97.3)
Head lift†	38.7	72.2			12.7 (2.6–32.6)	11.9 (2.3–32.4)
Tail lift†	29.0	77.8			22.2 (0.6–60.3)	24.9 (2.3–72.9)
Head side-to-side†	29.0	66.7			25.7 (5.5–81.5)	19.5 (1.1–47.4)
Pec fin flutter R	25.8	22.2			61.2 (3.8–98.6)	50.8 (30.0–93.7)
Pec fin flutter L	12.9	38.9			29.4 (4.3–69.2)	37.8 (7.0–87.0)
Pec joint moves	19.4	22.2			18.3 (1.2–46.2)	28.9 (0.5–78.3)
Tail hover	16.1	22.2			26.1 (2.2–55.2)	16.9 (0.2–38.7)

Tail side-to-side	0.0	44.4			0.0 (0.0–0.0)	15.8 (0.3–46.3)
Body tremble	9.7	16.7			28.3 (0.2–84.2)	20.3 (8.6–27.6)
Vocalisation	3.2	22.2			7.0 (7.0–7.0)	24.1 (5.1–60.2)
Body rocking	16.1	0.0			10.4 (5.2–23.2)	0.0 (0.0–0.0)
Eye open l	6.5	16.7			44.0 (14.2–73.7)	29.7 (2.4–61.9)
Eye open r	6.5	11.1			10.9 (2.5–19.3)	33.4 (2.9–63.8)
Body tenses	3.2	11.1			8.4 (8.4–8.4)	12.5 (5.1–20.0)
Tail arch	0.0	11.1			0.0 (0.0–0.0)	15.8 (12.4–19.1)
Tail fluke slapping	6.5	0.0			28.3 (19.9–36.7)	0.0 (0.0–0.0)
Whole body arching/ thrashing	0.0	11.1			0.0 (0.0–0.0)	5.4 (2.4–8.4)
Mouth open	0.0	5.6			0.0 (0.0–0.0)	17.2 (17.2–17.2)
Point behaviours						
Blowhole twitch	16.1	38.9	5.6 ± 2.9	6.1 ± 2.3		
Nuchal pad twitch	6.5	11.1	9.5 ± 7.6	5.8 ± 2.1		
Open-close blowhole	3.2	16.7	0.4 ± 0.0	3.1 ± 1.6		

Water from blowhole	3.2	5.6	3.6 ± 0.0	0.7 ± 0.0
Head-pec fin jerk/flinch	0.0	16.7	0.0 ± 0.0	1.4 ± 0.7
Movement in lower jaw	0.0	5.6	0.0 ± 0.0	6.9 ± 0.0
Physiological parameters				
Respiration rate	67.7	61.1	4.1 ± 0.6	4.9 ± 0.8
Heartbeat	9.7	0.0	48.8 ± 11.6	

4.3.3 Human intervention with stranded odontocetes

From video footage of all stranded odontocetes, a total of 1061 events were coded from 13 different human interventions (Appendix 8 Table A8.3). The types of human intervention were not mutually exclusive. Indeed, some types of human intervention always occurred simultaneously (e.g., human rolling an individual also required direct contact with the stranded animal).

4.3.3.1 Quantifying human intervention with stranded pilot whales

All types of human intervention would have been feasible to assess if they occurred with the stranded pilot whales. Humans were present at all pilot whale stranding events that were observed, and, on average, a human was within 2 m of the focal animal (present) for 97% of observed time (Table 4.6). Aside from human presence, the interventions that were most prevalent, occurring with over half of the stranded pilot whales, were human watering (65%) and human touching (59%). The other interactions with the longest average duration per individual focal animal were human places sand by sides (96.8%), human touching (61.1%) and human noise (61.2%; Table 4.6).

Table 4.6 Types of human intervention that occurred with focal stranded pilot whales. Prevalence (% of individual focal stranded cetaceans that the intervention occurred with) and relative duration (% and range) of human intervention with focal stranded pilot whales (n = 49) calculated for those individuals undergoing the intervention across 11 stranding events between 2010 and March 2022. See Appendix 8 Table A8.3 for descriptions of intervention types.

Intervention	Prevalence	Relative duration of individual monitoring
Present	100.0	97.4 (35.5–100)
Watering	65.3	36.0 (0.5–86.8)
Touching	59.2	61.1 (3.3–100)
Digging	36.7	51.3 (4.6–99.8)
Rolling	24.5	33.8 (0.4–93.5)
Noise	8.2	61.2 (16.4–98.8)
Holds dorsal fin	6.1	35.0 (2.9–97.6)
Places sand by sides	2.0	96.8 (96.8–96.8)
Rubbing	2.0	21.6 (21.6–21.6)

4.4 Discussion

A range of potential animal- and resource-/management-based welfare indicators were able to be non-invasively observed and/or measured in stranded cetaceans. This chapter systematically characterised, for the first time, the ethology of stranded odontocetes, with 30 different behaviours described. A quantitative assessment of these welfare indicators, including fine-scale behaviour and human intervention, from 49 live stranded pilot whales was undertaken. Previous studies have highlighted the need for systematic assessment of free-ranging cetacean welfare but have also emphasised challenges due to limited behavioural and physiological data (Nicol et al. 2020; King et al. 2021). This chapter contributes pivotal baseline data which can be used to develop a feasible WAF specific to cetacean strandings.

4.4.1 *Holistic welfare assessments are feasible at cetacean stranding events*

A range of indicators related to different aspects of welfare were feasibly evaluated via video footage captured at cetacean strandings. Not only is this useful to enable remote experts to undertake animal assessments (Boys et al. 2022b, 2022d; Chapters 2 and 3), but the non-invasive measurability of these indicators minimises further welfare compromise for cetaceans that are experiencing physiological stress (Cowan and Curry 2008; Fernandez et al. 2017). Although invasive measures (e.g., blood sampling to evaluate haematological parameters) are informative for assessing the health of wild cetaceans (Wells et al. 2004; Schwacke et al. 2014; Barratclough et al. 2019), the use of non-invasive methods for welfare assessments is preferable. Further focus should be to validate the scoring of these indicators from video against live observations and among various indicators that reflect health and welfare status, as well as with known survivorship data.

From the 18 proposed indicators and composite behavioural parameters (Table 4.1), ten non-behavioural, five animal behaviour and three human intervention indicators were delineated as prevalent and thus feasible to assess from video footage. Importantly, the feasible indicators identified were representative of three physical/functional domains (nutrition, physical environment, health) and one situation-related domain (behavioural interactions) of the Five Domains Model for welfare assessment (Mellor et al. 2020), suggesting that holistic welfare assessments of stranded cetaceans could be achievable using these indicators. Of these, nine welfare status indicators represented three domains. The most feasible to assess were body condition (D1: nutrition), respiration and bleeding/fluid/mucus from orifices (D3: health), and body posture and composite behavioural indicators (D4: behavioural interactions). Potential welfare alerting indicators that could be consistently assessed were age class (D1), substrate type (D2), dry vs in-water stranding (D2), availability of equipment and weather conditions (D2), presence of other pod members (D4), and the composite behavioural indicator related to the amount and type of human intervention (D4).

Some potential indicators could not be consistently assessed from the video footage. Heart rate could not be evaluated in most animals as this required a postural position of lateral or dorsal recumbency. This chapter does not recommend that stranded cetaceans be placed into lateral recumbency to facilitate assessment of heart rate, as this may cause pulmonary compression (Geraci and Lounsbury 2005). Thus, heart rate is unlikely to be feasible as a remotely assessed indicator of the welfare state of stranded cetaceans, though in-field assessments via palpation may be possible with appropriately trained personnel.

Trauma/injuries, skin blistering and skin disease could not be assessed across all body regions bilaterally in approximately 40% of pilot whales, as they were covered to reduce hyperthermia and sunburn risk (Geraci and Lounsbury 2005). Furthermore, in more than two-thirds of cases, bilateral observation of an animal's body was not possible due to camera positioning. These factors likely negatively biased the prevalence of observed blistering and injuries. However, if systematic assessment frameworks were implemented to guide evaluations at strandings, video and/or photographs of all body regions could be rapidly captured before interventions occur, allowing for subsequent assessment of these indicators. This would require minimum time involvement and thus, would be unlikely to cause additional welfare compromise. The application of such a framework would ensure consideration of all relevant welfare information and facilitate holistic, multidimensional assessments (Fraser et al. 1997; Beausoleil et al. 2018).

Additionally, although respiratory events were feasible to assess in all video footage if they occurred, the short duration of some videos utilised in this chapter compromised the ability to assess respiratory rate for every individual. Importantly, cetacean species have extended breath holds (Berta et al. 2015), thus video footage should be collected for at least five minutes to enable assessment of respiratory rate.

Results from this chapter suggest a similar behavioural repertoire among stranded odontocete species. Only one behaviour was not displayed by pilot whales (head arch) and this was only exhibited by two animals, one pygmy killer whale and one Cuvier's beaked whale, possibly indicating severe physiological stress (Townsend 1999; Townsend et al. 2018). In contrast, nine behaviours were only displayed by pilot whales, likely due to the small sample size of the other species (n = 4). Therefore, the findings contribute valuable baseline ethological data from which other studies can assess stranded odontocete behaviour, though future efforts should further examine for species-specific differences.

Information on environmental conditions is important to provide context when interpreting welfare status indicators such as behaviours and can influence management decisions (Lesimple 2020). In this chapter, the substrate, whether animals were dry or in-water stranded, and the weather conditions could be easily assessed from video footage. However, other alerting indicators required additional information, for example, determining whether individuals were re-stranded required access to stranding reports. Multiple stranding events can cause compounding damage and sustained physiological stress (Fernandez et al. 2017), which likely compromise both welfare and survival likelihood (Fernandez et al. 2017; Boys et al. 2022b; Chapter 2).

Interestingly, almost 60% of the pilot whales had stranded more than once when observed, suggesting that re-floated animals often do not remain at sea, despite re-floatation being considered a 'success' (Wiley et al. 2001). When examining whether stranding circumstances (re-stranded vs initially stranded and dry or in-water stranded) affected the prevalent behaviours displayed by pilot whales, some differences were found (see section 4.4.2 for further discussion). However, further data collection is required to enable correlations among resource-/management-based indicators and animal-based indicators to better understand the welfare risk they reflect (Boulton et al. 2020).

4.4.2 *Preliminary welfare assessment of stranded pilot whales*

Most pilot whales observed were mass stranded and assessed as adults in normal body condition, based on an external visual assessment of the epaxial musculature and concavity of the nuchal crest (Joblon et al. 2014). This outwardly healthy appearance has been reported previously at mass strandings (Gales 1992; Bogomolni et al. 2010) and generally suggests that hunger or sickness likely have minimal impacts upon these individuals. In contrast, two single stranded animals were in poor (thin) body condition, suggesting they were likely experiencing welfare compromise in the form of hunger and thirst prior to stranding. Indeed, one of these individuals was a neonate which likely stranded due to maternal-filial separation (Diaz-Delgado et al. 2018; Câmara et al. 2019a), suggesting that the welfare of this animal was significantly compromised at stranding. Such animals are also suggested to have low survival likelihood, and end-of-life decisions or long-term captivity are generally indicated (Whaley and Borkowski 2009; Boys et al. 2022c; Chapter 6).

Few injuries were observed with those noted considered to be superficial. These may have occurred due to the stranding event itself and were likely minimal due to the sandy substrate. External injuries are less frequently observed in mass stranded animals, whereas single strandings can be related to some form of trauma (Arbelo et al. 2013; Diaz-Delgado et al. 2018). Likewise, fluid or mucus discharge from the mouth or blowhole was rare, and when present was mild. Additionally, faeces were evident from only three animals involved in the same mass stranding. Presence of vomiting and/or faecal discharges can be indicative of underlying health conditions (Waltzek et al. 2012), as well as indicating that animals are stressed (Townsend 1999; Sampson et al. 2012). Prolonged vomiting or diarrhoea can lead to dehydration and therefore, should be considered welfare-relevant and included in evaluations.

Notably, despite widespread human interventions such as covering and overcast weather conditions, nearly 60% of animals had skin blistering, with serious blistering developed on more than a third. Both the number of affected animals and the severity of skin blistering was likely underestimated since most individuals were covered in sheets and/or had only one side of the body visible in the videos. The common occurrence corroborates the opinions of experts who indicated sunburn as a major welfare concern (Boys et al. 2022b; Chapter 2) and suggested it as an indicator for assessing stranded cetacean welfare (Boys et al. 2022d; Chapter 3). Severe forms involving dermo-epidermal clefting with ulceration (observed in 20.4% of pilot whales) are likely to cause pain (Boys et al. 2022d; Chapter 3) and critical fluid loss (Gales et al. 2008b), leading to dehydration, hypovolemic shock (Martinez-Levasseur et al. 2011; Groch et al. 2018) and potential infection. The results suggest there is considerable cause for welfare concern for many ‘managed’ live stranded pilot whales based on this indicator alone. Additional assessment of weather conditions will be useful to predict any further skin damage that may occur. Future studies should assess the extent of fluid, protein and electrolyte loss that may occur when bullae ulcerate and rupture, as this will likely impact both welfare and survivorship of stranded cetaceans. Such indicator data will be important to inform decision-making around re-floatation versus euthanasia.

Lateral curvature of the caudal peduncle was noted in 20% of animals, in all stranding circumstances. This posture has been reported in stranded cetaceans during rehabilitation and is proposed to predict reduced swimming ability and muscular myopathy (Gulland et al. 2018; Câmara et al. 2020). Additionally, four animals were observed with their pectoral fins oriented laterally and superior to the dorsal plane, which may indicate damage to joints, such as dislocations. Such postural abnormalities and/or underlying muscle or joint damage are likely to cause pain and in the longer-term may detrimentally affect swimming and foraging ability (Fish 2002). Thus, such individuals may be deemed non-releasable (Townsend 1999; Harms et al. 2018; Câmara et al. 2020; Boys et al. 2022c; Chapter 6). Postural abnormalities should be correlated with other behavioural, physiological and/or pathological indicators to better understand their welfare significance (Lesimple 2020), and inform the use of this indicator in welfare assessments (Watters et al. 2021).

Almost all animals were observed in ventral recumbency for most of the video footage. This is likely due to the fact that human intervention occurred at all stranding events and righting stranded cetaceans onto their ventrum is part of standard stranding response procedures (Geraci and Lounsbury 2005; Simeone and Moore 2018b). This recumbency position is thought to reduce pulmonary compression compared to lateral recumbency (Geraci and Lounsbury 2005) and so should minimise discomfort associated with breathing. Therefore, recumbency position should be considered in welfare assessments.

Interestingly, vocalisation during filming was and only heard where focal animals were calves or adults in the presence of a calf, suggesting possible maternal-filial connection. Previous studies suggest vocalisations are linked to cetacean welfare state in captive situations (Castellote and Fossa 2006; Dibble et al. 2016; Eskelinen et al. 2021) and may effect epimeletic behaviour provided to wild distressed conspecifics (Kuczaj et al.

2015). Accordingly, it is recommended that additional data be collected at stranding events to further assess the validity of vocalisations as a welfare indicator and to compile a comprehensive vocal repertoire for strandings.

All point behaviours had low prevalence and low rate of occurrence, meaning they will not be useful parameters for detecting any effects of environmental conditions or human interventions on cetacean welfare. In contrast, five state behaviours were prevalent, being displayed by more than 40% of the pilot whales (tail flutter, dorsal fin flutter, head lift, tail lift and head side-to-side). When expressed, tail flutter and dorsal fin flutter were displayed, on average, for more than 40% of the observation time. Additionally, though less prevalent, right pectoral fin flutter occurred for more than 50% of observation time when expressed. Fin fluttering behaviours may be forms of muscle fasciculations or tremors. These fasciculations have previously been suggested as clinical signs of capture myopathy (Fernandez et al. 2017; Câmara et al. 2020) and underlying health conditions (van Elk et al. 2014). Therefore, they are important to consider in welfare assessments.

Notably, dorsal fin flutter was observed in a significantly higher proportion of initial stranded animals than re-stranded animals, and in a greater proportion of in-water strandings than dry strandings. In the case of initial versus re-stranded animals, it may be that re-stranded animals become too fatigued after re-stranding to display dorsal fin fluttering. However, in the case of in-water versus dry stranding, the expression of the behaviour appears to be context specific, and thus may represent the animal's response to its situation. Therefore, the use of such a behaviour as a welfare indicator must consider the animal's conditions and must be interpreted in the specific context of the stranding. Such behaviours may also be affected by human interventions and thus, could be used to evaluate the effects on potential welfare state (Palmer et al. 2021). Future work should correlate these behaviours with physiological and/or pathological indicators to validate their reflection of welfare states (Watters et al. 2021) and inform their use in decision-making

Although prevalent within the study population, head, and tail lift were displayed on average for only 12% and 24% of the observation time, respectively. Notably both behaviours occurred in a significantly larger proportion of animals that were in-water stranded than dry stranded, suggesting that their expression may be context specific.

However, these behaviours may be related to arching, which was not observed in pilot whales, but is proposed to be a sign of severe physiological stress in cetaceans (Townsend 1999; Townsend et al. 2018). Further data collection on these behaviours and correlation with the specific strandings context should be undertaken to better understand the welfare state they may reflect and inform their use in welfare assessments for decision-making.

Many of the head lifting events occurred simultaneously with respiration. This is likely due to compression of the thoracic cavity when the animal is not supported by water (the case for all pilot whales observed) which can cause breathing difficulties (Mazzariol et al. 2015; Townsend et al. 2018). Furthermore, three pilot whales from the same mass stranding displayed delayed inhalation following exhalation, for up to 6 secs. Such respiratory delays are suggested to be indicative of shock and typically imply an end-of-life decision (Mazzariol et al. 2015). Further observation of head lifting during respiration events and delayed inhalation, and correlation of these with pathology, will be important to assess, as this could provide data to infer the unpleasant experience of breathlessness (Lansing et al. 2009; Beausoleil and Mellor 2015b). These indicators should be considered important aspects to include in welfare assessments (Yon et al. 2019; Boulton et al. 2020) and inform decision-making around re-floatation versus euthanasia.

There were negligible differences in the frequency or duration of prevalent behaviours between initial stranded animals or those observed during re-stranding and between dry or in-water stranded animals. This may be due to the inherent physiologically stressful situation of stranding, whereby behavioural differences caused by stranding circumstances are likely minimal. However, it is also possible that the lack of statistically significant effects is due to the sample size being too small to detect biologically relevant differences in behavioural expression. These common behaviours should be further correlated with physiological and/or pathological indicators to better understand their welfare significance (Watters et al. 2021). They can then be considered for investigating the effects of various human interventions or stranding situations on animal welfare (Yon et al. 2019; Lesimple 2020; Palmer et al. 2021).

Human presence occurred nearly constantly for almost all pilot whales observed. Watering, touching, and digging out occurred with more than a third of the pilot whales, and when occurring lasted for more than a third of the observation period. These high levels of interventions may negatively affect the welfare state of stranded cetaceans, since humans may be perceived as threatening (Mellor et al. 2020), particularly when encountered in an inherently physiologically stressful situation. However, appropriate, minimal intervention may also reduce other welfare concerns. For example, the provision of sheets and cooling water over the body should reduce the risk of hyperthermia and sunburn (Geraci and Lounsbury 2005), which may otherwise cause pain and discomfort (Boys et al. 2022b, 2022d; Chapters 2 and 3). Future research should examine differences in stranded cetacean behavioural and physiological parameters with and without human intervention, to investigate the effects of differing interventions on animal welfare (Watters et al. 2021).

4.4.3 Chapter considerations

Due to the stochastic nature of stranding events, opportunistic filming by the public was an important data source in this chapter. Despite many videos being short in duration, this chapter was able to identify and evaluate physical and environmental indicators and characterise behaviour. Similar video length has been used elsewhere (Ghaskadbi et al. 2016; Harvey et al. 2021), however, these data are unlikely to provide accurate estimates of behavioural time budgets and respiratory rate of stranded cetaceans. Furthermore, welfare compromise is expected to worsen throughout a stranding (Fernandez et al. 2017; Boys et al. 2022b; Chapter 2), and time stranded is considered a major concern for survival likelihood (Boys et al. 2022b; Chapter 2). Accordingly, it is recommended that standardised methods for data collection are applied as a routine part of cetacean stranding responses. This should include video recording from cameras mounted on poles and longer filming duration, ideally from the onset of stranding to re-floatation or euthanasia, in order to fully evaluate the severity, duration and progression of welfare impacts (Mellor et al. 2009a; Mellor 2017). Standardised and continuous automated data collection will facilitate further investigation of indicators and the effects of human activities without hindering timely intervention to improve animal welfare and survival likelihood.

The experts consulted in Chapter 3 (Boys et al. 2022d) considered animal responsiveness via reflex testing to be a valuable and practical indicator. However, this was not tested at the stranding events presented here, despite it featuring in the New Zealand Standard Operating Procedure for cetacean strandings (Boys et al. 2022c;

Chapter 6). Nonetheless, it is likely that responsiveness could be evaluated via video footage with correct camera positioning, thus its feasibility should be assessed at future stranding events. Other valuable measures, such as body temperature, may also be taken in-field to augment remote evaluation from video, though this may be limited by equipment and availability of appropriately trained/skilled personnel. Finally, future studies should aim to collect data from both single and mass strandings to enable statistical evaluation of the effects of stranding type on the indicators presented. Evaluation of these additional data will ensure comprehensive welfare assessments at future stranding events to inform decision-making.

4.5 Conclusion

Video data provided valuable welfare-relevant information and highlighted the potential for experts to undertake assessments remotely. Importantly, the findings present an initial proof of concept concerning the feasibility of non-invasive welfare indicators, including behaviour, relevant to stranded odontocetes. However, additional data are required to explore the value of such indicators for predicting stranding outcomes such as remaining at sea following re-floatation and longer-term survival, and to understand the effects of environmental conditions and human interventions on welfare and survivorship. Such information will better support decision-making concerning re-floatation versus euthanasia. This chapter highlights the value of applying the Five Domains Model to facilitate holistic welfare assessments, allowing for more rapid, informed prognoses of individual cetaceans. Including indicators that are practical to measure and validated in welfare assessment protocols will allow for more holistic, transparent, and justifiable evaluation of stranded cetacean welfare states. This will facilitate appropriate management interventions leading to the best animal welfare and conservation outcomes from stranding events. The subsequent chapter applies these welfare indicators to undertake a holistic assessment at another odontocete stranding event. Furthermore, it explores possible relationships among observed pathology and indicators, as well as describing potential welfare concerns related to euthanasia.

Chapter 5 A case study: Assessing animal welfare during a stranding of pygmy killer whales (*Feresa attenuata*)

Rebecca M. Boys sets up camera equipment at mass stranding of pygmy killer whales (*Feresa attenuata*).
Photo credit: Department of Conservation/Te Papa Atawhai, Aotearoa New Zealand.

This chapter is a reformatted version of the following manuscript:

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Abstract

The lack of empirical assessment of cetacean welfare to inform strandings interventions is problematic. Here, potential indicators of welfare state and two composite behavioural indicators (animal ethology and human intervention) are described for two stranded pygmy killer whales (*Feresa attenuata*). Euthanasia procedures and welfare-relevant pathology are further detailed. Each animal was filmed for 3.5 and 1.5h respectively, allowing assessment of 16 potential welfare parameters and behavioural indicators. Eight human interventions and 19 animal behaviours were identified. Animal 1 and 2 displayed 18 and 12 of these behaviours, respectively. Examination of ballistics euthanasia via video, documented atypical projectile placement and revealed various animal behavioural responses both during and post application of ballistics. Unfortunately, welfare implications related to euthanasia could not be robustly assessed as insensibility was not verified real-time in-field. Ischemia-reperfusion injuries, including pulmonary oedema and renal degeneration were documented in both animals. Potential relationships among histopathology and observed welfare indicators are explored to infer potential affective experiences relevant to welfare state. The results suggest these animals likely experienced breathlessness, fatigue, discomfort, and hunger. Findings highlight the importance of verifying insensibility in-field and correct application of end-of-life procedures. Welfare-centric assessment is recommended to improve current animal welfare outcomes during strandings management.

Keywords: Animal welfare science; Ballistics; Behaviour; Cetacean; Euthanasia; Stranding; Marine mammal; Pathology

5.1 Introduction

Live cetacean strandings are physiologically stressful situations where an animal is alive on the shore (Geraci and Lounsbury 2005; Moore et al. 2018a). These animals can vary in their state from appearing outwardly healthy to those that are clinically ill or moribund (Cowan and Curry 2008; Arbelo et al. 2013; Herráez et al. 2013; Diaz-Delgado et al. 2018; Câmara et al. 2020). Regardless of their state, live strandings are life-threatening situations for cetaceans, which are poorly adapted to the terrestrial environment. Therefore, understanding the welfare state and survival likelihood of stranded cetaceans is crucial to inform appropriate decision-making for strandings response (IWC 2016a; Boys et al. 2022b; Chapter 2).

During live strandings, human intervention commonly occurs, generally with the aim of re-floating as many animals as possible whilst ensuring animal welfare through supportive care (Geraci and Lounsbury 2005; Gales et al. 2008b; Moore et al. 2018a). First response interventions typically include minimising pressure on internal organs by righting animals into a position on the sternum, and reducing the risk of hyperthermia and sunburn by covering animals with sheets and pouring water over the body (Geraci and Lounsbury 2005). Depending upon the animal's condition, it may then be re-floated and released at sea, or undergo further human intervention either through rehabilitation in captivity (where legal) or end-of-life procedures, including euthanasia or palliative care (Moore et al. 2007).

Although such response procedures have become common, there are limited data available to assess stranded cetacean welfare or survival likelihood and inform decisions about when and how to intervene (Boys et al. 2022b, c; Chapters 2 and 6). Notably, in some regions, strandings response may not be coordinated under a management system. Even in regions where management policies and procedures are in place, protocols may lack the detail required to undertake informed decision-making (Boys et al. 2022c; Chapter 6). This can lead to inappropriate intervention and unrealistic expectations from responders, particularly during discussions about emotive topics such as euthanasia (Gales et al. 2008b; Boys et al. 2022c; Stockin et al. 2022; Chapter 6). Delays to euthanasia and/or undertaking inappropriate interventions can prolong suffering of debilitated and/or moribund animals and cause further welfare compromise (Geraci and Lounsbury 2005; Perrin and Geraci 2008; Sharp et al. 2014; Brownlow et al. 2015a).

Therefore, it is vital that welfare-relevant empirical evidence be applied to inform intervention decisions.

However, the information required to inform end-of-life decision-making and guide euthanasia procedures is also lacking (Barco et al. 2016; Boys et al. 2021, 2022c; Chapter 6 and 7). This may compound welfare concerns at stranding events where animals are deemed non-viable for re-floatation. In cases where end-of-life procedures are necessary, evaluations should be undertaken by examining both animal-based (e.g., behaviour) and resource-/management-based (e.g., equipment or personnel) indicators, to highlight potential welfare concerns and provide data to enable any welfare implications to be addressed. In this way, intervention procedures can be further improved to ensure the best animal welfare outcomes possible.

Recently, major welfare knowledge gaps for stranded cetaceans were identified by a group of experts, including interpreting behavioural/physiological parameters, diagnosing internal injuries and euthanasia decision-making (Boys et al. 2022b; Chapter 2). Notably, key barriers to assessing stranded cetacean welfare related to the limited data collection at strandings to inform decision-making (Boys et al. 2022b; Chapter 2). These same experts suggested that assessments of stranded cetacean welfare may be undertaken in a systematic manner by applying the Five Domains Model framework for assessing animal welfare (Mellor et al. 2020). In this framework, indicators relating to the nutrition, physical environment, health, and behavioural interactions of the animals are observed and/or measured, and the cumulative impacts are used to infer the potential welfare state (affective/mental experience) of the animal (Mellor and Beausoleil 2015; Beausoleil and Mellor 2017; Beausoleil et al. 2018). Various animal and resource-/management-based indicators were highlighted by these experts as valuable for assessing welfare (Boys et al. 2022d; Chapter 3). A variety of these indicators, including animal body condition, respiration rate, body posture, animal behaviours and human intervention types, were found to be feasible to assess from video taken at live stranding events of long-finned pilot whales (*Globicephala melas edwardii*) (Boys et al. 2022a; Chapter 4). However, additional assessment of these kinds of indicators for other species in variable stranding contexts would provide further information on how they reflect animal welfare state.

The collection of pathological data and samples from individuals that do not survive a stranding but are monitored ante-mortem could be used to correlate features of internal state and external indicators (e.g. behaviour) to enhance understanding of welfare state ante-mortem (Camps et al. 2019; Câmara et al. 2020). Additionally, evaluation of behavioural and physiological indicators during euthanasia could provide information on the welfare implications of end-of-life procedures. Such welfare-relevant information would improve decision-making at future stranding events.

Here, this recently gained knowledge on welfare assessments for live stranded cetaceans is applied (Boys et al. 2022b, 2022d; Chapters 2 and 3) to a live stranding event of pygmy killer whales (*Feresa attenuata*). Specifically, this chapter aims to (1) describe the physical state, behaviour and conditions of live stranded pygmy killer whales to make inferences about their welfare state, using a holistic system developed for another odontocete species (Boys et al. 2022a; Chapter 4) and (2) explore the relationship between externally observable indicators displayed by live animals and histopathological changes discovered post-mortem, to better interpret the live indicators displayed in the context of the stranding. Due to the context of this specific stranding event, I further (3) describe the application of, and the animals' behavioural responses to, ballistics euthanasia, to make inferences about the welfare implications of this killing method. Such data can be used to further develop a generally applicable welfare assessment framework (WAF) for cetacean stranding events and provide important insights into welfare concerns associated with end-of-life procedures.

5.2 Methods

5.2.1 Stranding event

A mass stranding of pygmy killer whales (*Feresa attenuata*) occurred at Waipu Cove (36°01'38.0"S 174°30'23.0"E), Northland, New Zealand (Figure 5.1) in March 2020. All animals (n = 4) were initially re-floated, although one individual re-stranded almost immediately and was subsequently euthanised by the agency responsible for managing stranding events, the Department of Conservation (DOC). The following day, beach patrols were conducted at first light to search for any other re-stranded animals. During these patrols, two re-stranded individuals (Animals 1 and 2) were located. Animal 1 was found alive in the shallows, buffeted by the incoming waves, whilst Animal 2 was discovered floating on its side over rocks in the estuary with the blowhole fully submerged. The sea state hindered an immediate re-float attempt, and as the animals showed signs of rapid deterioration, the decision to euthanise was made. Euthanasia was undertaken by a warranted DOC officer via ballistics, following the Standard Operating Procedure (SOP) that guides strandings management in New Zealand (Boren 2012; Boys et al. 2021, 2022c; Chapters 6 and 7). Following euthanasia, the animals were prepared for burial by a subtribe (hapū) of local indigenous Māori (Patuharakeke), who permitted opportunistic post-mortem sampling of tissues which were subsequently submitted for veterinary histopathological assessment.

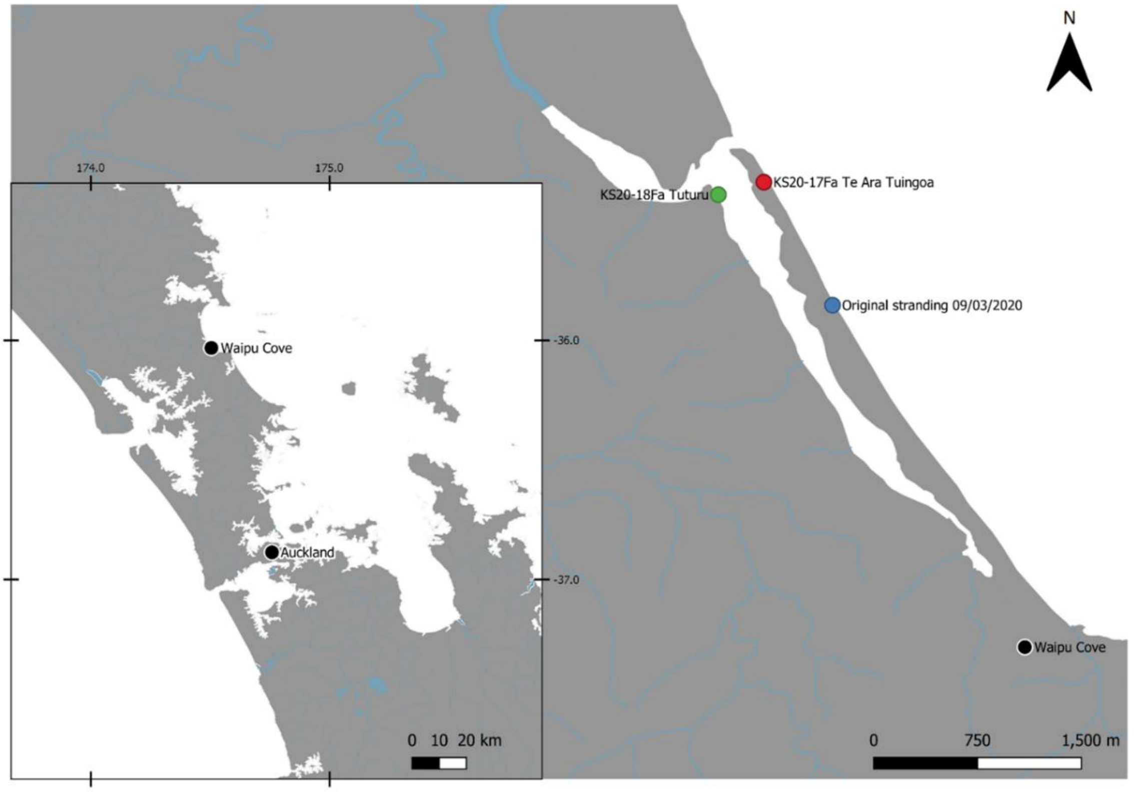

Figure 5.1 Stranding locations on 09/03/2020 (blue point) and on 10/03/2020 (red Animal 1 and green Animal 2 points) at Waipu Cove (black point), Northland, New Zealand. Inset: Map of northern area of North Island, New Zealand, showing Auckland and Waipu Cove.

5.2.2 *Data collection: Welfare indicators*

Prior to euthanasia, data were collected from the two re-stranded animals on a number of indicators reported to be valuable for understanding stranded cetacean welfare state and to be practically measurable from video footage (Boys et al. 2022a, 2022d; Chapters 3 and 4). As in the previous chapter, indicators were selected to represent multiple dimensions of animal welfare, as described by the Five Domains Model for animal welfare assessment (Mellor et al. 2020). Briefly, indicators were selected to represent each of three physical/functional domains (Nutrition, Physical environment, Health) and the situation-related domain (Behavioural interactions) (Table 5.1). According to the Model, this kind of observable information is used to infer the mental/affective experiences of the animal, which are most directly relevant to understanding its welfare state (Mellor and Beausoleil 2015; Beausoleil and Mellor 2017; Beausoleil et al. 2018).

These selected indicators were split into animal-based indicators that directly reflect animal state (welfare status), and those that are welfare-alerting indicators (both animal and resource/management-based), which have the potential to affect animal state (Harvey et al. 2020). These indicators and other parameters deemed feasible to assess due to the stranding context (Table 5.1) were examined for each live focal individual (n = 2) via direct observations in-field during the stranding event and post-stranding using video footage collected during the event.

Table 5.1 Potential welfare indicators organised into the three physical/functional domains and one situation-related domain of the Five Domains Model for welfare assessment (Mellor et al. 2020) following Boys et al. (2022a, 2022d; Chapters 3 and 4). Within each domain, indicators are organised according to whether they provide direct information on the animal's welfare status or potential welfare risk (alerting) information. *composite behavioural categories that include multiple indicators.

Domain	**Indicators**	
	Welfare status	**Welfare alerting**
1: Nutrition	Body condition	Animal age class
2: Physical environment	Skin condition/blistering	Initial strand vs Re-strand Dry-strand vs In-water strand Availability of equipment Substrate type Weather, sea, and tidal conditions
3: Health	Signs of trauma, injuries Signs of skin illness and disease	

	Respiration rate and character/effort Bleeding/fluids/mucus from orifices Eye condition Animal’s level of response to stimuli/reflexes	
4: Behavioural interactions	Body posture *Movements and behaviours Animal vocalisation	Presence and status of pod members *Type and duration of human interaction

Video footage was collected using two GoPro Hero 7 Black cameras per animal. These were mounted cranio-laterally and angled caudally (0–45°; Figure 5.2) approximately 1.5 m from each animal at a height of 0.5 m. Filming occurred at 720p and 60 fps in wide angle view, which along with the camera placement, ensured that the entire body was filmed bilaterally. Filming commenced as soon as each individual had been placed in ventral recumbency and provided with necessary first aid (i.e., water cooling and covering in wet sheets). Animal 1 and Animal 2 were filmed continuously for 3.5 hours and 1.5 hours, respectively. Filming duration was dictated by ongoing assessment of the animals until euthanasia occurred. Permission was granted by Patuharakeke to continue video monitoring the cetaceans during the euthanasia procedures.

Figure 5.2 Two GoPro cameras mounted cranio-laterally and angled caudally to enable both sides of the body of the pygmy killer whale (*Feresa attenuata*) Animal 1 to be assessed

continuously during stranding. Note the right lateral curvature of the peduncle. Photo credit: Rebecca M. Boys

5.2.2.1 *Welfare indicator assessment*

Data were collected for welfare indicators following Boys et al. (2022a; Chapter 4) as summarised below. Animal behaviours and human interventions were examined via video footage only, whilst eye condition and animal reflexes were examined by in-field observations only. All other welfare indicators were examined both in real-time in-field and retrospectively via video footage. Video footage was examined manually at 0.8x speed by one observer (RMB) at least twice to identify all cetacean behaviours and human interventions. Additionally, a subset of videos was examined by two independent observers to confirm animal behaviour and human intervention classification. Behaviours were not mutually exclusive, with multiple events occurring simultaneously.

Domain 1: Nutrition

Body condition score was assessed by examining the shape of the epaxial musculature and concavity of the nuchal crest (Joblon et al. 2014; IJsseldijk et al. 2021); animals were scored as emaciated, thin, normal, or robust (Boys et al. 2022a; Chapter 4). Age class was based on length and sexual maturity. Animals were classified as adult (≥236 cm and/or sexually mature following Clua et al. (2014)), juvenile (over one third of the length of an adult) or calf (less than one third of the length of an adult and/or with visible foetal folds).

Domain 2: Physical environment

Skin blistering was assessed qualitatively based on the presence of dermal necrosis, cutaneous bullae or ulceration (Groch et al. 2018; Boys et al. 2022a; Chapter 4). Data on the stranding circumstances based on the animals being initial or re-stranded and being dry-stranded or in-water stranded were recorded. Equipment availability was noted based on the use of sheets over the animals' body and water being poured over the animal for cooling, as well as the availability of spades for digging, and re-floatation mats. The substrate type, weather, sea swell and tidal conditions were also observed (Boys et al. 2022a; Chapter 4), with those most prevalent (>50% duration) throughout the filmed stranding period being recorded.

Domain 3: Health

External injuries were qualitatively assessed based on being superficial or penetrating wounds and the area of the body involved. Skin illness/disease was considered based on the presence or absence of cutaneous lesions following Van Bressem et al. (2007; Boys et al. 2022a; Chapter 4).

Respiration rate was measured based on visual observation of opening and closing of the blowhole in combination with audible exhalation (Kremers et al. 2016). Respiration rate was measured in-field every 30 minutes for a period of 60 seconds to examine changes over the course of the stranding. Additionally, an average respiration rate across the total monitored period per individual was calculated from video footage. Respiratory abnormalities were qualitatively assessed by examining for immediate inhalation following exhalation (Mazzariol et al. 2015; Martins et al. 2020) and other unusual respiratory occurrences e.g., chuffing (Lusseau 2006; Mazzariol et al. 2015; Fire et al. 2020).

Additionally, in-field observations were conducted every 30 minutes to examine the accessible orifices for discharge, mucus, blood, faeces, and vomiting; these were recorded as present or absent and based on the orifice of origin. Finally, the open eyes were examined for trauma and presence of any ocular abnormalities following Colitz et al. (2016) and Colitz (2019). These were recorded as present or absent for each eye.

In the field, individual responsiveness was assessed every 30 minutes via testing the palpebral reflex (by gently tapping near the eye and looking for a blink response) and blowhole response (by gently pressing around the edges of the blowhole and examining for blowhole tightening). Additionally, the menace response was also monitored, by rapidly moving the flattened palm of the hand toward the open eye and examining for a blink response or withdrawal of the eye into the socket (Butterworth et al. 2004b). Each of these reflexes were tested three times at every testing point and were noted as being present if observed 2–3 times at the test point, reduced if only observed once at the test point or absent if no response was observed. Such reflexes have been shown to be reliable indicators of sensibility in cetaceans and should not be influenced by learned behaviours or human presence (Butterworth et al. 2004b).

Domain 4: Behavioural interactions

Body posture was assessed based on the recumbency position being ventral or lateral. Presence and type (lateral, dorsal, ventral) of body curvature was recorded (Boys et al. 2022a; Chapter 4). The frequency or duration of various behaviours, including vocalisation, was quantified. Behaviours were identified and coded per second using BORIS v7.9.6 (Friard and Gamba 2016) by applying the stranded odontocete ethogram (Boys et al. 2022a; Chapter 4; Appendix 8 Table A8.2). Respiration rate was also included in this ethogram (Boys et al. 2022a; Chapter 4).

The presence and status of conspecifics was recorded (1) stranded or floating and (2) alive or dead. Finally, human intervention was characterised following the ethogram constructed for human intervention (Boys et al. 2022a; Chapter 4; Appendix 8 Table A8.3). Duration of each intervention type was quantified based on its occurrence per animal and was coded in BORIS. Human intervention was considered to begin occurring when a human was within ~2 m of the focal cetacean.

5.2.3 Data collection: Euthanasia

Video footage was re-examined, from 2-minutes prior to the initial shot, at 0.5x speed using BORIS to understand the ballistics euthanasia procedures applied. Data collected on the application of, and animal's response to, ballistics euthanasia were: orientation of firearm discharge (dorso-ventral or lateral; Hampton et al. 2014b; IWC 2014), approximate projectile entry location based on animal anatomical features, number of shots (a minimum number may be determined prior to application of method), and fine-scale animal behaviour during and post-euthanasia. All animal behaviours were characterised and coded per second in BORIS and quantified based on their frequency or duration.

5.2.4 Data collection: Opportunistic post-mortem sampling

The requirement for an onsite immediate burial prevented a full systematic post-mortem examination. However, external morphology and biometric measurements were recorded (see Appendix 9, Tables A9.2 and A9.3) and a basic in-field dissection was permitted to opportunistically access key organs for subsequent pathological assessment. Samples collected from each animal included skeletal muscle (*longissimus dorsi*), taken at the epaxial section in-line with the dorsal fin, liver, kidney, lung, spleen, and bladder for histopathology screening. The stomach was extracted, and chambers examined for blockages and lesions. All prey remains were collected and subsequently identified where possible. The testes were obtained whole and were subsequently sectioned and examined histologically to determine sexual maturity following Betty et al. (2019) (see supplementary material).

All tissue samples were fixed in 10% buffered formalin and subsequently processed by standard methods into paraffin blocks, cut into 5-μm-thick sections, then stained with haematoxylin and eosin and submitted for histopathological evaluation. In addition, Perl's iron staining was used to differentiate between lipofuscin and hemosiderin in sections of liver and kidney (Orchard 2018).

5.2.5 Data analysis: Welfare indicators

A quantitative assessment of behavioural and physiological indicators was conducted for each focal individual following Boys et al. (2022a; Chapter 4). Briefly, the frequency and duration of animal behavioural and physiological parameters, and the duration of human intervention were calculated whilst accounting for video duration. All parameters were classified as either point events (non-variable duration) or states (variable duration). Frequency of point events was calculated as the number of occurrences per minute over the observation period for the focal animal. The duration of state parameters was calculated as the percentage of the total filming time that the state occurred for each focal animal. Respiration rate was calculated per minute for each assessment undertaken in-field to examine for changes over the course of the monitored stranding and was quantified as an average rate per minute for each animal across the total monitored stranding period.

5.3 Results

5.3.1 Welfare indicator assessment

Video footage was collected for 3.5 and 1.5 h, respectively, for Animal 1 and Animal 2. Both sides of the body were observed for both focal animals throughout the filmed stranding period.

Domain 1 (Nutrition): Both individuals were evaluated to be in normal body condition, yet minimal stomach contents were present; only a few fish eye lenses. Both were classified as adults, based on size and sexual maturity (see Appendix 9, Table SA9.4 and Figures A9.1 and A9.2).

Domain 2 (Physical environment): An external morphological assessment of both individuals found no skin blistering. *A priori* information identified both as re-stranded individuals, having been re-floated the night prior. Both were dry stranded at the time of assessment. Standard stranding response equipment available included sheets to cover the animals and buckets to pour water over the animals, spades, and a re-floating mat. The substrate type was identified as sandy for both individuals. Prevailing weather and sea conditions were overcast, with medium to large swell on an outgoing tide.

Domain 3 (Health): Animal 1 was found to have no obvious injuries nor visible skin lesions. The respiration rate assessed in-field remained constant throughout the monitored period (range: 2.5–3.7 breath/min, SD = 0.4) and the average rate across the 3.5 h monitoring was considered within the normal range for delphinid species (Table 5.2). However, double chuffing respiration, with two forceful exhalations prior to inhalation was noted in 16% of respiratory events (n = 88). No discharge from the blowhole or mouth was observed, and no vomiting or faeces were produced by this animal throughout monitoring. Eye condition was also normal, with no trauma or abnormalities noted.

Animal 2 also had no significant injuries or trauma on gross examination, though superficial lacerations on the tail flukes, dorsal fin, and rostrum were evident. Skin condition was considered normal, with no skin lesions evident. The respiration rate assessed in-field was considered marginally elevated for delphinid species (6 breaths/min) at the start of observation, but at subsequent assessment (30 minutes into observation) it had reduced and then remained constant (range: 2.0–3.0 breaths/min, SD = 0.5) for the remainder of the observation. The average respiration rate across the 1.5 h monitoring period was within normal range (Table 5.2). No abnormal respiratory character was observed. No visible discharge from the blowhole or mouth was noted, and no vomiting or faeces were produced throughout the monitoring period. Both eyes were in normal condition, with no visible trauma or abnormalities.

Animal 1 displayed palpebral reflex and menace response consistently (i.e., positive response 3 times at each test point) throughout the stranding, until the final hour of life when both reflex responses were reduced (i.e., present once) for the final two test points. However, the blowhole response was absent throughout the observation period. In contrast, although the blowhole and palpebral reflexes were present (i.e., positive response twice at each test point) in Animal 2 for the entire monitored period, the menace response was absent.

Domain 4 (Behavioural interactions): Animal 1 was in ventral recumbency throughout the observation period, with signs of right lateral curvature of the peduncle beginning approximately 2 hours into monitoring (Figure 1). Animal 2 was also in ventral recumbency throughout, though no body curvature was observed. Of the 30 behaviours characterised in Boys et al. (2022a; Chapter 4; Appendix 8 Table A8.2), 19 were identified in this chapter (Table 5.2). Fine-scale data on the behavioural and one physiological indicator (respiration) across the monitored period are provided in section 5.3.1.1. Audible vocalisations were not evident from either individual.

Both animals formed part of a mass stranding (n = 4). Aside from the focal animals being monitored, there was one stranded dead conspecific. However, none of the individuals were in visual contact with each other. Eight types of human intervention were identified (Chapter 4; Appendix 8 Table A8.3) and all occurred with both animals. Further details and quantification of human intervention are provided in section 5.3.1.2.

5.3.1.1 Quantitative assessment of behavioural indicators

Eighteen behavioural indicators were recorded for Animal 1 over the 3.5 h observation period, four point events and 14 state behaviours (Table 5.2). A total of 12 behavioural indicators were recorded for Animal 2 over the 1.5 h observation period; three point events and nine state behaviours (Table 5.2).

The frequency and duration of behaviours varied between individuals. One behaviour (mouth open) displayed briefly by Animal 2 was not displayed at all by Animal 1. For those behaviours observed in both individuals, Animal 1 generally displayed them at a higher rate of occurrence or for longer duration. The exception was movement in the lower jaw, which occurred at a higher rate in Animal 2. The durations of head-related events were similar for both individuals, whereas the tail-related events lasted longer in Animal 1. For both individuals, head lift occurred simultaneously with most respiration events. This synchrony occurred in 71% and 60% of respiration events for Animal 1 and Animal 2, respectively (Figure 5.3).

Table 5.2 Frequency (rate/min) and relative duration (%) of total monitoring time of behavioural events displayed by two live stranded pygmy killer whales *(Feresa attenuata*) (Animal 1: 3.5 h

and Animal 2: 1.5 h). See Chapter 4 Appendix Table A8.2 for descriptions of behaviours.
*rate/min across the total observation period for each focal animal.

	Frequency		Relative duration	
Behaviour	**Animal 1**	**Animal 2**	**Animal 1**	**Animal 2**
State behaviour				
Ventral recumbency			100.0	100.0
Tail flutter			97.4	6.3
Dorsal fin flutter			46.6	15.8
Tail lift			46.6	0.3
Tail hover			43.2	1.6
Head side-to-side			35.5	26.2
Head lift			14.6	13.4
Body tremble			5.0	<0.01
Body rocking			1.0	
Pec fin flutter R			<0.01	0.3
Tail arch			7.2	
Pec fin flutter L			6.5	
Tail side-to-side			6.5	
Head arch			2.0	
Body tenses			0.1	
Mouth open				0.3
Point behaviours				
Blowhole twitch	0.5	0.2		
Movement in lower jaw	0.2	3.6		
Water from blowhole	0.1			
Physiological parameters				
*Respiration	3.0	2.6		

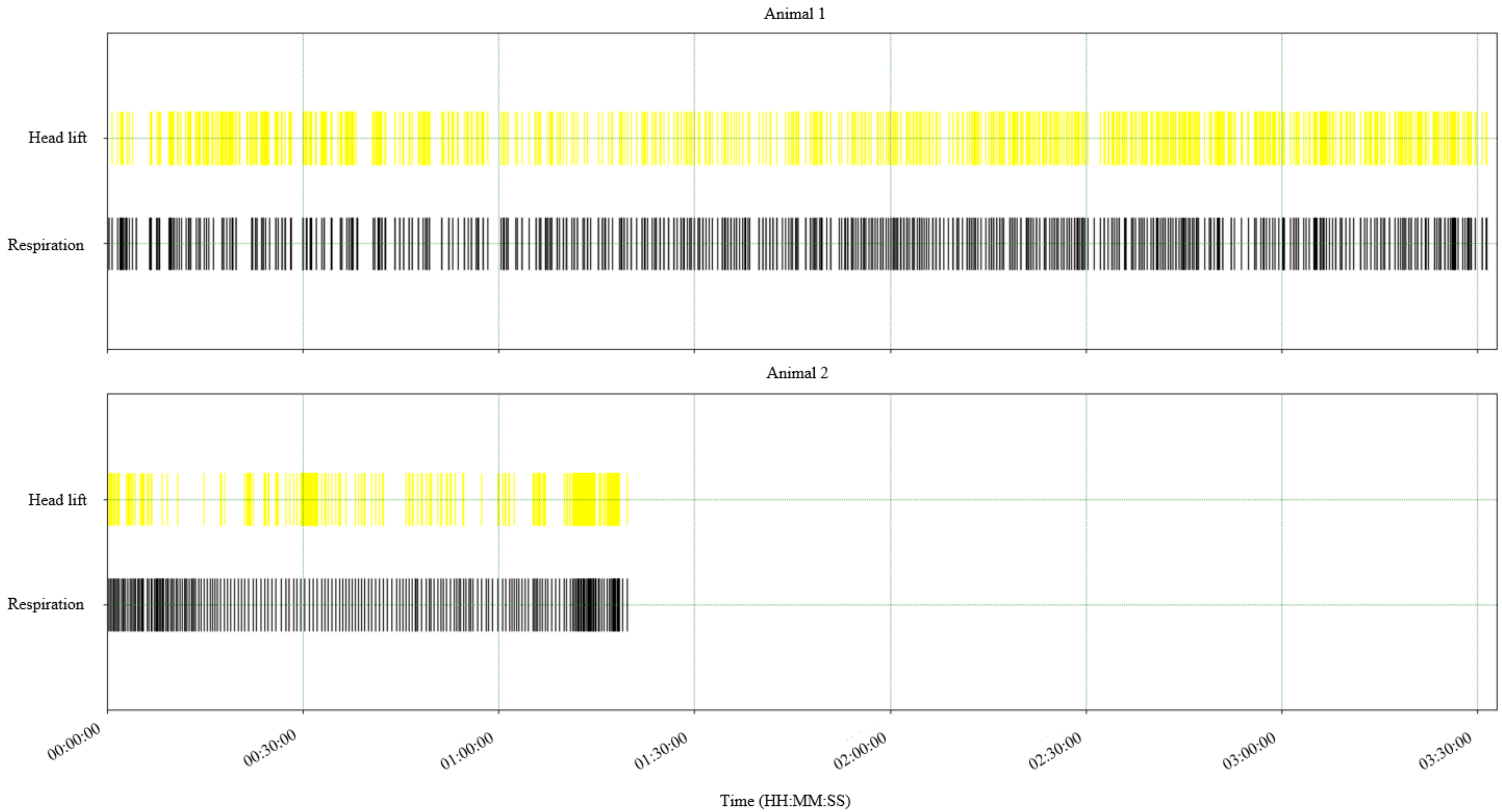

Figure 5.3 Occurrence of head lifting and respiration events in two live stranded pygmy killer whales (*Feresa attenuata*; Animal 1 and Animal 2).

5.3.1.2 *Quantifying human intervention*

For both individuals, eight types of human intervention occurred, with the duration of each intervention varying between focal animals (Table 5.3). A total of 527 and 232 discrete human interventions occurred with Animal 1 and Animal 2, respectively. Humans were present with both focal animals for the majority of the observation period, approximately 2.6 h of total 3.5 h and 1.3 h of total 1.5 h, respectively (Table 5.3). In general, the relative duration of human intervention was lower for Animal 1 than Animal 2 (Table 5.3).

Table 5.3 The relative duration (% of total monitoring period) of different types of human intervention that occurred with two stranded pygmy killer whales (*Feresa attenuata*; Animal 1: 3.5 h observation period and Animal 2: 1.5 h) in which human intervention occurred. See Chapter 4 Appendix 8 Table A8.3 for description of human intervention types.

	Relative duration	
Human intervention	**Animal 1**	**Animal 2**
Present	74.40	97.90
Watering	23.60	36.40
Touching	12.20	15.70
Digging	8.10	8.20
Rolling	1.80	2.70
Dog present	1.60	2.10
Noise	1.00	2.10
Reflex test	0.90	0.50

5.3.2 *Euthanasia assessment*

Dorso-ventral orientation for firearm discharge was applied to euthanise both individuals using a Bergara .308 calibre rifle. Prior to the application of the method, it was determined that a minimum of three shots would be employed per animal, each shot involved a Winchester soft-point 150gr projectile. Firearm discharge was anterior to the animal with the three shots angled at approximately 70° ventro-caudally on the dorsal midline. The first projectile for both focal animals entered anterior to the blowhole and likely into the melon based on the observation of clear fluid expelled from the projectile entry site in both individuals. For both animals, the second projectile entered the blowhole and the third was caudal to the blowhole. Notably, criteria for assessing insensibility were not examined in-field for either animal following application of the euthanasia method. A total of 10 animal behavioural responses were characterised during and post-ballistics euthanasia (Appendix 9 Table A9.1).

Animal 1: Time between the initial and secondary shot was 8 seconds, and between the first and final shot was 16.5 seconds. Stiffening of the peduncle, tail fluttering, tail arching, dorsal fin flutter and body tremble occurred after every shot (Figure 5.4). Jaw open occurred after the initial shot, whilst agonal convulsions, lasting 7.5 seconds, only commenced after the third shot. Relaxation of the epaxial musculature occurred 13.8 seconds after the final shot. Tail lifting was observed in this animal 35.3 seconds after the final shot and continued for 27 seconds.

Animal 2: Time between the initial and secondary shot was 6.8 seconds, and between the initial and final shot was 14.8 seconds (Figure 5.5). Stiffening of the peduncle, tail flutter and tail lift occurred after every shot. Additionally, body tremble occurred after the initial and second shots were discharged (Figure 5.5). Agonal convulsions occurred only after the third shot, lasting 3.3 seconds, followed by observation of the jaw open. Relaxation of the epaxial musculature only occurred 16.8 seconds after the final shot. Tail fluttering began with agonal convulsions after the third shot and continued for 52.5 seconds. Dorsal fin fluttering which began after the initial shot, continued for an additional 90.7 seconds following the third shot.

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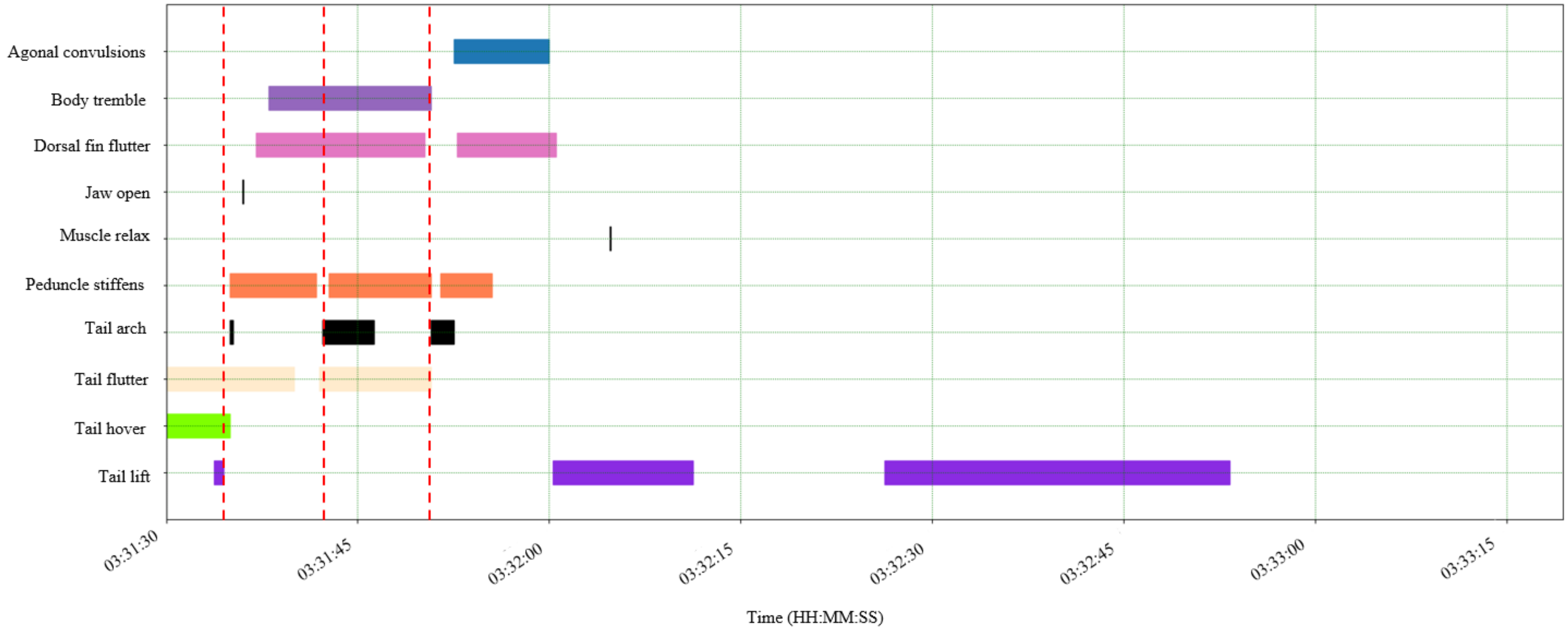

Figure 5.4 Behavioural events related to euthanasia of pygmy killer whale (*Feresa attenuata*) Animal 1. Each shot is indicated by a red dashed line.

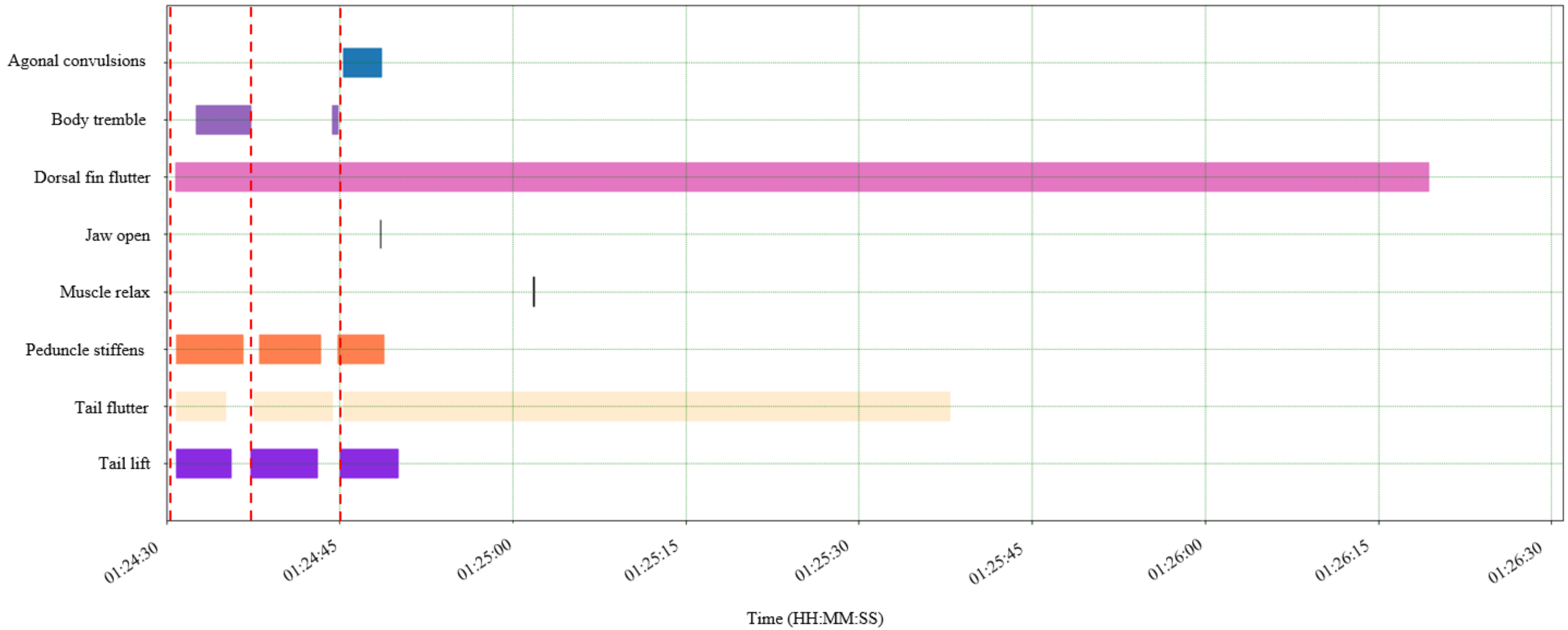

Figure 5.5 Behavioural events related to euthanasia of pygmy killer whale (*Feresa attenuata*) Animal 2. Each shot is indicated by a red dashed line.

5.3.3 Histopathology

The lungs of both animals displayed marked diffuse congestion and the presence of proteinaceous fluid (oedema) within multiple bronchioles and alveolar spaces along with mildly increased numbers of alveolar macrophages and small numbers of erythrocytes. Additional patchy over-expansion of sub-pleural alveolar spaces was also evident. Within the hepatic tissues of both animals, large numbers of Kupffer cells contained iron in the form of hemosiderin which was confirmed with a Perl's Iron stain. Similar pigment was not observed within hepatocytes.

Renal tissue sampled from both individuals revealed cytoplasmic swelling and vacuolation of the proximal renal tubular epithelial cells. No convincing evidence for intracytoplasmic myoglobin droplets or myoglobin casts within tubular lumina were evident, but many of these cells did contain iron in the form of hemosiderin which was confirmed with a Perl's Iron stain. Additionally, Animal 2 displayed rhabdomyolysis in the *longissimus dorsi* muscle; evidenced by multiple individual and small groups of myofibers exhibiting loss of cross striations, fragmentation, and hyper-eosinophilia of the sarcoplasm and nuclear pyknosis.

5.4 Discussion

Since strandings response aims to optimise animal welfare, the assessment of welfare indicators is crucial to inform decision-making. By applying the principles of welfare assessment in the context of cetacean strandings articulated in Boys et al. (2022a; Chapter 4), this chapter provides further evidence of the ability to undertake holistic assessments using various potential welfare indicators. Opportunistic collection of key tissue samples post-mortem enabled exploration of potential relationships among external welfare indicators and available histopathology. Additionally, this chapter contributes a fine-scale evaluation of the application of, and animals' behavioural responses to, ballistics euthanasia procedures for stranded cetaceans.

5.4.1 Preliminary welfare assessment: Welfare indicators

Potential indicators representative of various animal welfare dimensions were assessed in an attempt to holistically understand the welfare state of these pygmy killer whales. The Five Domains Model for assessing animal welfare was used to structure the collection of data, with indicators representing each of the three physical/functional domains (Nutrition, Physical environment and Health) and one situation-related domain (Behavioural interactions) of the Five Domains Model (Mellor et al. 2020).

In terms of nutritional status (Domain 1), both animals were considered in normal body condition for mature adult males of this species, as has been reported in other mass stranding events (Gales 1992; Bogomolni et al. 2010). However, stomach contents revealed few prey remains, suggesting that the animals may not have fed in the days immediately prior to stranding (Sekiguchi and Best 1997), with foraging impossible during the ~17 hour stranding event. Since delphinid species have elevated energetic needs and require regular foraging on high caloric prey (Benoit-Bird 2004; Hin et al. 2019), these animals would likely have experienced progressively growing hunger and/or weakness during the assessment period.

In terms of physical state due to environmental conditions (Domain 2), no skin blistering was evident on either animal, which contrasts with the common occurrence at some stranding events (Groch et al. 2018; Boys et al. 2022a; Chapter 4). These two animals were discovered and monitored on an overcast day and were rapidly protected with sheets and cooling water, minimising ultraviolet exposure (Geraci and Lounsbury 2005), suggesting minimal impacts from sun exposure. However, other environmental factors may have impacted the animals' welfare. These animals were both known to have re-stranded and due to the large swell and outgoing tide, re-floatation attempts were not possible immediately. The longer a cetacean is stranded and/or the more times an animal re-strands, the more compounding damage and sustained physiological stress response they will endure (Fernandez et al. 2017), compromising both its welfare and survival likelihood (Boys et al. 2022b; Chapter 2).

Both animals were located on a sandy beach, although Animal 2 had previously been floating over rocks in the estuary. This likely explains the superficial lacerations on the tail fluke, dorsal fin, and rostrum (Domain 3). While such wounds have minimal survival impacts, they may cause some discomfort or pain (Boys et al. 2022d; Chapter 3). The character of Animal 1's breathing, with forceful double chuffing exhalations, was suggestive of respiratory irritation (Fire et al. 2020). Additionally, both individuals frequently elevated the cranial/ventral region during respiration, indicating potential breathing difficulties due to compression of the thoracic cavity (Mazzariol et al. 2015; Townsend et al. 2018). Such breathing difficulties were supported by histopathological findings (see section 5.4.2 for further discussion). No skin lesions or eye abnormalities were noted in either individual, nor were excretions observed from any orifices throughout the monitored period. Overall, these animals appeared outwardly healthy based on the sampling and examination possible. Accordingly, any welfare impacts likely occurred due to the stranding event rather than due to pre-existing health conditions.

Notably, in Animal 1 the palpebral reflex and menace response diminished over the course of the monitored period, from being present during the first 5 tests and then both reduced (i.e., one positive response) at the last two reflex testing points in the final hour of life. In contrast, in Animal 2, the palpebral reflex was present throughout the monitored period, but the menace response was never present. These indicators are considered reliable tests of consciousness for cetaceans and do not appear to be influenced by learned behaviours or be context specific (Butterworth et al. 2004b). Diminished response or loss of these neurological indicators typically implies physiological compromise (Townsend 1999; Butterworth et al. 2004b; Mazzariol et al. 2015; Townsend et al. 2018), and indicates that animals are not viable for release (Boys et al. 2022c; Chapter 6). However, it is important to note that any response (even if reduced) to a combination of reflex tests suggests the animal retains a level of sensibility (Butterworth et al. 2004b). Therefore, if end-of-life procedures are undertaken, it should be assumed that such animals are conscious and aware of welfare-relevant experiences. This highlights the critical importance of verifying insensibility following application of euthanasia methods to ensure a humane death and evaluate the potential duration of any suffering (Leary et al. 2020).

In Domain 4, 11 of 19 behaviours were displayed by both animals. Animal 1 was relatively active displaying tail fluttering for most of the 3.5 h observation period, as well as spending more than a third of the observation period displaying dorsal fin fluttering, tail lift, tail hover and head side to side. In contrast, Animal 2 was predominantly inactive throughout the monitored period. This animal spent approximately 25% of the 1.5 h observation period displaying head side to side and ca. 15% of time displaying head lifting (mostly occurring with respiration) and dorsal fin fluttering. Interestingly, previously dorsal fin fluttering was evident in a significantly greater proportion of initial stranded rather than re-stranded animals (Boys et al. 2022a; Chapter 4). However, such fluttering may represent forms of muscle fasciculations, which are considered clinical signs of capture myopathy (Câmara et al. 2020). Therefore, further data collection should aim to correlate such behaviours with specific stranding contexts, and specifically with physiological and/or pathological data, to better understand the welfare state they reflect.

Although tail and head arch were only displayed by Animal 1 and occurred for short durations, arching is considered to be a sign of severe physiological stress (Townsend 1999; Townsend et al. 2018). Therefore, observations of these behaviours are important to record as part of a welfare assessment. Additionally, Animal 1 also displayed lateral curvature of the peduncle. Such body arching has been reported previously in stranded and rehabilitated animals that were compromised due to rhabdomyolysis, secondary to lack of swimming (Wells et al. 2013; Gulland et al. 2018; Câmara et al. 2020). All point event behaviours exhibited had a low rate of occurrence. Therefore, these behaviours may not be applicable for use in WAFs (Watters et al. 2021), however, future research should note their occurrence to better evaluate feasibility and reliability. Overall, the behaviours displayed here were similar to those previously reported in pilot whales (Boys et al. 2022a; Chapter 4), emphasising their wider applicability in a WAF for stranded odontocetes. Their prevalence and prolonged duration also suggests they are suitable to examine the effects of differing stranding circumstances or human interventions on behaviour (Yon et al. 2019).

Lastly, human intervention occurred with both animals throughout the stranding and included several procedures, some of which are part of standard stranding response (e.g., watering; Geraci and Lounsbury 2005). Some interventions undertaken at this stranding event likely reduced potential welfare compromise, for example righting animals onto their ventrum should minimise pulmonary compression, though both animals still appeared to have breathing difficulties. These may have occurred since the animals were re-stranded and likely endured an extended period stranded, causing pulmonary damage as evidenced on histopathology (see section 5.4.2). The covering of both animals and pouring water over their bodies should have reduced hyperthermia and sunburn risk (Geraci and Lounsbury 2005). Indeed, neither animal was observed to have skin blistering which commonly occurs due to sun exposure (Groch et al. 2018). All intervention types were similar to those observed previously (Boys et al. 2022a; Chapter 4), though occurred for shorter durations suggesting these pygmy killer whales were subject to less human interaction during the monitored period. This was likely due to the limited public attendance at the current stranding event, with most interventions involving only DOC, hapū, and a researcher (RMB). Since stranded cetaceans are unaccustomed to humans, it is likely that interactions cause additional, undue distress and may be perceived as threatening (Mellor et al. 2020; Boys et al. 2022b; Chapter 2). Therefore, only minimal, necessary and appropriate interventions should be undertaken as part of strandings response (Geraci and Lounsbury 2005). Further data collection should be undertaken to enable assessments of the effects of different intervention types on stranded cetacean welfare states (Mellor and Reid 1994; Broom and Fraser 2007; Drake and Fraser 2010).

5.4.2 Preliminary welfare assessment: Welfare-relevant histopathology

Histological findings were consistent with ischaemia-reperfusion injury, including pulmonary congestion and oedemas, and renal degeneration and vacuolation in both animals. Additionally, acute degenerative lesions were evident in the skeletal muscle (rhabdomyolysis and hyper-eosinophilia) in Animal 2. Such findings are commonly attributed to capture myopathy and a significant release of catecholamines which occurs as a manifestation of an extreme physiological stress response (Herráez et al. 2007, 2013; Sierra et al. 2014; Bonsembiante et al. 2017; Câmara et al. 2020).

Histopathological findings support the interpretation of breathing difficulties, with both individuals exhibiting significant pulmonary congestion and oedema which would have impeded breathing. Such pulmonary congestion/oedema are commonly observed post-mortem in stranded cetaceans (Domiciano et al. 2016; Diaz-Delgado et al. 2018). I suggest that observation of head lifting in synchrony with respiration may be used to infer some sort of unpleasant breathlessness (Beausoleil and Mellor 2015b) in stranded cetaceans. Such respiratory impairment will impact significantly on welfare during stranding, as well as being life-threatening (Beausoleil and Mellor 2015b; Boys et al. 2022b, 2022d; Chapters 2 and 3). Indeed, it may play a role in re-stranding events, with oxygen exchange limited due to fluid filled alveolar spaces.

Exertion, trauma and crush muscular injury during the stranding are the likely cause of muscular lysis observed in this chapter and have been previously reported in stranding events (Herráez et al. 2007, 2013). Such pathology has been noted in animals observed arching and with lateral curvature of the peduncle (Câmara et al. 2020). Such injuries are notable welfare concerns due to the potential pain and discomfort caused (Pongratz et al. 2002), with prolonged exertion leading to significant fatigue, potentially impacting the likelihood of survival (Fernandez et al. 2017). It is suggested, that where such behaviours are permanent and veterinary care is not available, animals should not be released (Wells et al. 2013).

Interestingly, rhabdomyolysis was only evident in Animal 2, which did not display arching behaviours or peduncle curvature. This animal displayed less behaviours and those occurring were observed for shorter durations than in Animal 1. This may have been due to animal weakness and/or exhaustion since this individual was first observed with the blowhole submerged in the estuary, indicating prior loss of the vestibulo-ocular reflex (Butterworth et al. 2004b). I also hypothesise that the failure to detect degenerative lesions in the skeletal muscle of Animal 1, and absence of myoglobinuric nephrosis in both animals, may be due to the limited tissue sampling that was possible in this instance. Future investigations should aim to collect tissue samples across all regions of each organ and musculature to improve accuracy of reliant pathological assessment (Câmara et al. 2019b).

Finally, histology of the livers from both animals showed the presence of iron within Kupffer cells, but not hepatocytes (Kupffer cell hemosiderosis). Previous studies of cetaceans have associated this pathology with iron overload disease (Venn-Watson et al. 2012; Ewing et al. 2020). While the aetiology and pathogenesis remain poorly understood, excessive dietary iron consumption, chronic inflammation, haemolysis/anaemia, and emaciation have been suggested. Iron was also present in the proximal tubular epithelial cells of the kidney, in the absence of a concurrent haemoglobinuria or myoglobinuric nephropathy. Concurrent hepatic and renal hemochromatosis could suggest previous bouts of intravascular haemolysis (Venn-Watson et al. 2012). Given that these individuals were in normal body condition and exhibiting no evidence of chronic inflammatory disease within the organs examined, the significance of the hemosiderosis and its association with this stranding remains unclear. Nonetheless, there are potential animal welfare implications, since such findings in humans have been associated with feelings of fatigue and malaise (McDonnell et al. 1999).

5.4.3 Welfare assessment of euthanasia procedures

Criteria to verify cetacean insensibility/death were not assessed in-field immediately following application of the euthanasia method, despite the mandate to do so within the New Zealand SOP (Boys et al. 2022c; Chapter 6). Behavioural responses specific to the euthanasia procedure in these animals included agonal convulsions, body tremble, jaw open, muscle relax and peduncle stiffening. Onset and cessation of agonal convulsions, and muscle relax were only observed following the third shot in both animals, while body tremble and peduncle stiffening occurred after each shot. The peduncle stiffening displayed by both animals after each shot was likely a form of tonic spasm, whilst the agonal convulsions were likely clonic spasms (Close et al. 1996; Leary et al. 2020). Notably, the jaw open did not occur in the same sequence for the two individuals, despite seemingly identical euthanasia procedures. For Animal 1, jaw open occurred following the first shot, whereas for Animal 2, it occurred after the third shot.

In other species, mouth gaping is suggested to indicate loss of cerebral cortex control (Erasmus et al. 2010), whilst cessation of musculoskeletal movements is indicative of spinal cord dysfunction (Dawson et al. 2007). However, there is a lack of data to support correlation of loss of consciousness and behavioural and/or physiological responses in cetaceans (Butterworth et al. 2004a; Brakes et al. 2006). Although both pygmy killer whales had reduced responses (see section 5.4.1 for further discussion) prior to the application of the euthanasia method, the animals still reacted to the combination of reflexes tested, suggesting some level of sensibility (Butterworth et al. 2004b). This indicates that both cetaceans were aware of welfare-relevant experiences at the time of euthanasia.

Following the final shot both animals displayed behavioural movements; for Animal 1 this involved tail lifting, whilst for Animal 2, both tail and dorsal fin fluttering were observed. Although such behavioural movements may be involuntary clonic spasms (Woods et al. 2010; Leary et al. 2020), without verification of insensibility in-field, unconsciousness cannot be confirmed. Verification of insensibility in cetaceans should include the assessment of a combination of criteria: lack of jaw tone, absence of menace, palpebral and corneal reflexes, fixed dilated pupils, lack of response to painful stimuli, no capillary refill time and ocular/skin temperature differential whereby the eye cools more rapidly after blood circulation ceases (Butterworth et al. 2004a; Brakes et al. 2006). Unfortunately, such indicators have not been validated to understand how they reflect different stages of insensibility. Future research should seek to examine for correlations between these behaviours and the loss of various reflexes, absence of heartbeat and/or electrical brain activity incompatible with conscious experience (Verhoeven et al. 2015, 2016) to further elucidate how they reflect insensibility/death in cetaceans.

Based on video analysis, the first shot likely entered the melon. This suggests inappropriate shot placement and the potential for the animals to suffer pain and distress from initial application of the method until insensibility occurred. Notably, the initial shot placement observed appears misaligned with the euthanasia guidance in the New Zealand SOP which states that shots should be a “handspan behind the blowhole” (Boren 2012; Boys et al. 2022c; Chapter 6). Skull morphology among cetacean species is highly variable (Gol’din 2014; Galatius et al. 2020) and thus species-specific reference points are required for accurate projectile placement (Boys et al. 2021; Chapter 7). However, the similarity of pygmy killer whale cranial morphology, including the anatomical location of the blowhole, to that of pilot whales detailed in the generic New Zealand SOP, unlikely explains melon penetration on this occasion. Experience levels between warranted officers who perform euthanasia are highly variable, therefore it is recommended that adequate, ongoing training be undertaken to ensure that potential welfare impacts are minimised during euthanasia.

Species-specific differences can also affect which equipment is most appropriate for technically enacting euthanasia. At this stranding, soft point projectiles were used. While these are recommended in the New Zealand SOP (Boren 2012; Boys et al. 2022c; Chapter 6), soft point projectiles are understood to have reduced penetration ability and lower killing efficiency (Øen and Knudsen 2007; Hampton et al. 2014b; Knox et al. 2018). Indeed, international recommendations suggest only the use of solid projectiles for cetaceans (Duignan and Anthony 2000; Øen and Knudsen 2007; Hampton et al. 2014b; Boys et al. 2021; Chapter 7). The implications of using soft projectiles at this event are unknown since post-mortem examination of the cranium was not possible. However, future studies should undertake dissection and/or imaging techniques such as computerised tomography and magnetic resonance imaging (Thali et al. 2003; Schwenk et al. 2016; Gascho et al. 2020) of the cranium to provide detailed evaluations of ballistics euthanasia welfare impacts.

5.5 Conclusion

A holistic welfare assessment of these pygmy killer whales during re-stranding is provided, which highlights potential welfare implications associated with ballistics euthanasia as applied. The findings suggest that these outwardly healthy pygmy killer whales were experiencing compromised welfare due to stranding. Based on the potential relationships among observed external indicators and results of histopathology, a decision of euthanasia was warranted due to these animals likely experiencing breathlessness, discomfort, fatigue, malaise, and hunger. Although these findings suggest potential links between welfare indicators and aspects of pathology opportunistically sampled, both dedicated live monitoring and veterinary pathology via full necropsies are required to conclusively elucidate links between welfare indicators, survival probability and observed pathology. Such data will better inform decision-making around re-floatation versus euthanasia. Both animals displayed several behavioural responses during and post application of ballistics. Notably, verification of insensibility was not undertaken in-field, hindering confirmation of unconsciousness during these responses. It is vital that such verification and recording of time to insensibility or death are always undertaken following application of euthanasia methods to enable an evaluation of welfare implications and to allow for improvements in end-of-life procedures. By applying the knowledge acquired in this chapter, strandings response can be more scientifically-informed and provide the best welfare outcomes for future stranded cetaceans. The welfare concerns associated with end-of-life procedures that have been highlighted in this chapter, are further explored in the subsequent chapter.

Chapter 6 When and how to say goodbye: An analysis of Standard Operating Procedures that guide end-of-life decision-making for stranded cetaceans in Australasia

Emaciated neonatal Cuvier's beaked whale (*Ziphius cavirostris*) single stranded and subsequently euthanised.
Photo credit: Department of Conservation/Te Papa Atawhai, Aotearoa New Zealand.

This chapter is a reformatted version of the following manuscript (CC-BY):

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Abstract

Standard Operating Procedures (SOPs) are tools used to ensure management best practice during emergency incidents including wildlife interventions, such as cetacean strandings. The compromised state of stranded cetaceans means humane end-of-life decisions may be considered, and SOPs frequently guide this process. This chapter evaluated SOPs for end-of-life decision-making and technically enacting euthanasia of stranded cetaceans across Australasia. The aim was to highlight similarities and differences in management and explore directions to improve stranded cetacean welfare. SOPs were requested from the eight government authorities across Australia and New Zealand. All SOPs were evaluated for decision-making criteria, yielding 29 parameters for the implementation of end-of-life decisions. Euthanasia and palliative care were options for end-of-life, with palliative care recommended when euthanasia was not feasible or presented human safety risks. Three euthanasia methods were recommended. Ballistics was recommended in seven SOPs, chemicals in five and explosives in three SOPs. Variability existed in the exact procedures and equipment recommended in all three methods. Additionally, only five SOPs provided criteria for verifying death or insensibility, while only two recommended time-to-death or insensibility (TTD) be recorded, hindering evaluation of the welfare impacts of end-of-life decisions and euthanasia procedures. The findings highlight the need for detailed guidance and consistency in end-of-life decisions and euthanasia techniques to ensure reliable welfare outcomes. Systematic, standardised data collection at euthanasia events across regions is required to facilitate assessment of welfare impacts and develop evidence-based recommendations. International collaboration is key to developing objective criteria necessary to ensure consistent guidance for end-of-life decisions.

Keywords: Death; Euthanasia; Management; Marine mammal; Strandings; Welfare

6.1 Introduction

Since the latter half of the 20th century, attention towards animal welfare in wildlife management has increased (Baker et al. 2016). Government bodies, such as wildlife and environmental agencies, generally develop and implement Standard Operating Procedures (SOPs) to guide wildlife interventions in the context of animal welfare, human health and safety, management of risk and liability, and to optimise the success of the intervention procedures. Such SOPs may be employed during interventions such as rescue, rehabilitation and end-of-life management and include descriptions of procedures relating to the capture, restraint, and killing of wild species (Sharp 2012; Broome et al. 2017). Consequently, SOPs can have considerable influence on animal welfare, and it is therefore crucial that they are underpinned by quantifiable scientific data.

Fundamentally, SOPs are tools to ensure consistent results in policy and management by providing detailed instructions to an operator on how to carry out a specific activity or procedure (Edelson and Bennett 1998). The use of SOPs aims to minimise errors and ensure that skills and knowledge are transferrable within a team, which is particularly important where personnel turnover may be high. To ensure that SOPs are followed correctly, they should be written in a clear, objective, and detailed manner to assure uniformity in procedures. This is particularly crucial in wildlife management where inconsistencies or malpractice can create serious risks to human health and safety as well as animal welfare (Cattet et al. 2008; Jacques et al. 2009; IWC 2014).

Cetacean strandings have been documented for centuries in most coastal nations (Aristotle 350AD). However, in many regions human responses to these events have changed significantly over time, from historical harvesting of animals as a resource to today's desire to rescue and, in some cases, rehabilitate stranded individuals (Manire et al. 2004; Mazzoil et al. 2008; Moore et al. 2018a; Câmara et al. 2020). This evolving societal desire has made it necessary for the responsible authorities (i.e., management agencies legislatively responsible for marine mammals) to lead response efforts, mainly to ensure public safety. Managing such obligations is particularly challenging where the risks to human safety or animal welfare are exacerbated by the scale of the event, such as in live mass strandings, and when there is a legal and moral obligation to work in partnership across cultures (Suisted and Neale 2004).

Australasia (Australia and New Zealand) has an international reputation for its high incidence of live mass stranding events of long-finned pilot whales (*Globicephala melas edwardii*), which commonly occur on the coastlines of New Zealand and Australia (Bradshaw et al. 2006; Groom and Coughran 2012; Oremus et al. 2013; Betty et al. 2020). Management of these stranding events can be logistically complex, with extensive public engagement and multiple stakeholders. In many cases, management of such large-scale events is undertaken via a Coordinated Incident Management System (CIMS) structure, with the responsible government agencies often implementing SOPs to guide decision-making and provide consistent field responses.

Management options for strandings include providing first aid to stranded cetaceans, re-floating animals that are likely to survive, and deciding whether, and when, to euthanise or provide palliative care to animals that are debilitated or have low likelihood of survival, i.e., end-of-life decision-making. Criteria for end-of-life decision-making may include animal-based factors, such as the health and injury status of the animal, the predicted likelihood of survival if re-floated, and resource/logistics-based factors such as manpower, human safety, and equipment availability (IWC 2014). Therefore, the SOPs implemented during strandings response must consider a range of issues including, but not limited to, animal welfare requirements.

When the decision to end the life of an animal is made, guidance on euthanasia and palliative care procedures is usually included in SOPs. However at a global scale, methods for the euthanasia of stranded cetaceans remain variable, with a lack of knowledge on welfare outcomes (Boys et al. 2021; Chapter 7). In addition, scientific data to support recommended euthanasia procedures in SOPs, in terms of welfare impacts and efficacy, are limited (Barco et al. 2016). In particular, data are needed on the intensity and duration of any welfare impacts occurring before irreversible loss of consciousness (Leary et al. 2020) as well as on verification of death. This lack of data regarding the welfare implications of euthanasia may be further complicated by the varying availability and cost of equipment as well as differences in regulations between countries (IWC 2014; Barco et al. 2016). This is particularly notable in some areas where there is no centralised advice and/or regulations, which can lead to significant variability in management approaches (IWC 2014). This brings into question, at what point is euthanasia chosen over palliative care, and how and why are particular euthanasia methods recommended in cetacean stranding SOPs?

Although many SOPs used in wildlife management include aspects of animal welfare, their development is rarely guided by those with expertise in animal welfare science or with oversight from institutional welfare or ethics committees (Hampton et al. 2016). Instead, SOPs are assumed to represent 'best practice' for providing a humane outcome based on their adherence to guidelines about the equipment and materials required, and the process of operation (Sharp and Saunders 2004). While these input resources (e.g., equipment, resourcing, and human safety analysis) do influence animal welfare outcomes, they alone cannot be used to evaluate animal welfare impacts. Thus, whether the recommended procedures in SOPs result in the best animal welfare outcomes (i.e., as humane as possible) is not always clear and there is value in assessing animal-based outputs (e.g., behaviour, physiological responses) to minimise uncertainty as to the humaneness of recommended/mandated procedures (Main et al. 2001; Boys et al. In review; Chapter 5).

This chapter reviewed current management practices for end-of-life decision-making and the euthanasia of stranded cetaceans in the region of Australasia. In undertaking this analysis, the aim was to highlight knowledge gaps and provide recommendations to ensure that procedures can be consistently followed to minimise animal welfare impacts. This was achieved by analysing current SOPs for cetacean stranding events across Australasia. SOPs from all geographical areas that respond to live cetacean stranding events were reviewed to assess (1) if and when end-of-life decisions should be undertaken, (2) methods of euthanasia and palliative care recommended, including any equipment and procedure details provided, and (3) verification of death or insensibility.

6.2 Methods

Government authorities involved in the development and implementation of SOPs relating to live cetacean strandings within the region of Australasia (Australia and New Zealand) were identified and contacted to request all relevant SOPs. This included one government department SOP from each of the seven territories or states with coastline in Australia and one government department SOP in New Zealand. The guidelines and recommendations in the American Veterinary Medical Association (AVMA) Guidelines for the Euthanasia of Animals (Leary et al. 2020) and Barco et al. (2016) were used to inform the key elements that should be included in SOPs for cetacean strandings where end-of-life decision-making is required. These key elements were the (1) criteria used to make end-of-life decisions and evaluating whether an animal is a suitable candidate for euthanasia or palliative care, (2) methods that should be implemented, including detailed information on procedures and equipment required to successfully undertake euthanasia and (3) process for verifying death or insensibility, including the combination of criteria for verification post-mortem. Each SOP was thoroughly reviewed to extract information on each of these key elements to facilitate comparison across countries and regionally to highlight any deficiencies in SOP guidelines.

Cetacean stranding events vary in their causation, which may include underlying health issues (Moore et al. 2018a), social cohesion (Oremus et al. 2013; Mazzariol et al. 2018), out-of-habitat and abnormal distribution (Chit et al. 2012), and human impacts (Bernaldo de Quiros et al. 2019). However, during the stranding event itself, both natural physiological stressors (Fernandez et al. 2017) and anthropogenic stressors due to stranding response (Geraci and Lounsbury 2005) can occur. These stressors will impact upon the welfare of the animal and affect its survival probability (Boys et al. 2022b; Chapter 2). Based on the understanding of animal-based factors related to strandings and the guidelines for human stranding response (Geraci and Lounsbury 2005; Boys et al. 2022d; Chapter 3), this chapter assessed the criteria for end-of-life decision-making identified in the SOPs and collated these into categories. There were four animal-based categories: (1) medical (health e.g., illness, injury), (2) social (e.g., mass stranding, social dependence), (3) behavioural (e.g., swimming ability, re-stranding attempts) and (4) species (e.g., normal distribution, coastal vs oceanic); and one additional category related to human stranding response, which depended on logistical factors (e.g., personnel/equipment availability, weather). Data were subsequently compiled into a matrix to examine the total number of criteria in each category from the eight SOPs and to examine differences among SOPs. Each SOP was further examined to assess whether recommendations of euthanasia or palliative care were provided based on particular categories of end-of-life criteria.

The euthanasia methods provided in the SOPs were categorised based on Barco et al (2016) into chemical and physical methods. The specific procedures and equipment to be used to implement the method were also noted. For chemical methods, this included the types and quantities of chemical agents, administration routes and needle specifications. For physical methods, this included size of the animal, anatomical landmarks used and energy requirements for penetration of the skull based on equipment type and dimensions. The collated data from each SOP were categorised into method, procedure, and equipment, and placed into a matrix which was used to examine differences in methods and level of information provided for undertaking euthanasia among SOPs.

Each SOP was examined to understand when palliative care may be undertaken and what procedures were recommended for palliative care of stranded cetaceans. The recommended procedures were compared among SOPs to examine for differences, and to assess how these procedures equated to those in the literature (Harms et al. 2018). Palliative care procedures found in the literature include ensuring breathing is unimpeded, protecting from scavengers, making appropriate postural changes, providing shade, assisting in temperature regulation and minimising handling and disturbance (Harms et al. 2018).

The inclusion and completeness of criteria to verify death or insensibility and calculate time-to-death or insensibility (TTD) following application of palliative care or the euthanasia method in the SOPs were assessed. Any criteria included were compared against those of Barco et al. (2016): absence of heartbeat, lack of jaw tone, absence of reflexes, fixed/dilated pupils, absence of respiration, lack of response to painful stimuli, no capillary refill time and ocular/skin temperature differential. The criteria to verify death or insensibility provided in each SOP were collated and categorised based on the recommendations, including a category of ‘other’ for criteria provided in SOPs but not included by Barco et al. (2016). All criteria were compiled into a matrix, to examine the total number of verification criteria, whether there were differences in criteria applied to assess death or insensibility among SOPs, and to examine how many criteria in combination are required to verify death or insensibility in each SOP. The inclusion of recommendations to assess the TTD — based on the time from application of palliative care or the euthanasia method until death or insensibility was verified — was also analysed to examine for differences in potential welfare implications among SOPs.

6.3 Results

Eight SOPs pertaining to live marine mammal stranding events that included end-of-life decisions for stranded cetaceans were obtained from government agencies across Australasia. These included one national SOP from Department of Conservation New Zealand (NZ; 2013), one territory and six state government SOPs from Australia, including Department of Land Resource Management Northern Territory (NT; n.d.), Department of Environment and Science Queensland (QLD; 2019), Department of Planning, Industry and Environment New South Wales (NSW; 2021), Department of Environment, Land, Water and Planning Victoria (VIC; 2015), Department of Environment, Water and Natural Resources South Australia (SA; 2017), Department of Parks and Wildlife Western Australia (WA; 2014, 2021) and Department of Primary Industries, Parks, Water and Environment Tasmania (TAS; 2016).

6.3.1 Criteria for end-of-life decision-making

A total of 29 criteria in five categories were provided for end-of-life decision-making within the eight SOPs. The medical category contained the most criteria (n = 15), followed by logistical (n = 6) and social (n = 4) categories, with two criteria in each of the behavioural and species categories (Table 6.1). All SOPs contained at least one criterion for end-of-life decision-making. As QLD's SOP stated that they follow the criteria provided by VIC, only the VIC criteria are presented below to avoid duplication (Table 6.1). Each SOP varied in the categories of criteria provided (Table 6.1). The SOP with the most criteria, covering all five categories, was VIC, whilst NT outlined the fewest criteria, covering only two categories (social and medical). All SOPs included criteria in the social and medical categories, whilst criteria in the logistical category were included in four SOPs (NZ, VIC, NSW, TAS), criteria in the behavioural category were included in three SOPs (WA, SA, VIC) and criteria in the species category were only included in NZ and VIC SOPs (Table 6.1).

Importantly, in six of the seven unique SOPs, it was recommended that end-of-life decisions be made if an animal met any one of the animal-based criteria (Table 6.1). In the VIC SOP, if any one of eight animal-based 'veterinary' criteria were met, an end-of-life decision should be made, whilst additional 'non-veterinary' criteria were to be considered as part of the triage process. The eight 'veterinary' criteria were: maternal dependence, disabling injuries, significant haemorrhage from orifices, rectal temperature above 42°C, blistering/sloughing of a significant portion of skin, loss of reflexes, loss of jaw tone and prolapse of the penis, and emaciated animals. In all SOPs, the logistical criteria appeared to be important as part of the decision-making process, but alone were not used to recommend an end-of-life decision.

In terms of the criteria, all SOPs included maternal dependency, whilst six of the seven unique SOPs (86%) included disabling injuries, and five of the seven unique SOPs (71%) included loss of reflexes and haemorrhaging from orifices (Table 6.1). Other criteria that were included in almost half (n = 3) of the unique SOPs were poor body condition, excessive skin sloughing/blistering over a large portion of the body, sustained muscle tremors, size too large for re-floatation and resource availability (Table 6.1). Criteria relating to rectal temperature were included in three SOPs (VIC, NSW and TAS) but varied in what temperature level would indicate an end-of-life decision (Table 6.1).

Review of these SOPs suggested that 'no response' may be chosen when weather conditions and sea state were dangerous and locations were inaccessible, which could lead to compromised human safety. Decisions for palliative care may be chosen when euthanasia was not feasible, and aside from the aforementioned safety considerations, were recommended based on logistical factors including the size of the animal and lack of appropriate equipment and skilled responders. The size of the animal that would necessitate palliative care rather than euthanasia did vary among SOPs, ranging from animals over 6 m in length in NZ to animals over 8 m in NSW, or with reference to a specific species in VIC (sperm whales *Physeter macrocephalus*). In NZ, one other criterion was also suggested as not conducive to undertaking euthanasia; this was where "significant antagonism" between the Department of Conservation (legislative agency) and local indigenous Māori people (iwi) and/or the public is likely.

Table 6.1 Criteria from seven unique Standard Operating Procedures (SOPs) used to evaluate if and when an end-of-life decision should be made for a stranded cetacean, compiled into four animal-based categories (behavioural, medical, social, species) and one resource-based (logistical) category. Total number of SOPs that included each criterion are indicated, where "✓" means the criteria is used.

Animal or Resource	Category	Criteria	NZ	WA	SA	VIC	NSW	TAS	NT	# SOPs
Animal	Behavioural	Inability to swim		✓	✓					2
Animal	Behavioural	Persistently re-stranding				✓				1
Animal	Medical	Disabling injuries (dislocated/broken tailstock), deep penetrating injures (thorax, abdomen)	✓	✓	✓	✓	✓	✓		6
Animal	Medical	Absence of reflexes from anus, genital opening, blowhole, tongue, eyes	✓		✓	✓	✓	✓		5
Animal	Medical	Haemorrhaging from mouth, blowhole, genital opening, or anus	✓		✓	✓	✓	✓		5
Animal	Medical	Excessive sloughing or blistering of skin over large portion of body	✓			✓	✓	✓		4
Animal	Medical	Poor body condition, obviously thin, emaciated	✓	✓		✓				3

Animal	Medical	Sustained muscle tremors, spasms, lateral or ventral flexion	✓			✓	✓			3
Animal	Medical	Protracted rapid breathing (>10/min indicates severe stress, physiological abnormality)	✓			✓				2
Animal	Medical	Significant mucus discharge	✓			✓				2
Animal	Medical	Rectal temperature 42°C or above				✓	✓			2
Animal	Medical	Loss of jaw tone				✓	✓			2
Animal	Medical	Prolapsed or protruding penis				✓	✓			2
Animal	Medical	Poor health			✓				✓	2
Animal	Medical	Fitness compromised by the stranding			✓					1
Animal	Medical	Rectal temperature 40°C or above						✓		1
Animal	Medical	Rectal temperature less than 35°C						✓		1
Animal	Social	Maternal dependence	✓	✓	✓	✓	✓	✓	✓	7
Animal	Social	Leader of group that precipitated mass stranding and is unfit			✓	✓				2

Animal	Social	Members of mass stranding that compromise survival of pod (injured, deteriorating)		✓	✓			2
Animal	Social	Social dependence			✓			1
Animal	Species	Coastal species	✓		✓			2
Animal	Species	Outside normal range for species			✓			1
Resource	Logistical	Resources are not available: equipment, people, cost	✓		✓	✓	✓	4
Resource	Logistical	Size too large for re-floatation			✓	✓	✓	3
Resource	Logistical	Location is remote limiting access for rescue			✓		✓	2
Resource	Logistical	Weather/sea conditions are dangerous	✓		✓			2
Resource	Logistical	Time since stranding			✓			1
Resource	Logistical	Danger to other animals or humans		✓				1

6.3.2 Methods, procedures, and equipment for the implementation of stranded cetacean euthanasia

Seven of the SOPs provided information on the methods, procedures, and equipment to be used for euthanasia (Table 6.2). However, the amount of detailed information on the recommended procedures and equipment highlighted differences among SOPs (Appendix 10 Tables A10.1, A10.2, A10.3). Although euthanasia was an option in the NT SOP, no information was provided on the euthanasia process itself, aside from stating that veterinary expertise must be involved.

Both chemical and physical means of euthanasia were evident across the SOPs, with physical methods including two techniques: ballistics and explosives (Table 6.2). While all seven SOPs included a ballistics method, five of the Australian SOPs stated they follow guidelines outlined by WA, which are based on ballistics trials (Hampton et al. 2014b), and are herein referred to as the WA SOP. Similarly, for the five SOPs that included chemical euthanasia, one (VIC) was followed in another state (SA) and is herein referred to as VIC. Three SOPs (WA, VIC, QLD) included the physical method of explosives, all of which followed the guidelines outlined in a peer-reviewed study (Coughran et al. 2012). Overall, this provided three unique SOPs for ballistics, four for chemical and one for explosives euthanasia.

Aside from availability of equipment and trained personnel, the guidelines for selecting which euthanasia method to employ were also based on animal size. For animals up to 8 m in length chemical methods were recommended, ballistics were suggested for animals up to 9 m. Explosives were suggested as an option for animals that were between 6 m and 13 m in length.

Table 6.2 National (NZ) and Australian state (WA, SA, VIC, NSW, QLD, TAS) cetacean stranding Standard Operating Procedures (SOPs) that include euthanasia with information provided on the method, procedures, and equipment, where "✓" means information is provided, "X" not provided and "NA" not applicable. SA, VIC, and QLD followed the WA SOP for ballistics recommendations, but did not contain some of the detailed information (**X**).

SOP element	**Key elements**	**NZ**	**WA**	**SA**	**VIC**	**NSW**	**QLD**	**TAS**
Method	Chemical euthanasia	X	X	✓: VIC SOP	✓	✓	✓	✓
Procedure	Administration route	NA	NA	✓	✓	✓	✓	✓
Procedure	Size of animal	NA	NA	✓	✓	✓	✓	✓
Equipment	Chemical type	NA	NA	✓	✓	✓	✓	✓
Equipment	Quantities	NA	NA	✓	✓	✓	X	✓
Equipment	Needle gauge	NA	NA	✓	✓	X	X	✓
Method	Ballistics euthanasia	✓	✓	✓: WA SOP	✓: WA SOP	✓	✓: WA SOP	✓: WA SOP

Procedure	No. shots recommended	X	✓	✓	✓	X	X	✓
Procedure	Anatomical landmark	✓	✓	✓	✓	✓	✓	✓
Procedure	Angle aim	✓	✓	✓	✓	✓	✓	✓
Procedure	Distance	X	✓	✓	✓	X	X	✓
Procedure	Size of animal	✓	✓	✓	✓	✓	✓	✓
Procedure	Diagrams provided	✓	✓	X	X	X	✓	✓
Equipment	Firearm type	✓	✓	✓	✓	✓	✓	✓
Equipment	Firearm calibre	✓	✓	✓	✓	✓	✓	✓
Equipment	Projectile type	✓	✓	✓	✓	✓	✓	✓
Equipment	Projectile grain	X	✓	✓	✓	X	✓	✓

Method	Explosives	X	✓: Follows (Coughran et al. 2012)	X	✓: Follows (Coughran et al. 2012)	X	✓: Follows (Coughran et al. 2012)	X

6.3.2.1 Chemical

Five SOPs included the use of chemical euthanasia. Since two followed the same guidance (SA, VIC), the four divergent SOPs (VIC, NSW, QLD, TAS) were examined for differences. All the SOPs using chemical euthanasia provided information on the euthanising agent to be administered (Appendix 10 Table A10.1). Two different euthanising agents were recommended, pentobarbital and potassium chloride. All five SOPs provided detailed information on the administration route, with three different administration routes identified (intravenous, intracardiac and via the blowhole). However, only VIC and TAS provided information on the needle gauge requirement. Three of the SOPs (VIC, NSW, TAS) further detailed dosages for each of the euthanising agents and additionally stated the use of sedatives prior to the euthanising agent. A total of seven different sedatives were suggested with midazolam and acepromazine being the most frequently recommended (Appendix 10 Table A10.1). All three of these SOPs additionally provided information on the sedative dosages and the two administration routes (intravenous and intramuscular), although only VIC and TAS provided information on the needle gauge requirements. Importantly, sedatives were always required prior to administration of potassium chloride as an euthanising agent, however, only VIC stated the time at which the euthanising agent should be given following sedation.

6.3.2.2 Ballistics

All seven SOPs included the use of ballistics methods. Since five SOPs followed the same guidance (WA, SA, VIC, QLD, TAS), the three divergent SOPs (WA, NSW, NZ) were examined to highlight differences. All SOPs included the use of rifles for euthanasia via ballistics, with one (NSW) also including the use of a shotgun. Additionally, a total of 11 different firearm calibres were suggested for use across all the SOPs (Appendix 10 Table A10.2). In NSW and NZ SOPs, multiple calibre firearms were suggested depending upon the body length of the animal. The WA SOP (employed in five states) was the only one to provide information on projectile shape that was required (blunt) and further stated that projectiles should be hydrostatically stabilised and solid. This SOP also required the largest projectile mass of 180 grain. The NSW SOP also stated that only solid projectiles should be used for rifles but did not provide required projectile grain. For the use of shotguns, this SOP stated a 28 gm slug or 9-lead pellet buckshot should be used. Only the NZ SOP recommended the use of soft or standard sporting round projectiles instead of solid projectiles but did not provide information on the projectile grain required.

All the SOPs stated that the brain was the target, but three varied in landmarks for this target. Specifically, two SOPs (NSW and QLD) stated that the angle of aim should be "through the blowhole", the WA SOP stated it should be "slightly posterior to the blowhole" and the NZ SOP suggested aim should be a "handspan behind the blowhole" (Figure 6.1). However, all SOPs also stated that a lateral shot undertaken a third to mid-way between the eye and pectoral fin could also be used (Figure 6.1). Only the WA SOP provided detail on the number of shots required, this was always three. WA was also the only SOP to provide detail on the distance from the cetacean at which the firearm should be discharged (0.5–1 m).

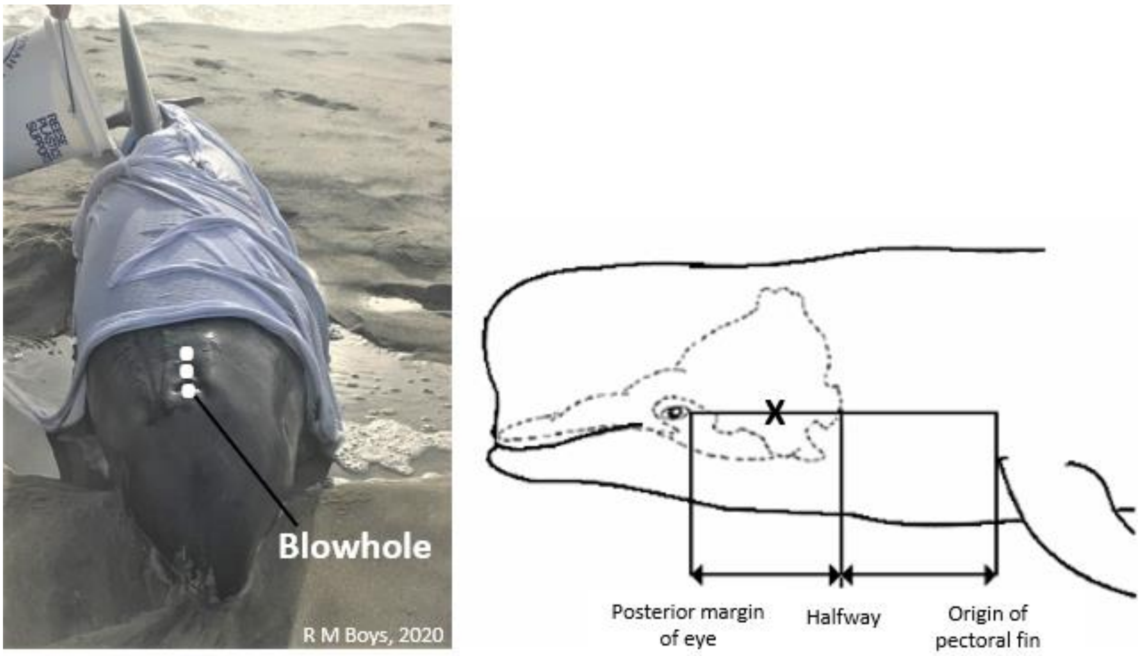

Figure 6.1 Recommended landmarks for euthanasia via ballistics for stranded cetaceans, either aiming dorso-ventrally (left), each white dot depicts approximate target point (closest to rostrum: "through the blowhole", middle dot: "slightly posterior to the blowhole", furthest from rostrum: "handspan behind the blowhole"; Photo credit: Rebecca M. Boys), or when aiming laterally (right) (IWC 2006).

6.3.2.3 Explosives

The three SOPs that included the use of explosives (WA, VIC, QLD) all provided the peer-reviewed manuscript (Coughran et al. 2012) in the SOP to enable the procedure to be followed. The method involves employing peri-cranial implosion to destroy the brain of large cetaceans (9–13 m), by constructing a triangular pyramid of explosives that is placed directly above the cranium. The study includes information on the type and amount of explosive required, as well as details on the placement and design of explosive charge. Importantly, the SOPs all note that this method can only be carried out by a licensed shot-firer (explosive detonation expert).

6.3.3 Procedures for palliative care

All SOPs, except one (WA), provided information on the recommended procedures to be used for palliative care. In all seven SOPs, these recommended procedures included first aid techniques. These procedures were similar to those suggested in the literature (Harms et al. 2018) and included maintaining the animal upright in sternal/ventral recumbency, cooling the animal by pouring water over the body, provision of shade and/or protection from sun by covering with wet sheets to prevent blistering, and minimising noise. Additionally, the VIC SOP also stated that "judicious use of sedative drugs" may be allowed to reduce animal suffering during the palliative process, with sedatives recommended following those for the euthanasia process (Appendix 10 Table A10.1). The WA SOP was the only one to not provide recommendations for the use of palliative care, although palliative care is mentioned as an option to be considered when evaluating the logistics of the stranding situation.

6.3.4 Criteria for verifying death or insensibility

The verification of death or insensibility was recommended in five SOPs (NZ, WA, SA, VIC, TAS) following the application of euthanasia, with only the VIC SOP also stating that death or insensibility should be confirmed following palliative care. Additionally, in only two SOPs (WA, NZ) was the TTD required to be recorded, although a recording form provided as an appendix in one other SOP (TAS) also contained a section to note TTD.

These same five SOPs provided criteria for death or insensibility and instructed that verification of death or insensibility be conducted following application of the euthanasia method. A total of seven criteria for verifying death or insensibility were stated within these SOPs, with all SOPs using a combination of at least three criteria to verify death or insensibility (Table 6.3). All five SOPs used absence of palpebral and corneal reflexes, and four of the SOPs (NZ, WA, VIC, TAS) used a further three of the same death or insensibility criteria: fixed dilated pupils, agonal convulsions, and slack lower jaw (Table 6.3). Only three of the SOPs (NZ, SA, TAS) recommended the absence of a heartbeat as a criterion and only one SOP (SA) suggested absence of breathing and deep pain reflexes as criteria. Six of these criteria for death or insensibility were included in the recommendations by Barco et al. (2016), whilst one criterion (unprovoked agonal convulsions) stated for use in four SOPs was not included in the Barco et al. (2016) recommendations.

Table 6.3 Criteria to verify death or insensibility of cetaceans following application of the euthanasia method that are provided in five cetacean stranding Standard Operating Procedures (NZ, WA, SA, VIC, TAS), where "✓" means the criteria is recommended to be used.

Category from Barco et al. (2016)	**Criteria**	**NZ**	**WA**	**SA**	**VIC**	**TAS**
Reflexes	Absence of palpebral and corneal reflexes	✓	✓	✓	✓	✓
Pupil fixed/dilated	Dilation of pupils	✓	✓		✓	✓
Other	Unprovoked agonal convulsions	✓	✓		✓	✓
Lack of jaw tone	Slack lower jaw	✓	✓		✓	✓
Absence heartbeat	Absence of heartbeat	✓		✓		✓
Absence of respiration	Absence of breathing			✓		
Pain reflexes	Absence of deep pain reflexes			✓		

6.4 Discussion

This chapter reveals several notable differences among SOPs being employed across Australasia for stranded cetacean end-of-life decision-making. The criteria applied for deciding upon end-of-life management for stranded cetaceans were variable among SOPs. Furthermore, there was a lack of detailed information on how to assess or quantify some criteria. When euthanasia was the chosen management option, the broad methods available were similar among SOPs, although varied in the detail provided. Specifically, details on recommended procedures and/or equipment were highly variable and, in some cases, lacking. These findings highlight the need to improve the level of detailed, specific guidance provided within SOPs.

Of particular concern was that only five of the eight SOPs required verification of death or insensibility and provided criteria to assess death or insensibility. Only one of these SOPs recommended death or insensibility be verified following the application of palliative care measures, whilst all five recommended verifying death or insensibility following application of euthanasia. This is particularly concerning since, without verifying death or insensibility, there is the possibility that the animal is left alive/conscious albeit severely debilitated and injured, significantly impacting welfare. Data on the verification of death or insensibility and assessment of TTD should be routinely and systematically collected to enable an evaluation of any welfare impacts associated with each procedure.

6.4.1 Criteria for end-of-life decision-making

All SOPs provided some criteria to assess whether an end-of-life decision is required for a stranded animal. Most of the criteria were animal based, with approximately 76% relating to the animal's welfare state (behavioural, medical, social) and/or being predictive of survivorship for the individual (behaviour, medical, species, social: maternal and social dependence) (Boys et al. 2022b, 2022d; Chapters 2 and 3). Notably, only approximately 20% of the criteria reflected human safety and logistical considerations, which based on the SOPs, appeared to influence end-of-life management only by leading to provision of palliative care rather than euthanasia.

Notably, only one criterion was recommended for use in all SOPs, this being maternal dependency in the social category. This suggests that dependent calves without a presumed mother would always be euthanised, as has been recommended previously (Whaley and Borkowski 2009; IWC 2014). Despite this being a unanimous criterion across all Australasian SOPs, there are examples of this not being followed (see Figure 6.2 Case Study; DOC 2021). The next most recommended criteria were all in the medical category; disabling injuries was recommended in six SOPs, followed by haemorrhaging from orifices and the absence of reflexes, recommended in five of the SOPs. Criteria recommended in four of the SOPs included excessive sloughing/blistering of skin (medical) and resource availability (logistical). Thus, it seems that most end-of-life decisions are related to the animal itself and largely to its physical health status.

Case Study: Management of the stranded killer whale calf “Toa” in New Zealand (DOC 2021)
“Toa” a 2.15m killer whale (*Orcinus orca*) estimated to be less than four months old (DOC 2021), with remnant foetal folds, yellow eye patch and no fully erupted teeth (DOC 2021), stranded on the afternoon of 11th July 2021 in Plimmerton, Wellington, New Zealand (NZ). The animal was cared for by various national organisations as well as public volunteers over a period of 12 days and eventually died on 23rd July, while end-of-life decision-making was still underway. Several features of the decision-making process for Toa appeared to contradict with the recommendations of the NZ Standard Operating Procedure (SOP). Searches from land and sea conducted during the days following the stranding failed to locate Toa’s pod (DOC 2021). From the onset of the stranding and throughout the period of human care, unequivocal national and international advice from experts, including veterinarians, welfare specialists and cetacean biologists, was to euthanise Toa on the grounds of maternal dependency (DOC 2021). This concurs with the recommendations in all Australasian SOPs, as well as in wider international guidelines such as National Oceanic and Atmospheric Administration’s Standards for Release (Whaley and Borkowski 2009). However, the extensive public engagement resulted in Toa remaining under human care, despite the maternal dependency criterion in the NZ SOP. Deviation from the national SOP in this instance likely occurred due to the potential for “significant antagonism” with the public, a reason detailed in the NZ SOP for not undertaking euthanasia (see Discussion section 6.4.1 for further details). In addition, the only method of euthanasia recommended in the NZ SOP is ballistics, due to the lack of veterinary personnel within NZ specifically trained to administer chemical euthanasia to marine mammals and concerns about eco-toxicity associated with chemical methods. However, when euthanasia options were considered for Toa from 14th July, chemical methods were proposed because of concerns about public perceptions of ballistics euthanasia. Had this course of action eventuated, it would have further contravened the NZ SOP. Of the Australasian SOPs, only NZ and Western Australia (WA) do not contain recommendations for chemical euthanasia. Despite this, the method was contemplated in this case due to consideration of public perception and the strong media attention. Future attention should be given to how training of personnel to apply chemical methods might be addressed, to facilitate euthanasia when it appears warranted according to the SOP’s current decision-

making criteria. The reluctance to promptly euthanise a maternally dependent killer whale and the proposal to use a euthanasia method not recommended in the SOP, highlight how public perceptions and good intentions may, at times, lead to decision-making that is not in the interests of animal welfare. This case highlights the need to review the NZ SOP for stranded cetacean end-of-life decision-making and, specifically, to explore how animal welfare can be prioritised while taking into account public perceptions.

Figure 6.2 Case study illustrating end-of-life decisions and consideration of euthanasia methods during a maternally dependent killer whale (*Orcinus orca*) stranding in New Zealand (NZ), with reference to the current NZ Standard Operating Procedure (version 2013; Boren 2012).

Although no explicit information was provided in the SOPs about the relative weighting of each of the criteria, it is likely that these most recommended criteria have the highest impact on decision-making. Importantly, in all but the VIC SOP, an end-of-life decision was indicated if any one of the animal-based criteria were met. In the VIC SOP, there were eight specific "veterinary" animal-based criteria (out of 18), the observation of any of which indicated an end-of-life decision. These eight criteria included maternal dependence in the social category, and seven others in the medical category.

Logistical criteria were mentioned in all SOPs to guide decisions about whether any intervention could occur at all. All SOPs used logistical criteria to make decisions of palliative care versus euthanasia, with palliative care suggested in situations considered dangerous for personnel or where euthanasia was not feasible due to accessibility or the large size of the animal. In seven SOPs, recommended procedures for palliative care were provided and these followed those suggested for first aid in the literature (Geraci and Lounsbury 2005; Harms et al. 2018). These procedures are recommended to minimise animal welfare impacts by reducing the risk of pain or discomfort due to injuries such as dislocations of pectoral joints, blistering of skin and fluid loss when blisters rupture, and hyperthermia (Geraci and Lounsbury 2005; Harms et al. 2018).

Notably, in the NZ SOP another reason for not undertaking euthanasia was presented. Euthanasia was not recommended where "significant antagonism" between the agency legally charged with managing stranding events (Department of Conservation) and members of local indigenous Māori and/or the public may occur. New Zealand law mandates collaborative decision-making between the Crown and local Māori in such situations (e.g., Conservation Act 1987), but different worldviews about wild animals and animal welfare (Woodhouse et al. 2021; Marsh et al. 2022) may lead to conflict about the most appropriate way to respond. Although it is clearly important that cultural and public expectations are met in wildlife management, an ethical dilemma may arise when such expectations appear to override consideration of the animal's welfare, as understood from the dominant Western 'animal welfare science' perspective which emphasises the acute mental experiences of the animal itself (Mellor et al. 2020). Such concerns have been highlighted previously in relation to delays in euthanasia of stranded cetaceans due to societal desires to rescue debilitated individuals (Gales et al. 2008b; DOC 2021). To ensure that animal welfare is a high priority at stranding events, it is critical for decision-makers to have clear, objective, scientifically based criteria to inform end-of-life decisions and that these are transparently communicated with all stakeholders. Ideally such criteria should be publicly socialised prior to stranding incidents so that when high profile species strand, the public are aware that individual animal welfare concerns are considerations when deciding upon management options (IWC 2014; Chapple 2014; Hampton and Teh-White 2019).

Most of the end-of-life criteria recommended in these SOPs were similar to those suggested in the published scientific literature, such as disabling locomotor injuries, wounds with full penetration into the thoracic and abdominal cavity, blistering to a large percentage of body surface area and significant haemorrhaging from anus, genital, blowhole and mouth (Needham 1993; Geraci and Lounsbury 2005; IWC 2014; Harms et al. 2018; Boys et al. 2022d; Chapter 3). However, some criteria were poorly described and for others variable thresholds for decision-making were suggested. The ambiguity of such criteria makes it not only difficult to be confident in decisions but also to evaluate the potential animal welfare implications of such decisions (Hampton and Hyndman 2019).

To illustrate, rectal temperature was recommended as a criterion in three SOPs, but the temperature value at which an end-of-life decision should be considered varied among SOPs. The critical value was given as 'above 42°C' in two SOPs and 'below 35°C or above 40°C' in another SOP. Current recommendations in the literature are that prolonged hypo- or hyperthermia where core body temperature is below 35°C or above 40°C should lead to an end-of-life decision for cetaceans (Gulland et al. 2018). Hyperthermia, indicative of overheating, commonly occurs in stranded cetaceans due to their compromised thermoregulatory ability out of water (Harms et al. 2018) and is worsened by exposure to direct sunlight (Geraci and Lounsbury 2005). This likely causes increased thermal discomfort to an already compromised animal (Boys et al. 2022d; Chapter 3) and in some cases can lead to acute mortality (Diaz-Delgado et al. 2018). Furthermore, hyperthermia often occurs alongside dehydration, which contributes to hypovolaemia and electrolyte imbalance (Harms et al. 2018). Hypovolaemia may also be indicative of hypothermia, which is less common in stranded cetaceans (Harms et al. 2018), but will also lead to thermal discomfort.

Likewise, 'excessive skin sloughing/blistering over a large proportion of the body' was a criterion used in four SOPs, yet there was no quantification of what constitutes a large area. A similar lack of quantification is also evident in the literature (Geraci and Lounsbury 2005; Gulland et al. 2018). When excessive, these sunlight-induced thermal burns can be equivalent to second-degree burns, with associated pain and fluid loss when blisters rupture (Harms et al. 2018; Boys et al. 2022d; Chapter 3). Such injuries have the potential to cause dehydration and hypovolaemic shock (Martinez-Levasseur et al. 2011; Groch et al. 2018). Three SOPs also included the criterion of 'sustained spasms/muscle tremors', yet no further description of spasms/tremors was provided in terms of how these may appear, e.g., involving the entire body, and over what time frame they should be considered as "sustained". Muscle tremors have been noted in stranded cetaceans and are generally linked to neurological abnormalities and worsening prognosis (Fernandez et al. 2017; Gulland et al. 2018; Moore et al. 2018b; Câmara et al. 2020). Accordingly, such tremors likely reflect a poor welfare state, however it should be additionally noted that descriptions of these tremors also remain limited within the scientific literature.

The lack of precise descriptors for end-of-life criteria may reduce their usefulness for identifying compromised individuals and may mean that inappropriate management action, such as re-floating a severely debilitated animal, is undertaken. This is particularly pertinent when personnel charged with decision-making at stranding events are not veterinarians and/or have limited knowledge of cetacean biology and behaviour. Furthermore, the high pressure situation of a stranding event may also mean that managers have difficulties following recommendations in SOPs (e.g., Figure 6.2 Case Study; DOC 2021). Therefore, it is of critical importance that the criteria used to assess the need for end-of-life decisions are well defined, objective and transparently discussed with all stakeholders to prevent prolonged suffering. The authors of the most comprehensive recommendations to date (IWC 2014; Barco et al. 2016) and other experts (Boys et al. 2022b; Chapter 2) acknowledge the need to improve knowledge and understanding of when to euthanise stranded cetaceans, further highlighting the limited data and expertise around end-of-life decision-making in this context.

6.4.2 *Methods, procedures, and equipment for the implementation of stranded cetacean euthanasia*

6.4.2.1 Chemical euthanasia

Chemical euthanasia can be rapid and effective if executed correctly, however the logistical complexity in stranding situations often makes it an unviable option without trained veterinarian input (Harms et al. 2018). In the five SOPs that contained guidance on chemical euthanasia, the most recommended chemical agent was sodium pentobarbital, a barbiturate. Barbiturates are the most accepted chemical agents for animal euthanasia (Leary et al. 2020); however, as controlled substances they can only be administered by a licensed veterinarian. For cetaceans, they are also required in large quantities to provide a lethal effect (Barco et al. 2016), causing concerns around eco-toxicity (Greer and Rowles 2000; O'Rourke 2002; Bischoff et al. 2011; Harms et al. 2014). Due to these high eco-toxicological risks, alternatives have been sought in some regions (Barnett et al. 2013; IWC 2014). These alternatives typically involve the use of sedatives prior to injection of a large quantity of potassium chloride (KCl) (Harms et al. 2014). Two of the SOPs suggested the use of KCl (NSW, TAS) which is non-toxic in the environment. These SOPs also provided details on the use of pre-euthanasia sedatives, including midazolam, acepromazine and xylazine, which are commonly reported in the literature (Kolesnikovas et al. 2012; Harms et al. 2014; Boys et al. 2021; Chapter 7). Sedatives may be used to reduce anxiety, however, importantly the use of KCl for euthanasia is only considered acceptable in an unconscious animal, since KCl acts as a neuromuscular blocking agent on the heart, respiratory and skeletal muscles. Without deep sedation, significant welfare compromise can occur, as an animal may experience suffocation/breathlessness due to respiratory arrest through diaphragm paralysis, and/or pain due to the heart muscle arresting and body muscular spasms before loss of consciousness (IWC 1981; Close et al. 1997; Leary et al. 2020).

To administer the appropriate dosage of sedative or euthanising chemicals, an accurate estimate of animal weight is necessary. In stranding situations, these can be estimated through length-to-weight equations (Lockyer 1976; Barco et al. 2016). However, details on the chemical dosage and needle gauge required in relation to animal size were provided only in three SOPs (NSW, TAS, VIC). This could lead to inaccurate dosages being applied in other jurisdictions, causing extended time to insensibility/loss of consciousness and death, and potentially, increased suffering (e.g., IWC 2014).

Intravenous administration is generally accepted as the most reliable and rapid route to administer euthanasia agents (Leary et al. 2020). In stranded cetaceans the most accessible vessels are those in the fluke, however, working around the fluke can be dangerous to personnel as animals may move suddenly and with force (Geraci and Lounsbury 2005). Furthermore, debilitated cetaceans commonly display vasoconstriction, and so superficial peripheral vessels may not be easily accessible (Harms et al. 2018). Nonetheless, this route was recommended in three SOPs (QLD, NSW, VIC). An alternative route which results in rapid death and provides a safer working environment for personnel (Harms et al. 2014) is through intracardiac administration, where the chemical agent is delivered directly into the heart. This route was recommended for use in four SOPs (QLD, NSW, TAS, VIC). However, administering euthanasia agents this way can be particularly challenging, requiring specialised needles and skilled marine mammal veterinary personnel to accurately access the heart chamber (Adams 2001; IWC 2014; Harms et al. 2014). Therefore, although recommended most in the SOPs, intracardiac administration may often not be a viable option at stranding events.

6.4.2.2 Physical euthanasia

6.4.2.2.1 Ballistics euthanasia

Seven SOPs included ballistics euthanasia as an option, but notably five of these followed the WA SOP which is based on ballistics trials on cetacean cadavers (Hampton et al. 2014b). All seven recommended the use of rifles as the firearm type, with a calibre of .30 being most recommended. These endorsements are in line with those based on ballistics trials and the wider peer-reviewed literature (RSPCA 1997; Geraci and Lounsbury 2005; Hampton et al. 2014b; IWC 2014; Harms et al. 2018). However, lower calibre firearms were also stated for use in two SOPs, including .260 and .270 in NZ and .223 and .243 in NSW. In fact, based on data reported by NZ to the International Whaling Commission (IWC), a total of 16 different firearm calibres have been employed in the country for stranded cetacean euthanasia since 2007 (Boys et al.

2021; Chapter 7). This is notable since previous research has highlighted the importance of using high calibre firearms to cause sufficient pathology for loss of brain function, through temporary cavitation in inelastic tissues such as the brain (Zhang et al. 2005; Hampton et al. 2014b; IWC 2014).

The NZ SOP was also the only one recommending the use of soft-nose projectiles. Soft-nose projectiles begin to deform as they hit tissue. Due to the thick blubber and extensive muscle on the nuchal, parietal and occipital regions of the cetacean skull, much of their kinetic energy will be absorbed (Harms et al. 2018). This could lead to lower penetration depth (Hampton et al. 2014a; Knox et al. 2018) and reduced killing efficiency (Øen and Knudsen 2007; Leary et al. 2020). Therefore, solid, non-deforming projectiles are typically endorsed for cetacean euthanasia (Duignan and Anthony 2000; Hampton et al. 2014b). The reason for NZ's recommendation of soft-nose projectiles is unknown, though it may be due to the reduced likelihood of projectiles exiting the body and ricocheting (Leary et al. 2020).

Projectile shape was only included in the WA SOP, where blunt-tipped projectiles are recommended to maximise penetration depth (Hampton et al. 2014b; Harms et al. 2018). The projectile shapes recommended for use in NZ remain unknown, however based on reported data to the IWC, pointed-nose projectiles are often employed (Boys et al. 2021; Chapter 7). This differs from recommendations in the literature which highlight that pointed projectiles may not penetrate the cetacean skull and can deviate when impacting with the skull due to the thickness and slope of the cranium (IWC 2000; Øen and Knudsen 2007), leading to ineffective killing. Similarly, projectile grain is also an important factor to ensure an efficient death. In the Australian SOPs, projectile grains were provided. Though these varied from 125 to 180 grain, they generally aligned with the peer reviewed literature which suggests a minimum of 140 grain should be used (RSPCA 1997; Geraci and Lounsbury 2005; Øen and Knudsen 2007; Boys et al. 2021; Chapter 7). The NZ SOP did not provide information on the projectile grain required, although based on reported data similar (140–180 grain) grain projectiles have been previously employed (Boys et al. 2021; Chapter 7).

If applied appropriately, ballistics can cause instantaneous death as the brain is targeted directly (Longair et al. 1991). All seven SOPs indicated that the brain was the target for ballistics euthanasia, with slight differences in the anatomical landmarks used. Both the dorso-ventral (Blackmore et al. 1995b; Geraci and Lounsbury 2005; Hampton et al. 2014b) and lateral orientations for firearm discharge (Blackmore et al. 1995b; RSPCA 1997; Barco et al. 2016) were recommended in all SOPs. For the dorso-ventral orientation, there were slight differences in aim; two SOPs recommended the aim be slightly posterior to the blowhole, whilst three recommended the aim be through the blowhole itself. Defined angle aim for ballistics euthanasia is a crucial detail to include since the melon, concave frontal surface and extensive sinuses of the cetacean skull, are likely to deflect a bullet (Barzdo and Vodden 1983). Furthermore, due to the variability in skull morphology among species (Rommel et al. 2006; Mead 2009; Gol'din 2014), it is important that species-specific knowledge of anatomy, including diagrams, for the most accurate orientation be provided to correctly target the brain (Øen and Knudsen 2007; Coughran et al. 2012; Hampton et al. 2014b; IWC 2014; Leary et al. 2020; Boys et al. In review; Chapter 5). Further work via necropsies should be carried out on a variety of species to record anatomical differences and provide species-specific recommendations for euthanasia via ballistics (IWC 2014).

Finally, it is worth noting that wildlife managers who are required to use firearms in their profession often receive minimal training regarding the selection of firearms, projectiles and their use to ensure humane application to wildlife (Caudell et al. 2009). It is, therefore, critical that SOPs recommending the use of firearms for the humane killing of stranded cetaceans provide detailed information on the equipment and procedures required to ensure a humane death, and that regular training is undertaken (IWC 2014).

6.4.2.2.2 Explosives

Three Australian SOPs contained recommendations for the use of explosives for euthanasia via peri-cranial implosion. The details provided for this technique referred solely to the study by Coughran et al. (2012). Few studies have mentioned the use of explosives for euthanasia of stranded cetaceans (Needham 1993; Coughran et al. 2012), likely due in part to the potential danger to personnel and social unacceptability (Greer et al. 2001). Nevertheless, few alternative techniques are available to reliably euthanise large cetacean species (IWC 2014). In NZ, a specialised firearm specific for sperm whales (SWED; Boren 2012) may be applied, but most areas implement chemical euthanasia (Harms et al. 2014). However, in areas where veterinary personnel and/or appropriate chemical agents are not available, such large cetaceans are left to die naturally, which may take several days (Daoust and Ortenburger 2001; Kolesnikovas et al. 2012; IWC 2014). Therefore, the use of physical methods that do not require veterinary training or large quantities of specialised chemicals may enable a more humane death, though licensed personnel will still be required when implementing explosives. Since the SOPs examined here only provided the peer-reviewed study for this technique, an additional checklist of equipment is provided (Appendix 10 Table A10.3) that was collated — but not previously published — by Coughran et al. (2012), which can simply be added to current SOPs and may allow for planning of large cetacean euthanasia via peri-cranial implosion at future stranding events.

6.4.3 Verifying death or insensibility

Five of the SOPs provided criteria and explicitly required verification of death or insensibility. In all, except the VIC SOP, verifying death or insensibility was only required following application of euthanasia and not following palliative care. Two of the SOPs that did not include criteria for verifying death or insensibility (NSW and QLD), did recommend assessing whether a stranded animal was alive using several criteria in the 'first response' section of the SOPs. It is therefore possible that following euthanasia, these criteria are applied to verify death or insensibility. However, without verification of death or insensibility being explicitly required, it is not possible to ascertain whether this occurs as part of strandings management in these jurisdictions.

The only criterion for verifying death or insensibility included in all five SOPs was absence of palpebral and corneal reflexes. Other common criteria included complete dilation of pupils, unprovoked agonal convulsions, and slack lower jaw (Butterworth et al. 2004a; Brakes et al. 2006). Importantly, although absence of breathing is recommended in one SOP (SA) as a criterion to verify death or insensibility, this needs to be carefully applied for cetaceans, since many species — such as beaked whales — may go into a dive reflex which can result in extended breath holds (Quick et al. 2020). Therefore, absence of breathing alone should not be taken to indicate mortality (Butterworth et al. 2004a; IWC 2014).

Three quarters of the criteria recommended by Barco et al. (2016) were suggested in the five SOPs, whilst one additional criterion (agonal convulsions) was provided in four of the SOPs. Although not included in the recommendations by Barco et al. (2016), this criterion has been included in other studies for assessing death or insensibility in cetaceans (Butterworth et al. 2004a; Brakes et al. 2006). Two criteria recommended in the literature (Butterworth et al. 2004a; Brakes et al. 2006; Barco et al. 2016) that were not included in the SOPs were "capillary refill time" and "ocular/skin temperature differential". It is likely that these were not included in SOPs for logistical reasons. Capillary refill is typically tested in the gums or tongue, requiring personnel to place their hands inside the mouth of a potentially live cetacean, which risks personnel safety (Butterworth et al. 2004a; Brakes et al. 2006). In contrast, assessing ocular temperature requires the use of specialised, costly infrared thermography cameras (Butterworth et al. 2004a; Brakes et al. 2006). However, the use of a combination of the other criteria recommended in the SOPs is likely sufficient to verify death or insensibility.

Verification of death or insensibility following euthanasia is critical to ensure that the technique is efficient and humane, by determining the duration of any suffering before an animal becomes insensible (Leary et al. 2020). Although the criteria in the SOPs followed those in the literature, there are limited data to validate how some of the criteria relate to stages of insensibility and death. Further work using electroencephalography, similar to that carried out in the farming sector (Blackmore et al. 1995b; Gibson et al. 2019), should be undertaken to validate these death or insensibility criteria along with any behavioural events that may be displayed (e.g., Boys et al. In review; Chapter 5). In the absence of valid criteria for recognising loss of consciousness in cetaceans, TTD is a key metric for understanding the welfare impacts of management procedures and for improving techniques (Hampton et al. 2015). However, only two SOPs (WA, NZ) required TTD be recorded, suggesting that in only these jurisdictions would continuous monitoring of the animal occur following the implementation of the euthanasia method.

To the best of my knowledge, data to assess the verification and TTD in euthanised stranded cetaceans are not publicly available for Australia. However, NZ data on stranded cetacean euthanasia have been provided to the IWC, and a recent analysis of these data revealed that 4% (n = 22; 2018–2019) of animals have been recorded as 'presumed instantly killed' (Boys et al. 2021; Chapter 7). These data suggest that in some cases verification of death or insensibility may not occur (e.g., Boys et al. In review; Chapter 5), despite the mandate to do so in the SOP. As noted above, failing to routinely verify death or insensibility and report such data precludes improvements to euthanasia procedures.

6.5 Recommendations

Whilst acknowledging the differing political, cultural, and geographical considerations related to stranding events, this chapter highlights the need for a consistent, unified approach to end-of-life decision-making and euthanasia procedures to improve the animal welfare outcomes. However, to achieve such goals, all the elements of these SOPs must be consistently followed, which as demonstrated, may not always occur. Here, some recommendations are provided for further thought.

First, end-of-life decision-making should be informed using criteria that are objective, science-based, well-defined, and transparent. These criteria should include outcome/animal-based indicators of welfare state that are appropriate for the species encountered and implementable across regions. Given the current lack of empirical data, an international expert workshop is recommended as a first step to establishing such criteria and developing protocols to enable standardised data collection (Barnett et al. 2013; IWC 2014).

Systematically collecting data on behavioural and physiological animal responses both during and following euthanasia procedures (e.g., Boys et al. In review; Chapter 5), would provide animal-based evidence to improve our understanding of the relative welfare impacts of procedures. Importantly, this should include routinely collecting data for verification of death or insensibility, including the time taken from the start of the euthanasia procedure until loss of consciousness or death can be confirmed. Additionally, various criteria for death or insensibility should be assessed, as highlighted in this chapter, to ensure that any welfare impacts can be robustly evaluated.

Currently, application of specific euthanasia methods and procedures may be limited due to the lack of species-specific recommendations. As an example, while chemical euthanasia was commonly recommended in the Australasian SOPs, there was limited advice on needle gauges and chemical dosages required for different species, though some are detailed elsewhere (Barnett et al. 2013; Barco et al. 2016). Since robust data on the euthanasia of stranded cetaceans are limited (Boys et al. 2021; Chapter 7), standardised, routine reporting of the procedures applied and outcomes of euthanasia events is strongly recommended (IWC 2014). This may be achieved by standardising data collection forms (e.g., Barnett et al. 2013; IWC 2014; Barco et al. 2016) across regions and establishing a centralised online, open-access database to help stranding managers worldwide evaluate the potential options for different species. Information on both successes and failures should be collected to improve and prevent errors (IWC 2014). The information gathered should include the following:

- Reason for considering end-of-life options for an individual animal;
- Rationale for selecting euthanasia or palliative care;
- Method, procedure, and equipment employed for euthanasia;
- Rationale for choosing the method employed;
- Criteria assessed to verify death or insensibility;
- Time from application of euthanasia method until death or insensibility is confirmed;
- Behavioural reactions during or post euthanasia.

An additional challenge to effective euthanasia is the requirement to have specialised equipment and training (IWC 2014). To illustrate, the most recommended method for administering chemical euthanasia in the Australasian SOPs was intracardiac injection, which requires substantial skill and training. Likewise, for ballistics euthanasia, there is a need for training to select the most appropriate firearm and projectiles and ensure correct application for the humane death of wildlife (Caudell et al. 2009). Providing detailed open-access information on the available options and training would contribute to improving the skill and confidence of local personnel to undertake the appropriate euthanasia procedure for the species and situation. However, this would need to be coupled with regular practical training of personnel involved in strandings response to optimise both animal welfare and human safety. In some cases, additional research on cadavers is needed to determine the most appropriate method, equipment and application for a wider range of species (IWC 2014; Boys et al. 2021; Chapter 7).

While it is acknowledged that the procedures and equipment required for euthanasia will vary depending upon the methods employed, sufficient details should always be included in guidelines such as SOPs. Table 6.4 illustrates the level of information that should be included in SOPs to ensure consistent application of various cetacean euthanasia procedures.

Table 6.4 Recommended information to include in Standard Operating Procedures to ensure consistent application of euthanasia methods for stranded cetaceans.

Method	Recommended information	Examples
Chemical		
	Administration routes	IV, IM, IC
	Anatomical areas for administration with diagrams	Peripheral vessels of fluke, dorsal fin, pectoral fin, epaxial musculature
	Chemical agents including sedatives	
	Dosages of each chemical agent and sedative based on animal weight or length	
	Guidance on combinations of sedatives and chemical agents	Use of sedatives prior to KCl
	Needle gauge requirements	
	Species-specific knowledge of any adverse reactions to specific chemical agents	
	Criteria to verify death or insensibility	
	Recording of time-to-death or insensibility (TTD)	
	Disposal of carcass following chemical euthanasia	
Ballistics		
	Firearm type	Rifle
	Firearm calibre	
	Projectile shape	Pointed, round, blunt
	Projectile nose characteristics	Soft, solid
	Projectile energy	
	Projectile weight/grain	
	Number of shots required	

	Recommended orientation for firearm discharge based on species skull morphology	Dorso-ventral or lateral
	Anatomical landmark with diagrams, including species-specific recommendations	Blowhole, mid-point between eye and insertion of pectoral fin
	Angle of aim	
	Distance from cetacean at firearm discharge	
	Criteria to verify death or insensibility	
	Recording of time-to-death or insensibility (TTD)	
Explosives	Explosive charge type	
	Explosive quantity	
	Detonator type	
	Anatomical landmark with diagrams	
	Design of explosive	Pyramid charge shape
	Size of animal	
	Criteria to verify death or insensibility	
	Recording of time-to-death or insensibility (TTD)	
	Additional equipment	See Appendix 10 Table A10.3

6.6 Conclusion

Overall, Standard Operating Procedures (SOPs) across Australasia contained some pertinent information to undertake end-of-life decisions and apply euthanasia methods. Nonetheless, clear variability among SOPs was evident in this chapter. Specifically, this chapter found differing criteria being applied for end-of-life decision-making among SOPs and limited detail to facilitate assessment of these criteria. SOPs should include standardised, defined criteria to guide assessments of individual animals when considering end-of-life decisions.

A lack of detail provided in most SOPs regarding the necessary equipment and appropriate procedures for euthanasia methods was of concern. The use of inappropriate equipment or incorrectly applied procedures may lead to severe impairment rather than mortality, significantly compromising welfare. To achieve reliable outcomes, detailed information must be provided to ensure that there is no ambiguity surrounding the implementation of euthanasia procedures, such as the most suitable equipment or method.

Concerningly, only two SOPs required TTD be recorded and only five provided criteria for verifying death or insensibility of cetaceans following euthanasia or palliative care. Assessment of such parameters is critical to ensure that the duration of any welfare compromise is minimised. Therefore, verifying death or insensibility following application of euthanasia methods or palliative care should be mandatory and criteria for verifying death or insensibility and calculating TTD should be included in all SOPs.

The NZ case study presented illustrates how public perceptions and good intentions can lead to decision-making that is not necessarily in the best interests of animal welfare. International collaboration is needed to develop SOPs that guide best practice stranding responses at cetacean stranding events around the world. Detailed, evidence-based criteria to guide end-of-life decisions should be provided. SOPs that recommend appropriate euthanasia methods, detail the necessary equipment and procedures, and encourage standardised data collection will be associated with better animal welfare outcomes. To better understand the guidelines examined, the final data chapter explores current best practise for stranded cetacean euthanasia at a global scale.

Chapter 7 Deathly silent: Exploring the global lack of data relating to stranded cetacean euthanasia

Dead long-finned pilot whale (*Globicephala melas edwardii*) with significant skin blistering at a mass stranding event.
Photo credit: Rebecca M. Boys.

This chapter is a reformatted version of the following manuscript (CC-BY):

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Abstract

The compromised state of stranded cetaceans means that euthanasia is often required. However, current knowledge and implementation of euthanasia methods remain highly variable, with limited data on practicalities and welfare impacts of procedures. This chapter evaluated the available published data on cetacean euthanasia highlighting knowledge gaps and providing direction to improve stranded cetacean welfare. A total of 2,147 peer-reviewed articles describing marine mammal euthanasia were examined. Of these 3.1% provided details on the method used, with 91% employing chemical methods. Two countries, United Kingdom (UK) and New Zealand (NZ), provided euthanasia reports to the International Whaling Commission (IWC) between 2007–2020. Methods employed were reported for 78.3% and 100% of individual cetaceans euthanised in the UK and NZ, respectively. In the UK chemical euthanasia was most common (52%), whilst in NZ only ballistics methods were used. Few data were available about time-to-death or insensibility (TTD); 0.5% of peer-reviewed articles provided TTD, whilst TTD was reported for 35% of individuals in the UK and for 98% in NZ. However, IWC reports lacked detail on how death or insensibility were assessed, with multiple individuals “presumed instantly” killed. Overall, the findings highlight the lack of available information on cetacean euthanasia and suggest increased data collection and application of appropriate methods to improve welfare.

Keywords: Cetacean; Death; Euthanasia; Insensibility; Marine mammals; Strandings; Welfare

7.1 Introduction

Cetacean strandings are predicted to increase in the future, as global marine mammal health continues to decline (Gulland and Hall 2007). Factors contributing to the decline include climate change (Schumann et al. 2013; Alvarado-Rybak et al. 2020a) and increasing anthropogenic activities (Arbelo et al. 2013; Bernaldo de Quiros et al. 2019). The characteristics of individual animals found stranded can vary significantly, with some animals appearing outwardly healthy, while others range from being clinically ill, to moribund or dead (Gales 1992). Despite their compromised state and a lack of empirical evidence to support rescue attempts, most live cetacean stranding events will involve human interventions driven by a societal desire to 'rescue' animals by attempting to re-float them (Moore et al. 2018a). Indeed, some intervention decisions have led to significantly debilitated individuals being re-floated, enduring prolonged suffering and leading to further re-strandings (Geraci and Lounsbury 2005; Perrin and Geraci 2008; Sharp et al. 2014; Brownlow et al. 2015b; Ogle 2017).

Most live stranding events involve compromised individuals with notable injuries and/or illness. Therefore, the stranding itself along with subsequent rescue attempts will likely compromise both animal welfare and survival (Boys et al. 2022b; Chapter 2), as well as hampering achievements of conservation goals. Consequently, in many cases re-floatation or rehabilitation of such debilitated animals is not feasible or desirable, and humane killing may be required to end suffering (Dunn 2006; Coughran et al. 2012; Boys et al. 2022c; Chapter 6). However, several factors elicit controversy when it comes to this decision-making. These include a lack of detailed guidelines and protocols for cetacean euthanasia, the absence of quantitative studies underpinning current protocols and a range of socio-economic, traditional and in some cases, religious beliefs (IWC 2014; Boys et al. 2022c; Chapter 6). To ensure animal welfare compromise is minimised, reliable methods for the humane killing of cetaceans will be increasingly required. To be viable, such methods need to be safe for personnel involved, humane, publicly accepted, and cost effective (Harms et al. 2014; Barco et al. 2016).

The word euthanasia comes from the Greek meaning good (eu) and death (thanatos). According to the American Veterinary Medical Association, euthanasia is used to describe the ending of the life of an individual animal that minimises distress and pain (Leary et al. 2020). In the case of stranded marine mammals, it should also include that it is the humane ending of life for an animal that is otherwise suffering. Therefore, techniques employed should result in a rapid loss of consciousness followed by cardiac arrest and the loss of brain function. Notably, methods should further minimise the level of anxiety or distress experienced by the animal prior to loss of consciousness (Mellor and Littin 2004).

Euthanasia methods applied to stranded cetaceans remain highly variable, with a lack of sufficient empirical data to support standardised procedures (Barco et al. 2016). Multiple approaches have been applied which can be broadly characterised into chemical (parenteral administration and inhalation) and physical (ballistics, explosives, and exsanguination). However, specific details such as the chemical and quantity employed, route of administration, firearm calibre and projectile characteristics, amount of explosive charge and artery cut can vary significantly (e.g., Boys et al. 2022b; Chapter 6). The most appropriate method will also vary depending upon the taxa stranded and features of the stranding event, such as location and the presence of trained personnel.

Though chemical euthanasia is common in captive settings, and may be rapid and effective if executed correctly, the logistical complexity in stranding situations often makes it a non-viable option (Harms et al. 2018). This is particularly the case in mass stranding scenarios or when dealing with large species. This is due to the fact that substances used are often controlled, requiring veterinary personnel for administration, and are required in relatively large quantities (Barco et al. 2016). On the other hand, when carried out appropriately, physical methods, such as ballistics, can cause instantaneous death (Grandin 2006), as they target the brain directly. However, these may be complicated by the unique cranial anatomy of cetaceans, which may lead to severe wounding rather than death if employed inappropriately (Øen and Knudsen 2007; Hampton et al. 2014b).

Following euthanasia, verification of death is vital to assess humaneness of the method by examining the duration and intensity of suffering before the animal becomes permanently insensible (Mellor and Littin 2004; Leary et al. 2020). The most commonly employed parameter to quantify humaneness is time-to-death or insensibility (TTD) (Knudsen 2005; Gales et al. 2008a). However, assessing death or insensibility in cetaceans can be complicated. The thick blubber layer means that reliable criteria, such as absence of a heartbeat (Close et al. 1996), cannot always be consistently employed. Although there continue to be discrepancies in the methods for assessing insensibility and death in cetaceans, several criteria are almost universally recommended. These include lack of jaw tone, absence of eye reflexes (menace, palpebral and corneal), fixed dilated pupils, lack of response to stimuli around blowhole, no capillary refill time and ocular/skin temperature differential (Butterworth et al. 2004b; Brakes et al. 2006; Boys et al. 2022c; Chapter 6).

Currently, there are few studies that provide information on marine mammal euthanasia (Daoust and Ortenburger 2001; Glanville et al. 2003; Dennison et al. 2007; Coughran et al. 2012; Gulland et al. 2012; Hampton et al. 2014b; Harms et al. 2014; Brownlow et al. 2015a; Thayer et al. 2018). Generally, there is little information on how often stranding events end in euthanasia, and in such cases, how euthanasia is actually achieved. Furthermore, there is also a lack of information on TTD in such cases and the criteria used to assess death or insensibility, necessary to understand welfare impacts, are often not reported. The aim of this chapter was to investigate the currently available information regarding cetacean euthanasia methods and efficacy based on TTD to highlight knowledge gaps and suggest directions for improving knowledge and welfare of stranded cetaceans. This was achieved by (1) examining the peer-reviewed literature at a global scale for articles pertaining to marine mammal euthanasia, (2) investigating unpublished data at a global scale via countries reporting cetacean deaths to the International Whaling Commission (IWC) and (3) investigating historical data collected by New Zealand (NZ), a country known for its high cetacean stranding incidence.

7.2 Methods

7.2.1 Peer-reviewed literature

Current international practice for marine mammal euthanasia was examined to assess what information is available, and to examine discrepancies between methods in the amount of information available as well as reported TTD. A search of the English language peer-reviewed literature was carried out using Web of Science and Google Scholar for the period January 1930 to September 2020. Publications involving marine mammals that had the word euthanasia or killing (or their derivatives) in the title, keywords, abstract and anywhere in the main text of the article were searched for (TS=(Euthan*) OR (Kill*) AND TS=(porpoise* OR dolphin* OR whale* OR manatee*

OR dugong* OR otter* OR "polar bear*" OR cetacean* OR pinniped* OR seal* OR "sea lion*" OR "marine mammal" *NOT* TOPIC: (sealant*) *NOT* TOPIC: (sealer*) *NOT* TOPIC: (construct*)). Publications that contained relevant words were compiled into a database using Microsoft Excel, in which duplicates were detected and removed manually. Furthermore, articles that related to hunting-only of marine mammals were removed. Each article was then categorised based on the taxon/species involved, with references to freshwater species further removed. Next, publications were extracted that contained some information on the methods applied. In the final stage publications that provided an estimated TTD were extracted. These two categories were based on either cessation of the heart or loss of all conscious reflexes (Butterworth et al. 2004b; Brakes et al. 2006). The collated data (Appendix 11 Table A11.1 and A11.2) were then used to investigate how many different methods were applied based on species/taxon. Taxa were separated into delphinid, delphinid (blackfish), mysticete, odontocete (other than delphinid), pinniped, mustelid and ursid (polar bears). No peer-reviewed studies were found that included sirenian in relation to euthanasia. The data were also used to investigate how often TTD data was reported, what criteria were reported to assess this and whether there were differences in TTD based on the method applied.

7.2.2 International Whaling Commission (IWC) data

The IWC encourages its member states (n = 88 as of 2020) to submit information on any individual cetacean-killing event including TTD (IWC 1981). While these reported data are submitted to the Whale Killing and Welfare Subcommittee and are available online within a public archive (https://archive.iwc.int/pages/home.php?login=true), they are not published in the scientific literature or summarised in any commission report.

Over the period of 2007–2020, six member states (Alaska, Greenland, New Zealand, Russia, St Vincent and Grenadines, and the United Kingdom) reported data on cetacean deaths, with most related to hunting (n = 4, Alaska, Greenland, Russia and St Vincent and Grenadines). The remaining two nations, New Zealand (NZ) and the United Kingdom (UK) have reported on the killing of individual cetaceans at stranding events for the purpose of ending suffering (euthanasia). The reports available span 13 years (2007–2020) for NZ and four years (2014–2018) for the UK.

The IWC archives were data mined specifically to extract information about cetacean euthanasia events, including (1) methods of euthanasia applied, (2) TTD, (3) taxa euthanised and (4) stranding type (single or mass). Given the anatomical variability of species reported, cetacea were split into five broad categories (mysticete, ziphiid, delphinid, phocoenid, delphinid (blackfish) and kogiid; see Appendix 1 Tables A11.3-A11.5). The kogiids were placed into their own category due to their anatomical differences from the other taxa, including their asymmetrical skull, concave cranium, small spermaceti organ and blowhole placement (Bloodworth and Odell 2008; Thornton et al. 2015), which may affect anatomical landmarks used for euthanasia via ballistics. Similarly, ziphiids were considered a separate category due to their unusual skull structure, including the thickened irregular nasal sinuses, variation in vertex and ultra-dense tissues (Rommel et al. 2006; Gol'din 2014) which may affect euthanasia via ballistics.

7.2.3 *New Zealand: Historical records*

As well as the data that NZ has reported to the IWC (2007–2020), opportunistic data on individual cetacean euthanasia prior to the initiation of these reports (1991–2006) has also been collected by the Department of Conservation (DOC). This data set was examined to extract additional information on (1) methods of euthanasia applied (2) TTD and (3) taxa euthanised (as detailed previously).

All data collected from the IWC, and historical records were broken down into categories of year, species, and the total number of individuals euthanised. The different methods applied for euthanasia were then related to each category, where available detailed information on firearm calibre and injection route was noted. The total number of individuals euthanised via each detailed method and the related TTD data was then added. Any further data provided, such as projectile characteristics and number of shots for ballistics, and chemical solution and dosage for chemical euthanasia, were also collated into this database. Finally, the species were collated into taxa categories to enable examination of any differences in taxa being euthanised, methods being applied, and TTD reported.

7.3 Results

7.3.1 *Peer-reviewed literature*

An examination of English-language peer-reviewed literature spanning 70 years (January 1930 to September 2020) revealed that articles pertaining to marine mammals and euthanasia have only been published since 1980. In the last 40 years a total of 2,147 articles referring to marine mammals (cetacea, pinniped, mustelid and ursid polar bear) in the context of euthanasia have been published. Only 3.1% (n = 66 / 2147) of those articles stated the euthanasia method applied (chemical or physical), with 10.4% (n = 7 / 66) of these discussing the euthanasia of multiple individuals where several methods were employed, including chemical injection, chemical inhalation, ballistics, and exsanguination.

Of those articles that reported methods, chemical euthanasia was most common (91%, n = 60 / 66), followed by one of the physical methods ballistics (12%, n = 8 / 66), with one article describing the use of both methods. For chemical euthanasia, the route of parenteral administration was reported for 73% (n = 44 / 60) of cases in which the method of euthanasia was reported. In some of these articles (n = 11), multiple routes were described due to their reporting of euthanasia for several individual animals. These routes included intra-muscular (IM; n = 15), intra-venous (IV; n = 35), intra-cardiac (IC; n = 7), intra-hepatic (IH; n = 1), intra-peritoneal (IP; n = 2), intra-thoracic (IT; n = 1), retrobulbar (n = 1), and three articles also described inhalation. The most common chemical euthanasia agents were barbiturates (n = 35). Several articles described the use of sedatives prior to euthanasia, including acepromazine, medetomidine, midazolam, xylazine and diazepam, with two articles describing their use alone sufficient to achieve euthanasia.

Firearm calibre was reported in 75% (n = 6 / 8) of ballistics cases, with six differing calibres reported. Projectile characteristics featured in only 38% (n = 3 / 8) of these cases, with all three being different projectiles. Four of the articles also provided detail on the orientation of firearm discharge, being either dorso-ventral (n = 4) or lateral (n = 2). One case provided detail on the method of explosives used and detailed the quantities, type, and location of set charges.

Time-to-death or insensibility (TTD) was detailed in very few articles (0.5%, n = 10 / 2147). Nine of the ten cases (90%) that reported TTD had employed chemical methods for euthanasia, and only one (10%), which reported instantaneous death, had employed the physical method of explosives. TTD following chemical injection varied from 5 mins to 49.7 h (median = 48 mins, mean = 4.7 h, SD = 13 h). Eight of the ten studies reported criteria used to confirm death or insensibility including ‘loss of palpebral, corneal and tongue reflexes', 'absence of respiration', 'absence of all vital signs', 'cessation of cardiac activity (movements and sound)', and 'relaxation of jaw muscles'.

Pinnipeds were the focus taxa of euthanasia literature that detailed methods (55.5%, n = 36 / 66), followed by delphinids (blackfish) (16.6%, n = 11) and mysticetes (16.6%, n = 11). In contrast, reporting of TTD primarily focused on mysticetes (60%, n = 6 / 10), delphinids (20%, n = 2 / 10) and other odontocetes (20%, n = 2 / 10).

7.3.2 IWC data

Of the 88 member nations, only two, UK and NZ, submitted individual stranded cetacean euthanasia data to the IWC as part of their National Progress reporting to the annual Scientific Commission meeting (Appendix 11 Tables A11.3, A11.4, A11.5). In addition, DOC in NZ also collected data on individual stranded cetacean euthanasia (1991–2006) prior to submission of the IWC reports (Table 7.1).

Table 7.1 Data collated from International Whaling Commission (IWC) reports and historical records of individual stranded cetacean euthanasia from the United Kingdom (UK) and New Zealand (NZ). NA = Not applicable.

		UK	**NZ**	**NZ (Historical records)**
	Years of data	2014–2018	2007–2020	1991–2006
	Total no. individuals euthanised	46	561	180
	No. species euthanised	10	19	13
	Method not reported	21.7% (n = 10)	0% (n = 0)	88% (n = 159)
Chemical methods	% of individuals chemical euthanasia	52.2% (n = 24)	NA	NA
	Chemical agent reported	100% (n = 24)	NA	NA
	Types of injection routes reported		NA	NA
	Intra-venous (IV)	75% (n = 18)		
	Intra-cardiac (IC)	8.3% (n = 2)		
	Intra-muscular (IM)			

	Intra-thoracic (IT)	4.2% (n = 1)		
	Intra-peritoneal (IP)	4.2% (n = 1)		
		4.2% (n = 1)		
Ballistics methods	% of individuals ballistics euthanasia	26.1% (n = 12)	100% (n = 561)	12% (n = 21)
	Firearm reported	42% (n = 5)	98% (n = 548)	43% (n = 9)
	No. firearm calibres	5	16	4
	No. projectiles reported	50% (n = 6); range: 1–3 (mean = 2, SD = 0.89)	68% (n = 379); range: 1–6 (mean = 1.3, SD = 0.7)	43% (n = 9); range: 1–11 (mean = 2.6, SD = 3.1)
	Projectile characteristics reported	16.7% (n = 2)	13% (n = 74)	0
	Orientation reported	n = 2: lateral	0	0
Assessment of death or insensibility	TTD reported	35% (n = 16)	98.4% (n = 552)	2% (n = 3)
	Presumed instantaneous death reported	17.4% (n = 8)	4% (n = 22)	1% (n = 2)

	Instantaneous death reported	0	84% (n = 472)	0
	TTD from all methods employed	range: 1–3 mins (mean = 2 mins, SD = 30 secs)	Range: 30 secs–12 h (mean = 55mins, SD = 191mins)	Range: 0–5 mins (mean = 5, SD = 0)
	Criteria to assess death or insensibility reported	2.2% (n = 1)	0.2% (n = 1)	0
Taxa	Mysticete	2.2% (n = 1)	1.6% (n = 9)	4% (n = 7)
	Ziphiid	2.2% (n = 1)	2.1% (n = 12)	4% (n = 7)
	Delphinid	57% (n = 26)	2.9% (n = 16)	8.3% (n = 15)
	Delphinid (blackfish)	19.5% (n = 9)	83% (n = 466)	64.4% (n = 116)
	Kogiid	N/A	10% (n = 58)	19.4% (n = 35)
	Phocoenid	20% (n = 9)	N/A	N/A

7.3.2.1 Methods within IWC data

Methods were not reported for 10 (21.7%) stranded cetaceans euthanised in the UK. Chemical methods to euthanise stranded cetaceans were most common in the UK (52.2%, n = 24 / 46). The chemical euthanasia agent was reported in all cases and was a barbiturate, with intravenous injection being the most common method (75%, n = 18 / 24). In NZ chemical euthanasia was not used.

Ballistics methods were used in 26.1% (n = 12 / 46) of cases in the UK. However, in only 42% (n = 5 / 12) of cases was the firearm calibre reported, with five different firearms being employed (.243, .308, .22, .270 and shotgun). Of these, four different firearms were used in the euthanasia of one delphinid (blackfish) species, the long-finned pilot whale (*Globicephala melas melas*), with .243 firearm being most common (Table 7.2). The number of projectiles used was reported in 50% (n = 6 / 12) of cases, with a range of 1–3 required (mean = 2, SD = 0.89). However, the projectile characteristics were reported in only 16.7% (n = 2 / 12) of cases, with soft-point projectiles reported for a single euthanised cetacean. The orientation for firearm discharge used (dorso-ventral or lateral) was recorded in only one case and described as lateral.

In NZ only ballistics methods were used between 2007–2020, with firearm type (n = 16) recorded in 98% of cases (n = 548 / 561). Of these, 10 different firearms were used to euthanise long finned pilot whales (*Globicephala melas edwardii)*, with a .30-06 firearm being most common (Table 7.2). However, the projectile characteristics were only recorded for 13% (n = 74 / 561) of individuals euthanised; all reported projectiles were soft-point with varying grain from 140–180gr. The number of projectiles required was reported in 68% (n = 379) / 561 of cases, ranging from 1–6 (mean = 1.3, SD = 0.7). The orientation used for firearm discharge was not reported for any individual. Similarly, between 1991 and 2006 ballistics was the only reported method used in NZ, though the method was recorded for only 12% of individual euthanised cetaceans (n = 21 / 180). Four different firearm calibres were reported, with no projectile characteristics, and number of projectiles used varied between 1–11 (mean = 2.6, SD = 3.1).

Table 7.2 Number of reported individual cetaceans euthanised using ballistics per taxon and per firearm type in United Kingdom (UK) and New Zealand (NZ) based on available International Whaling Commission (IWC) data between 2007–2020.

	NZ					**UK**					**Total individuals euthanised per firearm**
Firearm calibre	Mysticete	Ziphiid	Delphinid	Kogiid	Delphinid (blackfish)	Mysticete	Ziphiid	Delphinid	Delphinid (blackfish)	Phocoenid	
.22			2							1	3
.223			2								2
.243			2		1				2		5
.270	2			1	19				1		23
.300				1							1
.303	1	4	1	18	151						175
.308	2	3	3	11	58				1		78
.30-06	3	2	1	27	219						252
.357			1								1

.416	1										1
.44 magnum		2									2
Bolt-action rifle 7mm-08					1						1
Boltgun			1								1
Bushmaster semiauto 7.62x39SP					6						6
Rifle 6.5x55					7						7
Shotgun			2		1				1		4
Unknown		1	1		3	1	1	1	3		11
Total individuals euthanised per taxon	9	12	16	58	466	1	1	1	8	1	573

7.3.2.2 Time-to-death or insensibility (TTD) within IWC data

TTD was not recorded in the UK prior to 2014. In the reported data, 35% (n = 16 / 46) of individual euthanised cetaceans had TTD recorded, with 17.4% (n = 8 / 46) presumed instantaneous (Table 7.1). All cases reported as presumed instantaneous involved ballistics as the method. For those not presumed instantaneous, TTD ranged from 1–3 mins (mean = 2 mins, SD = 30 secs) and related to chemical methods.

In NZ between 2007 and 2020, 84% (n = 472 / 561) of animals were reported as instantly killed, with an additional 4% (n = 22 / 561) recorded as 'presumed instantaneous' (Table 7.1). Individual cetaceans that were not killed instantly had a reported TTD from 30 secs up to 12 h (mean = 55 mins, SD = 191 mins). TTD data were not recorded for nine individual animals (1.6%). Between 1991–2006, only three of 180 (2%) individual euthanised cetaceans had TTD recorded with two (1%) reported as presumed instantaneous.

In the UK, the reported criteria used to assess TTD included "no respiration, no apex beat detectable by palpation or auscultation and no corneal reflex", however the use of these criteria was only directly reported as used on one animal (2.2%). In NZ, the reports provided a summary of criteria used to assess TTD, including "no further breathing, complete dilation of the pupils; onset of unprovoked agonal convulsions (violent uncoordinated thrashing); absence of palpebral (closure of eyelid when corner of eyelid touched) and corneal (closure of eyelid if eye touched) reflexes and slack lower jaw". Details of these criteria being implemented following application of euthanasia method were only reported for 0.2% (n = 1) of animals.

7.3.2.3 Taxa and stranding type within IWC data

In the UK, a total of 46 cetaceans of 10 different species were euthanised between 2014 and 2018. Most (57%, n = 26 / 46) were classified as delphinids (Table 7.1). The stranding type (mass or single) was not provided, except in one case where multiple animals were reported as being euthanised. In NZ, a total of 561 stranded cetaceans of 19 different species were euthanised at stranding events between 2007 and 2020. Most (83%, n = 466 / 561) were classified as delphinid (blackfish) (Table 7.1). Delphinid (blackfish) were also found to dominate the historical DOC data (1991–2006) though a greater proportion of kogiids were reported as euthanised during this earlier period.

Overall, a total of 33 mass and 42 single stranding events were recorded in the NZ data, and a further 30 events were not identified by stranding type.

7.4 Discussion

This chapter revealed several notable gaps in the current reporting of cetacean euthanasia. What was reported suggested that two broad methods are commonly used, chemical and ballistics, but that the associated approaches and equipment vary. This highlights the need for standardised protocols for euthanasia of different taxa. Of particular concern was the lack of reporting on the criteria used to assess death or insensibility and the time from application of the method to confirmed death or insensibility (TTD), which limits our understanding of the duration of any welfare impacts associated with killing.

The low and poorly detailed reporting in much of the peer-reviewed literature regarding employing a particular method and the associated TTD likely thwarts any improvements to current practises. Additionally, this lack of data will likely impact implementation of euthanasia or may result in the practice being carried out inappropriately, resulting in welfare concerns. It is likely that further information exists which may only be discussed during workshops, meetings or in the grey literature (Marsh and Bramber 1999; Øen 2003). This may be further exacerbated in some cases by a reluctance to share events that went awry. However, such experiences and information are critical if improvements in euthanasia and related welfare outcomes are to be achieved.

In this chapter, peer-reviewed articles detailing marine mammals and euthanasia were only found post-1980, which may be due to the fact that the first Marine Mammal Protection Act (USA) was enacted in 1972, followed by New Zealand in 1978 and the Wildlife and Countryside Act 1981 in the UK, all of which include regulations around the treatment and disposal of sick or injured marine mammals. Following this, a number of workshops were held focussing on humane killing techniques for hunted whales (IWC 1981) and cetacean stranding events (Barzdo and Vodden 1983). These workshops may have highlighted research priorities around the killing methods for cetaceans, which then proliferated into published research.

Although reports from the IWC archives provide more data than the peer-reviewed literature, these are limited in the detailed information provided regarding the method and the welfare impact assessments (TTD) undertaken. Furthermore, the UK and NZ reports do not provide insights as to how techniques may be further developed to improve welfare outcomes, despite their submission to a subcommittee of the IWC that focuses on welfare implications.

Currently, the most comprehensive guidance for stranded cetacean euthanasia originate from non-peer-reviewed sources, where the extensive knowledge of experts in the field have been collated (Boren 2012; Barnett et al. 2013; Hampton et al. 2014a; Daoust and Ortenburger 2015; Barco et al. 2016). Further work should aim to build on this knowledge by improving data collection at euthanasia events. Additionally, where possible, robust scientific trials should be considered to assess methods that will help to strengthen current guidance and welfare outcomes.

7.4.1 Chemical method

In the UK chemical methods were the most commonly reported way to kill stranded cetaceans over the four-year reporting period. This is similar to what was found in the literature (91% of articles), where it was noted that chemical euthanasia is often considered as the most reliable and socially acceptable method, likely due to the similarities with companion animal euthanasia (Harms et al. 2014; Leary et al. 2020). This chapter also found that the most commonly reported route of administration for chemical euthanasia in the UK was intravenous injection. This was also the case in the data collected through the peer-reviewed literature, where 77% (n = 34) of chemical euthanasia cases involved intravenous injection, with 11 of these describing stranded cetacean euthanasia (e.g., Daoust and Ortenburger 2001; Dunn 2006). Use of the intra-venous route may be due to the fact that it is considered the most rapid and reliable way to humanely euthanise mammals (Leary et al. 2020) and so has become common practise for marine mammals. However, in moribund cetaceans the peripheral circulation will start to collapse and so the vasculature in the peduncle may be the most accessible site, but this poses danger to personnel working around the flukes during potential excitatory phases. Furthermore, due to the large size of cetaceans, relatively large doses are required which are expensive and the onset of action of the drug may take some time (Harms et al. 2018). However, TTD was reportedly fast (1–3 mins) following chemical euthanasia in the UK.

Although chemical methods may be more aesthetically pleasing, there are compelling welfare arguments for employing the method that will provide the shortest TTD over public sentiment (Dunn 2006; Coughran et al. 2012). In this chapter it was found that chemical euthanasia was never reported to cause instantaneous death, with TTD from the peer-reviewed literature varying between 5 mins and 49.7 h (mean = 4.7 h, SD = 13 h), and from the UK data ranging from 1–3 mins (mean = 2 mins, SD = 30 secs). The delayed TTD is due to the time that it takes to inject the chemical solution and for it to circulate to the heart and brain (Harms et al. 2018). Despite the longer TTD during chemical euthanasia, in some cases it will cause less suffering than if inappropriate physical methods were applied or employed incorrectly. Finally, possible eco-toxicological hazards may occur due to residues bioaccumulating in the environment and there is the possibility of secondary toxicosis (Greer and Rowles 2000; O'Rourke 2002; Bischoff et al. 2011; Harms et al. 2014), this is one of the primary reasons that such chemical methods are not employed in NZ stranding events (L. Boren DOC, *pers. comm.*). Though ballistics using lead bullets may also come with their own eco-toxicological risks (Hunt et al. 2006). Another reason for not employing chemical euthanasia likely relates to the lack of specialist veterinary personnel at stranding events to administer such drugs effectively and safely (Barco et al. 2016; Harms et al. 2018).

7.4.2 Ballistics method

NZ only employed ballistics across the 13-year period of reporting to the IWC, with no other methods reported by DOC in the data that were collected in the 16 years prior, indicating this is likely the only method employed, as observed in the NZ Standard Operating Procedure (SOP) (Boys et al. 2022c; Chapter 6). In the UK, ballistics were also employed on 26.1% of individual cetaceans. However, in the peer-reviewed literature this method was much less commonly reported with only 12% of articles describing its application. Physical methods, such as ballistics, are often preferred for the killing of medium-sized mammals as they can be instantaneous, do not require veterinary expertise and pose less contamination risk than chemical methods (Barco et al. 2016). Although ballistics have been demonstrated as effective on small cetaceans (<6 m; Blackmore et al. 1995b; Hampton et al. 2014b), the most effective orientation for firearm discharge (dorso-ventral or lateral) and studies of ballistics euthanasia for larger cetaceans (>6 m) are lacking. The type of firearm and projectiles used should differ depending on species anatomy and size, with larger animals requiring a higher muzzle energy (Hampton et al. 2014b; Leary et al. 2020) (i.e., high calibre firearms), and large projectiles (Øen and Knudsen 2007). Inappropriate discharge of a firearm on a cetacean can cause negative welfare impacts, yet few studies have examined the likelihood of ballistics causing instantaneous death by examining cranial pathology (Blackmore et al. 1995b; Øen and Knudsen 2007; Hampton et al. 2014b).

In NZ sixteen different firearm calibres were reported, including the most prevalent being .30 calibre (.30-06, .300, .303, .308) accounting for 89% (n = 504) of cases between 2007 and 2020. The firearms reported in the UK were similar to those reported in NZ and in the wider literature (Hampton et al. 2014b; Hunter et al. 2017). The wide range of firearms reported by NZ and the UK likely represent the variety that may be employed elsewhere (e.g., Boys et al. 2022b; Chapter 6). Such an array of firearm types, calibres and associated projectiles may mean that equipment inappropriate for the euthanasia of cetacean species is employed. This could cause animals to be severely injured but remain alive/conscious, significantly reducing their welfare (Øen and Knudsen 2007; Hampton et al. 2014b). This is supported by the data reported in NZ which was found to have wide ranging TTD from 30 secs to 12 h (mean = 55 mins, SD = 191 mins). Therefore, the wide range of firearm calibres reported suggests that field-testing of these to assess their suitability for different species and sizes of cetaceans would prove useful. This is particularly highlighted where smaller calibre firearms (e.g., .22, .243) have been employed, evidenced both in the UK and NZ data, and where they are currently part of guidance in SOPs (Boren 2012; Boys et al. 2022c; Chapter 6). In contrast, recommendations based on ballistics trials on cetacean cadavers have stated that only larger .30 calibre should be employed (Hampton et al. 2014b).

The projectile characteristics are as important as the firearm calibre employed for influencing terminal ballistics (Bradley-Siemens and Brower 2016). Yet the reported data from the UK and NZ shows that projectile characteristics were reported in only 16.7% and 13% of individual cetacean euthanasia cases, respectively. Those reported showed that soft-pointed profile (expanding) projectiles of varying grain were used. Such soft projectiles are also recommended in the NZ SOP (Boren 2012; Boys et al. 2022c; Chapter 6) for stranded cetacean euthanasia, though no detail on their required shape is provided. Another SOP (Hampton et al. 2014a) for Western Australia, which based its recommendations on ballistics testing (Hampton et al. 2014b), states that only solid projectiles should be used. Furthermore, a clinical report by NZ veterinarians also recommends the use of only “rifle of calibre 0.303 or greater and solid bullets” for all stranded cetaceans (Duignan and Anthony 2000). Such recommendations are due to the fact that soft-point bullets have proven unreliable due to lower penetration depth (Hampton et al. 2014a; Knox et al. 2018) and lack killing efficiency (IWC 2000; Øen and Knudsen 2007; Leary et al. 2020). This is due to the unique cranial anatomy of cetaceans, where the skin, thick blubber and muscle around the cetacean melon absorb kinetic energy. Furthermore, the anterior surface of the thick cranium is also concave with extensive sinuses which are likely to cause bullet deflection (Barzdo and Vodden 1983). This means that non-expanding projectiles (solid) should be used to ensure maximum penetration depth with minimum projectile deviation (Daoust and Ortenburger 2015; Leary et al. 2020). The reasons why NZ is using (e.g., Boys et al. In review; Chapter 5) and recommending (Boys et al. 2022c; Chapter 6) the use of soft-point projectiles is unknown, though it may simply be due to projectile availability.

To ensure euthanasia via ballistics is humane, the brain should be destroyed instantly (Longair et al. 1991). Typically, this is achieved by aiming for the occipital condyles or brainstem in order to cause instantaneous death (Blackmore et al. 1995b; Geraci and Lounsbury 2005). There are two main orientations for this target when discharging a firearm, dorso-ventral and lateral. These orientations were tested in a ballistics trial in NZ which found that dorso-ventral was most appropriate for smaller cetaceans and lateral for larger cetaceans (Blackmore et al. 1995b). Despite this study being well cited in other publications (Hampton et al. 2014b) and guidelines (Boren 2012; Hampton et al. 2014a), the orientation of firearm discharge employed for euthanasia was rarely reported. In this chapter only four peer-reviewed articles were found, all of which reported the use of dorso-ventral orientation and two additionally reported lateral orientation. Similarly, in the data reported to the IWC, only the UK provided the orientation of firearm discharge for the euthanasia of a single stranded cetacean. Orientation of firearm discharge will be affected by the positioning of the stranded cetacean and the species involved. It has previously been noted that the extensive muscle on the nuchal, parietal and occipital regions of the cetacean skull mean that occipital shooting will be ineffective (Barzdo and Vodden 1983). Furthermore, the unique cranial anatomy of cetaceans also varies between species. Therefore, it is important that orientation of discharge is appropriate as suggested in guidelines (Hampton et al. 2014a; Barco et al. 2016) and is also reported, as this will provide species-specific knowledge regarding the most appropriate orientation and external anatomical landmarks to ensure correct shot placement and instantaneous death (Hampton et al. 2014b; Barco et al. 2016; Boys et al. In review; Chapter 5).

7.4.3 Taxa euthanised

In the peer-reviewed literature that examined the euthanasia of wider marine mammal taxa, pinnipeds were most commonly reported on. However, when looking specifically at those articles that described euthanasia related to stranding events (n = 44), delphinids, including blackfish, and mysticetes were the subjects of most articles. Similarly, the euthanasia data reported to the IWC was delphinid focussed. In the UK, euthanasia of delphinids was most commonly reported, whilst in NZ the cetacean taxa most commonly reported as euthanised was delphinid (blackfish). The majority of these individuals were pilot whales, which primarily reflects their high stranding incidence (Betty et al. 2020; Boys et al. 2022a; Chapter 4). However, it may also relate to the fact that smaller cetaceans such as delphinids are considered to be simpler to humanely kill, in comparison to larger cetaceans such as mysticetes. This highlights the global need to increase ballistics studies and knowledge on how to humanely kill larger cetacean species. The data reported to the IWC also highlights the fact that there are a wide range of species (n = 23) reported as stranded and euthanised in NZ and the UK. This further supports the notion that additional work on euthanasia methods is required to ensure the most appropriate method and associated equipment are used for the species in question. In terms of ballistics, this should include ballistics trials on cadavers to ensure the most appropriate orientation for firearm discharge, firearm type/calibre and projectile are employed, particularly in relation to the varying skull morphology between species (Galatius et al. 2020). For chemical euthanasia this should include detailed documentation of the chemical agent and associated sedatives used, along with details of the needle gauge, dosages and any behavioural reaction that may occur (Barco et al. 2016).

Likely due to the layout of the IWC reporting forms, the type of stranding event (mass or single) was generally not recorded. However, euthanasia at mass stranding events is likely to be more complex to manage due to the number of animals and often the variety of stakeholder views which may make end-of-life decisions particularly contentious (Dubois 2003; Gales et al. 2008b; Boys et al. 2022c; Stockin et al. 2022; Chapter 6). It has also previously been suggested that exposure of animals to the noise and visual destruction of their conspecifics may increase their anxiety and fear (National Research Council 1992), suggesting a possible reduction in the welfare of conscious mass stranded cetaceans during the euthanasia of their moribund pod members. This highlights the need to euthanise multiple individuals rapidly, but this may also mean that carrying out individual assessments of TTD becomes logistically difficult, as was stated in one NZ report as the reason TTD data was not collected for each individual (IWC 2016c). This is despite the fact that such data is imperative to assess welfare impacts and ensure humane killing.

7.4.4 *Time-to-death or insensibility (TTD)*

TTD was rarely reported in the literature with only 10 (0.5%) articles reporting data. In the reports to the IWC, the UK provided TTD for 35% of individuals, but it was also noted on one of the reports that such data was only starting to be collected after 2014. NZ, on the other hand, reported TTD for almost all individuals (98%) between 2007 and 2020, a notable improvement in reporting when compared to the 1991 to 2006 data. However, several NZ cases were reported as "presumed instantaneous", highlighting uncertainty as to how and when death or insensibility was being confirmed (e.g., Boys et al. In review; Chapter 5). Unsurprisingly, this chapter found that reported instantaneous death only occurred when employing physical euthanasia methods, such as ballistics and explosives. This is due to the fact that chemical euthanasia takes time from the point of injection for the agent to circulate to the heart and brain (Harms et al. 2018). Even though death from chemical euthanasia was not instant, in the reported IWC data it was not vastly variable (1–3 mins). This suggests lower welfare impacts at the population level from chemical euthanasia reported in the IWC data compared with death by ballistics which varied widely from 30 secs to 12 h.

For most individuals in the UK and NZ, details on the criteria used to assess death or insensibility were not provided. The verification of death is imperative when the euthanasia of an animal is carried out (Greer et al. 2001). Due to the fact that assessment of death using 'gold standards' such as cessation of cardiac activity (Close et al. 1996) can be complex in cetaceans, the implementation of multiple criteria should be used to confirm death or at least insensibility (Butterworth et al. 2004b; Brakes et al. 2006). Although the NZ SOP requires verification of death or insensibility and provides details on the criteria used to assess death or insensibility (Boren 2012; Boys et al. 2022c; Chapter 6), one report (IWC 2016c) examined actually stated that "*TTDs were not* *recorded for individual whale at […] but were estimated to all be under 3 mins*". No details were provided as to why 3 mins was the estimation and a further nine animals had no TTD recorded. This reported lack of assessment of death or insensibility in these euthanised cetaceans and unverified assumption of death leaves significant uncertainty regarding the welfare impacts of the killing (Boys et al. In review; Chapter 5).

The difficulties in assessing, and lack of validation of, the criteria for death or insensibility in cetaceans also limits current understanding of the humaneness of methods. Although current guidelines recommended by the IWC are those suggested by Knudsen (2005), these differ from the criteria suggested as reliable for assessing insensibility and death collated through expert opinion (Butterworth et al. 2004b; Brakes et al. 2006). These criteria are more similar to those reported in the peer-reviewed literature, including cessation of cardiac movements and loss of palpebral and corneal reflexes. The current criteria recommended by the IWC were originally developed for use in the humane killing of cetaceans hunted at sea, however this has limited the assessment of their validity due to logistical complexities. The implementation of all recommended criteria (Brakes et al. 2006) and examination of other criteria not yet implemented at stranding events could greatly enhance our understanding of the humaneness of killing procedures. However, there is a need to assess the validity of all recommended criteria as has been done for domesticated animals (Verhoeven et al. 2015, 2016).

7.5 Conclusion

Historically, few peer-reviewed articles have focussed on the topic of marine mammal euthanasia, and those that have mentioned euthanasia have provided little detail on how killing was achieved and how long it took for an animal to die. Greater detail has been reported to the IWC for stranded cetacean euthanasia by the UK and NZ in recent years. The data available suggest that chemical and ballistics methods are most commonly employed, with some geographical differences, but that detailed reporting of equipment is lacking. They also highlight that most euthanasia events involve delphinids, which may be in part due to their high incidence of stranding but is also likely due to the increased complexities for euthanising larger and unusual species. The data from IWC also lacks some important information, such as detail on the projectile characteristics and orientation of firearm discharge used for ballistics. Notably, little information is reported on the criteria for death or insensibility that were assessed for each individual, reducing the ability to assess welfare impacts of killing. Furthermore, just two of the 88 member nations of the IWC have reported on stranded cetacean euthanasia, highlighting how a simple increase in the reporting rate could significantly improve our knowledge of methods and welfare impacts globally.

Not only is further work on methods of killing required to assess humaneness, but validation of criteria used for assessing death or insensibility is needed to enhance understanding of the welfare impacts of killing methods. The assessment and detailed reporting of the species, method, and TTD following euthanasia of an individual could improve our understanding of the welfare impacts from particular techniques and provide species-specific guidance. This improved knowledge would also allow managers to educate the wider community on the importance of euthanasia and appropriate methods as a viable welfare-oriented option for stranded cetaceans with low survival likelihood. Overall, such improvements would result in the best welfare outcomes for compromised stranded cetaceans.

Chapter 8 Conclusions

Stranded long-finned pilot whale (*Globicephala melas edwardii*) is prepared for re-floatation as part of mass strandings response.

Photo credit: Rebecca M. Boys.

This thesis aimed to develop a conceptual framework to enhance the practical ability of applying animal welfare science at cetacean strandings. Specifically, this thesis bridges critical voids of knowledge in the understanding of animal welfare science as applied to stranded cetaceans. The findings presented highlight how integrating welfare science alongside conservation biology could better achieve welfare and conservation goals in strandings management. I used five key research objectives to achieve this aim:

1) Characterise welfare and survival likelihood in terms of stranded cetaceans and highlight major knowledge gaps and key concerns likely to affect individual animals.
2) Identify and provide face validity to potential feasible welfare and survival relevant indicators for stranded cetaceans.
3) Ascertain the feasibility of potential welfare indicators, providing preliminary welfare assessments in stranding situations and highlighting welfare concerns.
4) Evaluate current management procedures for undertaking end-of-life decision-making and technically enacting euthanasia of stranded cetaceans.
5) Assess current euthanasia procedures and potential welfare outcomes to ensure the use of appropriate techniques and equipment for humane outcomes.

In this chapter, I outline the novel contributions that this doctoral thesis makes to scientific knowledge regarding cetacean strandings. Specifically, I synthesise the key results among the chapters more holistically and proceed to explain their wider management implications. Recommendations and future research priorities are also detailed.

8.1 Summary of research contributions

Despite aiming to optimise animal welfare, management at cetacean stranding events lacks evidence-based welfare science as part of the decision-making process for strandings response. Furthermore, along with the limited empirical evidence, the extensive media interest and varying values and ethics among strandings responders can lead to controversial decisions that may not be in the best interest of animal welfare (Dubois 2003; Moore et al. 2007; Gales et al. 2008b; Boys et al. 2022c; Stockin et al. 2022; Chapter 6). This thesis addressed this critical gap in knowledge by collecting and applying, for the first time, data on live stranded cetaceans from a welfare-centric perspective. This thesis provides a comprehensive investigation of how animal welfare science can and should be an integral part of cetacean stranding response.

Chapter 1 outlined contextual information relevant to this work and highlighted the need for animal welfare science to be integrated into cetacean strandings management. The conceptual framework developed (Figure 8.1) to achieve this incorporation was established in Chapters 2 and 3, with Chapter 4 providing robust scientific foundations for undertaking welfare assessments by evaluating indicator feasibility. Chapter 5 utilised this knowledge to undertake preliminary welfare assessments at a stranding of pygmy killer whales. The context of this stranding also provided the opportunity to explore potential relationships among indicators and histopathology. Additionally, Chapter 5 identified welfare implications related to ballistics euthanasia and highlighted the need for further research into end-of-life decisions. This was investigated in Chapters 6 and 7 by examining when and how to undertake end-of-life decisions, and by investigating current euthanasia methods and procedures used as part of strandings management. These results collectively provided key recommendations to ensure the best welfare outcomes associated with end-of-life procedures.

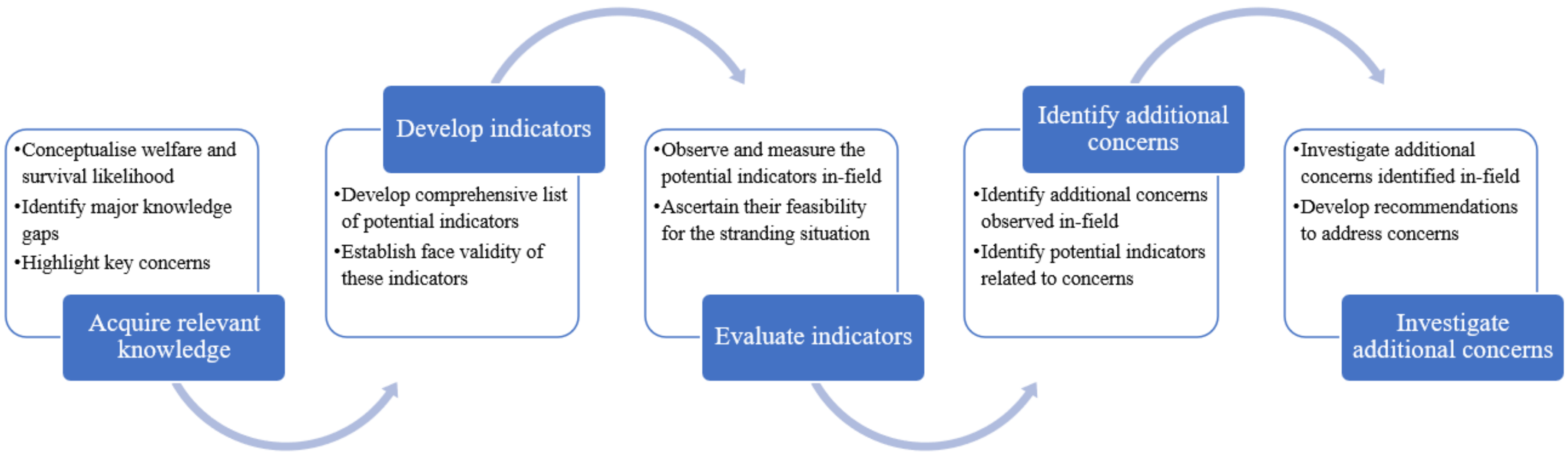

Figure 8.1 Steps achieved in this thesis towards the development of a framework to facilitate the application of welfare science at cetacean stranding events.

The first conceptualisation of stranded cetacean welfare and survival likelihood, and a comprehensive overview of relevant knowledge gaps and key concerns are presented in Chapter 2. These data are the vital foundation that are built on throughout the thesis. These data were generated by gathering the opinions of international and interdisciplinary experts via the Delphi method. The findings demonstrate inextricable links between animal welfare and survival likelihood, and similar understanding of stranded cetacean welfare across disciplines. Both concepts were multifaceted and included characterisation based on animal health, biological function, and behaviour. Welfare also incorporated animal mental state, and survival likelihood a minimum longevity of 6-months post-release. Therefore, this thesis considered stranded cetacean welfare from the contemporary welfare science approach, which encompasses the interrelated aspects of biological function, behaviour and animal mental state (Appleby 1999; Mellor 2016). Thus, the Five Domains Model for assessing animal welfare (Mellor et al. 2020) was utilised throughout this thesis to guide the conceptual development of a holistic framework to scientifically inform strandings management.

Major knowledge gaps for welfare related to diagnosing internal injuries, interpreting behavioural and physiological parameters, and euthanasia decision-making. For survival, a single major knowledge gap that was highlighted was post-release monitoring. Barriers to undertaking both welfare and survival likelihood assessments were similar, relating to the lack of empirical data and limited trained personnel to undertake assessments at strandings. Many key concerns were considered to negatively affect both welfare and survival likelihood, including difficulty breathing, organ compression, physical trauma, skin damage, separation from conspecifics and the "stress" and suffering caused by stranding and human intervention. Importantly, these concerns highlight that welfare compromise of even healthy animals, is likely at stranding events. However, further data collection at strandings is required to provide the empirical evidence necessary to inform decision-making. The findings of Chapter 2 provide the first guidance on facilitating more holistic evaluations of stranded cetaceans by addressing both welfare and survival concurrently.

In Chapter 3, opinions of the same experts (Chapter 2) were gathered to establish the first comprehensive list of potentially valuable and practical to observe/measure indicators of stranded cetacean welfare and survival likelihood. The complement of indicators generated (Chapter 3) highlight a holistic approach to assessing welfare and survival likelihood concurrently, with most indicators being the same for both concepts. Importantly, the indicators are representative of all three physical/functional domains and one situation-related domain in the Five Domains Model, emphasising its potential for developing an assessment framework for cetacean strandings. Notably, there are direct links between many of the concerns gathered in Chapter 2 and the indicators generated (Chapter 3), highlighting their applicability in an assessment to address relevant concerns. In this chapter, face validity of these indicators was inferred through the conceptualisation generated in Chapter 2. Chapter 3 provides direction for further data collection to be conducted at stranding events to evaluate the feasibility of the indicators (Chapters 4 and 5). Given the paucity of data and knowledge available to assess stranded cetacean welfare and survival likelihood, this chapter provides an important contribution to the development of a scientific, systematic assessment framework.

In Chapter 4, data were collected at live stranding events of long-finned pilot whales (*Globicephala melas edwardii*) to evaluate the feasibility of the potential welfare indicators (Chapter 3). This chapter identified, for the first time, observable and/or measurable animal-based indicators (physical, behavioural, and physiological) displayed by stranded cetaceans. Data collected enabled the construction of the first ethogram specific to stranded odontocetes using fine-scale behavioural data. It also contributes the first comprehensive overview of resource-/management-based indicators, including types of human intervention occurring with stranded cetaceans. Utilising the Five Domains Model for animal welfare assessment, the results provide the first systematic, structured welfare assessment of stranded cetaceans, and additionally contribute insights into key welfare concerns (Chapter 2). Furthermore, the chapter demonstrates that a complement of indicators can be measured non-invasively via video, highlighting the potential for remote experts to undertake assessments, a barrier that was emphasised in Chapters 2 and 3. Notably, although focused on welfare, the indicators found to be feasible in this chapter, were also considered valuable for assessing survival likelihood (Chapter 3), evidencing the possibility of holistically assessing stranded cetaceans. Further data collection should focus on assessing indicator validity and reliability. Overall, the findings of this chapter provide novel foundational data for developing a feasible welfare assessment framework (WAF) specific to stranded cetaceans that can inform decision-making.

Using the knowledge gained in Chapter 4, the feasible welfare indicators were applied to a stranding case study (Chapter 5) involving pygmy killer whales (*Feresa attenuata*). The results of Chapter 5 provided holistic welfare assessments of these animals and highlight the applicability of the ethogram developed in Chapter 4 for assessing wider odontocete species. Chapter 5 also contributes the first fine-scale data on euthanasia via ballistics for stranded cetaceans. These data provided the opportunity to describe potential welfare implications related to euthanasia at strandings; a key welfare concern that was highlighted in Chapter 2. The results demonstrated various animal behavioural responses may occur during and post application of ballistics. Notably, results evidenced that death or insensibility are not always verified following euthanasia, hindering robust welfare assessment. The death of these pygmy killer whales allowed for basic, opportunistic sampling and histopathological analysis. The results suggest that the animals were presumably enduring capture myopathy and muscular lysis as part of an extreme physiological stress response. As such, potential affective states experienced would have likely included breathlessness, pain, discomfort, and fatigue (Chapter 3) and furthermore, would have impacted upon survival likelihood (Chapter 2). The knowledge acquired in this chapter provides further evidence of the significance of integrating animal welfare science at stranding events to ensure scientifically-informed and humane decision-making.

The welfare concerns relating to euthanasia (Chapters 2 and 5) were investigated in Chapter 6 by reviewing the Standard Operating Procedures (SOPs) used to guide end-of-life decision-making within the region of Australasia. These SOPs were found to provide guidance on deciding upon an end-of-life decision and instruction on technically enacting euthanasia at stranding events. Various animal- and resource-based criteria were provided that would lead to recommendations for an end-of-life decision. However, the criteria used for decision-making and the amount of information provided on how to assess the criteria varied between SOPs. Importantly, the criteria were related to the concerns raised in Chapter 2 and the indicators generated for assessing welfare and survival likelihood (Chapter 3); furthermore, many were similar to those indicators assessed at live stranding events (Chapters 4 and 5). In terms of technically enacting euthanasia, chemical and physical methods were recommended in SOPs. However, the level of detail, and type of equipment and procedures for each method varied between SOPs. In some cases, the limited information would likely hinder appropriate euthanasia. Notably, welfare assessment outcomes, including verifying death or insensibility and recording time-to-death or insensibility (TTD) were lacking. Furthermore, the criteria recommended to verify death or insensibility also varied between SOPs. These findings provide further evidence of potential welfare concerns, such as those observed in Chapter 5.

To better understand the variable and limited guidance for end-of-life decisions (Chapter 6), in Chapter 7 the methods, procedures, and associated welfare implications for stranded cetacean euthanasia were examined globally. Exploring the peer-reviewed literature and an unpublished global database, three euthanasia methods were found. The findings highlighted that the level of detail provided on euthanasia methods is limited, and that procedures and equipment being implemented are highly variable. Furthermore, notable gaps in the reporting of welfare implications were evident; very limited information was reported on the criteria used to verify death or insensibility and TTD was rarely recorded for differing methods. Collectively, the findings of Chapters 6 and 7 emphasise key knowledge gaps and potential welfare concerns that must be addressed to ensure humane strandings management. Furthermore, these chapters emphasise the importance of increased data collection and reporting of end-of-life decisions at stranding events to ascertain welfare implications.

8.2 Implications of research findings

Humans have increasingly realised their detrimental effects on free-ranging wildlife and the need for animal welfare to be considered in conservation (Paquet and Darimon 2010; Butterworth 2017; Hampton and Hyndman 2019). This has led to the development of conservation welfare; an emerging discipline which aims to apply animal welfare science to conservation management of free-ranging wildlife (Beausoleil 2014; Beausoleil et al. 2018). While the importance of integrating welfare science into conservation has been acknowledged (Fraser 2010; Papastavrou et al. 2017; Hampton and Hyndman 2019), there has been limited research in this area for free-ranging cetaceans (Nicol et al. 2020; King et al. 2021). Live cetacean stranding events are a quintessential example of where this discipline can be integrated into management. While strandings response sits within a welfare ethic, it is typically undertaken by management agencies from a conservation perspective. Thus, until now, data and research at strandings have not explored the concepts of welfare and survival likelihood concurrently or from a welfare-centric approach.

Management of cetacean strandings aims to achieve conservation goals through improving survival of as many individuals as possible and providing supportive care to ensure animal welfare. It is, therefore, crucial that decision-making at stranding events is scientifically-informed by empirical evidence relevant to both the welfare state and likelihood of survival of individual cetaceans. However, the current lack of data means that intervention decisions are often uninformed.

This doctoral research fills several significant knowledge gaps by delineating evidence on how the concepts of animal welfare and survival likelihood can be assessed concurrently, and by identifying important features to include in animal evaluations for decision-making. It also serves as a base of fundamental data on animal and resource-/management-based indicators from which further work can be undertaken. Moreover, it has demonstrated irrefutable welfare concerns around end-of-life procedures and serves as a resource for the development of detailed protocols to improve humane endings for non-viable stranded cetaceans. Collectively, these data provide a novel contribution to the scientific discipline of conservation welfare, which is critical for effective, ethical management of live cetacean stranding events. Specifically, my thesis highlights that:

- Concepts of stranded cetacean welfare and survival are interrelated and understood in a similar way across disciplines, demonstrating their potential to be integrated in management.
- Assessments of animal welfare and survival likelihood can be undertaken concurrently from a holistic approach, by applying a complement of indicators.
- Various animal and resource-/management-based indicators can be non-invasively and remotely observed/measured at live stranding events, providing holistic welfare assessments, that also assist in identifying welfare concerns.
- Detailed protocols and guidance for end-of-life decision-making and technically enacting euthanasia are required to ensure humane welfare outcomes for non-viable cetaceans.

8.3 Future directions

The research in this thesis has provided an important novel contribution to the multidisciplinary scientific understanding of cetacean strandings. Although this thesis has bridged various significant knowledge gaps, it has also highlighted several remaining. Since cetacean strandings occur globally and are likely to increase in frequency due to climate change and anthropogenic impacts (Gulland and Hall 2007; Simeone et al. 2015; Alvarado-Rybak et al. 2020a), undertaking further data collection should be considered a priority. Such data collection should include assessments following re-floatation of stranded cetaceans to enable evaluation of the severity, intensity, and duration of welfare impacts. This is of particular importance since 60% of the cetaceans observed had re-stranded at least once (Chapter 4), suggesting that re-floated animals often do not remain at sea, despite re-floatation being considered a "successful" rescue. These data will improve our current ability to systematically and scientifically, apply the holistic framework developed in this thesis to inform decision-making.

8.3.1 Welfare concerns and indicators

Some welfare concerns and indicators currently recommended to inform decision-making have limited data available and/or are provided with minimal information, making their application challenging. For example, skin blistering suggested as a major welfare concern (Chapter 2) and considered valuable and feasible to assess (Chapters 3 and 4), is currently used to inform end-of-life decision-making for stranded cetaceans (Chapter 6). However, in SOPs guiding decision-making, its assessment is not quantified. Severe skin blistering will likely lead to dehydration due to fluid loss and may lead to hypovolemic shock (Gales et al. 2008b; Martinez-Levasseur et al. 2011; Groch et al. 2018). However, to the best of my knowledge, there have been no studies to examine the constituents of blister fluid in terms of electrolytes or the volume lost due to ruptures. Such research would provide significant data to validate the indicator as a potential measure of dehydration and to provide quantification that would ensure its objective assessment for decision-making at strandings.

Similarly, body condition was a major concern (Chapter 2) and was found to be a valuable and feasible indicator (Chapters 3–5). It is also included as a criterion to undertake end-of-life decisions (Chapter 6). Whilst there have been studies to externally measure body condition via visual assessment (Joblon et al. 2014; Clegg et al. 2015) as was applied in this thesis (Chapters 4 and 5), there have been no validation studies comparing the visual scores with measurements of blubber or muscle thickness. In other mammal species this has been carried out using ultrasound (Mellish et al. 2004; Morfeld et al. 2014) and has enabled robust evaluation of body condition as part of welfare assessments. Such research should be undertaken with stranded cetaceans and would likely be best initiated using cadavers at post-mortem before trialling the methods in the field with live animals.

Another concern highlighted in this study was hyperthermia (Chapter 2), related to this, the indicator of core body temperature was considered valuable but impractical to measure (Chapter 3) due to the need for specialised thermistor probes and trained personnel (Gulland et al. 2018). Previous research has found that cetacean core body temperature may be measurable through the blowhole (Melero et al. 2015) and others suggest it may be measurable through infrared thermography of the eyes (Brakes et al. 2006). Future research should investigate the feasibility of using infrared thermography cameras at strandings to non-invasively evaluate core body temperature of stranded cetaceans as part of welfare assessments.

In terms of technically enacting euthanasia, field-testing must be carried out on all methods to ensure standard guidance on equipment and procedures to be implemented and to identify species-specific considerations (Chapters 6 and 7). For example, as has been implemented in terrestrial mammals (Thomson et al. 2013; Lund et al. 2021), varying firearm and projectile combinations could be tested on cetacean cadavers, with radiological imaging and cranial dissection subsequently undertaken to evaluate efficacy of euthanasia methods and highlight potential welfare implications.

Death or insensibility should always be verified following application of euthanasia methods to evaluate humaneness or to inform when palliative care should end (Chapters 5 and 6). Limited understanding currently exists regarding the validity of criteria for assessing insensibility in cetaceans (Butterworth et al. 2004a; Brakes et al. 2006). Future research should undertake assessments of current criteria in combination with physiological, behavioural and electroencephalographic measures, as have been applied to terrestrial mammals (Verhoeven et al. 2015, 2016; Kells et al. 2018; Gibson et al. 2019). Accordingly, end-of-life decision-making can be better evaluated, and any welfare implications minimised to ensure the most humane methods are applied appropriately.

8.3.2 Scientific validation of indicators at stranding events

The findings of Chapter 2 evidenced that stranded cetacean welfare aligns with the understanding that physical and mental states are interlinked. Furthermore, this chapter provided data on potential welfare impacts that were representative of the domains in the Five Domains Model framework for animal welfare assessment. In Chapter 3, valuable indicators for assessing these welfare impacts and some suggestions of potential affective states that cetaceans may be experiencing, when these indicators are observed, were generated. This provided face validity to these welfare indicators (Chapter 3) which were subsequently shown to be feasible to assess at live stranding events (Chapters 4 and 5). Additionally, indicator reliability was tested to some extent based on the feasibility of assessing the same indicators across multiple individual cetaceans at different stranding events (Chapters 4 and 5). The final stage in the process of developing a WAF for cetacean strandings will be to scientifically validate these indicators and grade the level of welfare compromise caused by the associated concerns (Figure 8.2).

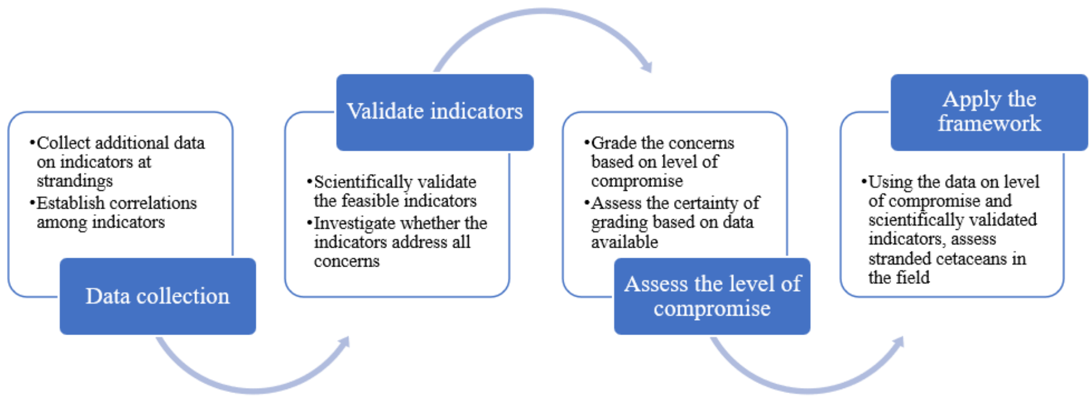

Figure 8.2 Next steps to finalise the development of an assessment framework for cetacean strandings.

In future studies it will be important to ensure that detailed information is collected regarding the stranding circumstances, including human intervention, as this will likely affect the indicators displayed. Data collection on the feasible indicators and other physiological measures (e.g., blow, faecal and blood samples), as well as pathological findings should be conducted to explore correlations (e.g., Chapter 5). This is particularly important for behaviour, since it is considered as a diagnostic tool for animal welfare, but requires validation using physiological indicators to ensure accurate assessments (Watters et al. 2021). Additionally, the temporal relationship of different indices with affective states should also be considered. For example, body condition provides an indication of long-term welfare (WelfareQuality 2009a), whereas behaviours provide current indications of welfare state based on the circumstance at the time of assessment (Yon et al. 2019).

Future research should build on this thesis by providing additional scientific evidence to robustly assess the reliability and repeatability of the indicators identified and evaluate links between these indicators and affective states. These data can then be used to develop a system for grading the intensity and duration of welfare impacts (Mellor, 2017). Validation of this grading scheme should be undertaken via workshops with similar expert groups as applied in Chapters 2 and 3. This assessment framework can then be applied at cetacean stranding events to unambiguously assess animal state and ensure measurable conservation objectives that incorporate animal welfare.

8.4 Concluding comments

This thesis makes a significant contribution to the scientific literature in the emerging field of conservation welfare. Specifically, my research offers breakthrough knowledge regarding the integration of animal welfare science and conservation biology at cetacean stranding events. The framework developed in this thesis lays the foundation for further research opportunities, which will enable improved assessment of the welfare and predicted survival likelihood of stranded cetaceans. Furthermore, the initiation of this research into the welfare of stranded cetaceans provides a benchmark against which future studies can be undertaken. The pivotal research presented provides crucial new insights into welfare science as an integral concept required for effective, ethical management at stranding events. As a consequence of this study, it is hoped that stranded cetacean welfare will become the subject of further research and be actively incorporated to inform management decisions.

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Appendices

Appendix 1 Information sheets provided to participants of the Delphi method employed: Chapters 2 and 3

Assessing welfare and survival in stranded cetaceans: Round 1

This study aims to gather expert opinion on the factors that are likely to affect the welfare and survival of stranded cetaceans, and to identify indicators that may be used to evaluate their welfare state and likelihood of survival. You have been identified as an expert in the field of cetacean biology, strandings and/or animal welfare. We would therefore like to invite you to participate.

Cetacean strandings are global phenomena that have been occurring for centuries. Research suggests that these events are occurring more frequently due to climate change and anthropogenic activities. Costly and logistically challenging attempts to 'rescue' live stranded cetaceans are often undertaken. Yet there is limited information regarding the success of such efforts, and the effects of stranding and human intervention on both the welfare and survival of individuals remain poorly understood.

To address this knowledge gap, this research project implements the Delphi technique, which uses iterative questionnaires to build consensus from expert opinion. In the first-round experts answer open unstructured questions, and these are then reviewed in the second round. The reviewing of answers is crucial to the success of a Delphi survey. Therefore, there will be at least two online questionnaires to complete. The first questionnaire asks you to identify key factors that may affect the welfare and survivorship of stranded cetaceans, as well as to suggest observable/measurable indicators that might be suitable to assess welfare state and likelihood of survival at cetacean strandings. The information gathered will be used to inform the design of the second questionnaire which will follow approximately 2 weeks later. Together, these data will provide the first stage in validating potential indicators of cetacean welfare and survival in the context of strandings.

This study is being undertaken as part of Rebecca Boys' PhD project and the findings will be used in a peer-reviewed publication as part of Rebecca's PhD thesis. A summary of the project findings will be made available to all participants.

No IP addresses or data identifying individual participants will be collected. Data collected about your region, area of expertise and current field of work will be used to examine trends in answers provided. The anonymised data will be stored in a password-protected computer for up to 5 years after the end of the study.

You are under no obligation to participate. Beginning the first questionnaire implies your consent to participate. You can choose not to answer some questions. There are 15 questions, and it should take approximately 20 minutes to complete. It must be completed by Friday 26th February 2021.

This project is being undertaken by Massey University PhD student Rebecca M Boys under the supervision of Prof. Karen A Stockin, Dr Emma L Betty, Dr Mat Pawley (School of Natural and Computational Sciences) and Assoc/Prof. Ngaio J Beausoleil (School of Veterinary Sciences). We thank you for your time in considering the invitation.

Please contact us if you have any questions about the project

Rebecca M Boys Tel: +64 272081137 Email: r.boys@massey.ac.nz

Prof. Karen Stockin Tel: +64 21423997 Email: k.a.stockin@massey.ac.nz

Assoc/Prof. Ngaio Beausoleil Tel: +64 69518174 Email: n.j.beausoleil@massey.ac.nz

This project has been evaluated by peer-review and judged to be low risk (Notification number: 4000023382). Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researchers named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Prof Craig Johnson, Director, Research Ethics, telephone (0064) 06 356 9099 x 85271, email humanethics@massey.ac.nz

Assessing welfare and survival in stranded cetaceans: Round 2

This study aims to gather expert opinion on the factors that are likely to affect the welfare and survival of stranded cetaceans, and to identify indicators that may be used to evaluate their welfare state and likelihood of survival. You have been identified as an expert in the field of cetacean biology, strandings and/or animal welfare. We would therefore like to invite you to participate.

Cetacean strandings are global phenomena that have been occurring for centuries. Research suggests that these events are occurring more frequently due to climate change and anthropogenic activities. Costly and logistically challenging attempts to 'rescue' live stranded cetaceans are often undertaken. Yet there is limited information regarding the success of such efforts, and the effects of stranding and human intervention on both the welfare and survival of individuals remain poorly understood.

To address this knowledge gap, this research project implements the Delphi technique, which uses iterative questionnaires to build consensus from expert opinion. In the first-round experts answer open unstructured questions, and these are then reviewed in the second round. The reviewing of answers is crucial to the success of a Delphi survey. The first questionnaire asked you to identify key factors that may affect the welfare and survivorship of stranded cetaceans, as well as to suggest observable/measurable indicators that might be suitable to assess welfare state and likelihood of survival at cetacean strandings. The information gathered was used to inform the design of this second questionnaire. Together, these data will provide the first stage in validating potential indicators of cetacean welfare and survival in the context of strandings.

This study is being undertaken as part of Rebecca Boys' PhD project and the findings will be used in a peer-reviewed publication as part of Rebecca's PhD thesis. A summary of the project findings will be made available to all participants.

No IP addresses or data identifying individual participants will be collected. Data collected about your region, area of expertise and current field of work will be used to examine trends in answers provided. The anonymised data will be stored in a password-protected computer for up to 5 years after the end of the study.

You are under no obligation to participate. Beginning the questionnaire implies your consent to participate. You can participate in the second questionnaire even if you did not complete the first questionnaire. You can choose not to answer some questions. There are 18 questions, and it should take approximately 30 minutes to complete. It must be completed by Friday 16th April 2021.

This project is being undertaken by Massey University PhD student Rebecca M Boys under the supervision of Prof. Karen A Stockin, Dr Emma L Betty, Dr Mat Pawley (School of Natural and Computational Sciences) and Assoc/Prof. Ngaio J Beausoleil (School of Veterinary Sciences). We thank you for your time in considering the invitation.

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Appendix 2 Questionnaire 1 of Delphi method: Chapters 2 and 3

Start of Block: Default Question Block

Assessing welfare and survival in stranded cetaceans- Round one

I would like to invite you to participate in this study. Before deciding whether to participate, please read the information sheet provided in the email fully to understand what is involved. If anything is not clear, please do not hesitate to contact the researcher (Rebecca M Boys r.boys@massey.ac.nz)

Project Description Cetacean strandings are global phenomena that have been occurring for centuries. Research suggests that these events are occurring more frequently due to climate change and anthropogenic activities. Strandings may involve one animal alone or many animals (mass stranding). Costly and logistically challenging attempts to 'rescue' live stranded cetaceans are often undertaken. Yet there is limited information regarding the success of such efforts, and the effects of stranding and human intervention on both the welfare and survival of individuals remains poorly understood. To address this knowledge gap, this research project implements the Delphi technique, which uses iterative questionnaires to build consensus from expert opinion. Therefore, there will be at least two online questionnaires to complete. This first questionnaire asks you to identify key factors that may affect the welfare and survivorship of stranded cetaceans, as well as to suggest observable/measurable indicators that might be suitable to assess welfare state and likelihood of survival at cetacean strandings. The information gathered will be used to inform the design of the second questionnaire. In this study a stranded cetacean is a wild whale, dolphin or porpoise that has "run aground" **alive**. A stranding event is considered as the time the animal first comes ashore until it either dies or is re-floated. Any events (e.g., natural or human) that occur whilst the animal is ashore should be considered as part of the stranding event. *This first round contains 15 questions and should take approximately 20 minutes to complete. It must be submitted by Friday 26th February 2021.* By clicking next you are indicating that you have read the information sheet and give your consent to take part.

Page Break

Please provide your details as a participant of this study

Region of work

- ○ Africa
- ○ Asia
- ○ Central America
- ○ Europe
- ○ North America
- ○ Oceania
- ○ South America

Please choose the field of **expertise** that most aligns with you:

- ○ Cetacean expert (including cetacean conservation and biology)
- ○ Animal welfare expert (including animal welfare science, welfare/animal ethics)
- ○ Cetacean expert with knowledge and/or focus on welfare
- ○ Animal welfare expert with knowledge and/or focus on cetaceans
- ○ Veterinarian
- ○ Other (please specify): ____

What is your **current** field of **work**?

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Welfare

The questions on this page relate to the welfare of stranded cetaceans.

Stranded cetacean: Whale, dolphin or porpoise that has 'run aground' alive
Stranding event: Time from when the animal comes ashore until it dies or is re-floated. The event includes both natural and human events.

While stranding events are likely to affect the welfare/well-being of stranded cetaceans, the ways in which welfare is affected remains largely unknown. To be able to assess welfare, we first need to understand what we mean by it.

In your own words, please explain what animal welfare/well-being means to you

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In your opinion what are the welfare issues at a cetacean stranding?

Please list all the issues that you think of

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What observable/measurable indicators do you think are most useful to assess welfare of stranded cetaceans?

These indicators can be both animal based (e.g. coat/fur condition) and non-animal based (resource/ environmental e.g. available habitat).

Where possible please be specific e.g. do not use broad terms such as "behaviour" without specifying particular behaviours that may be observed.

Please list all indicators that you think of

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Thinking about all the current information available regarding cetacean strandings, please score how useful the information is for you to be able to assess the welfare of a stranded cetacean

(0= Not useful at all/ no information, 10= Very useful/ all information needed is available)

If you feel that you are not familiar enough with cetacean literature please choose "Not Applicable"

	Not Applicable 0 1 2 3 4 5 6 7 8 9 10
1	

Please tell me about any discrepancies in the information currently available for assessing stranded cetacean welfare e.g. if you feel there is useful information for assessing welfare in relation to one specific area, whilst for another there is not any information at all

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In your opinion what is currently the most significant knowledge gap, which if addressed would improve the ability to assess the welfare of stranded cetaceans?

If you feel there are not any gaps in knowledge please put "N/A"

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Please provide additional comments on what welfare/well-being means to you when considering stranded cetaceans.

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Please provide all additional comments relating to welfare here

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Page Break

Survival

The questions on this page relate to the survival of stranded cetaceans.

Stranded cetacean: Whale, dolphin or porpoise that has 'run aground' alive. Stranding event: Time from when the animal comes ashore until it dies or is re-floated. The event includes both natural and human events.

Stranding events may affect the survival likelihood of a stranded cetacean, however the ways in which survival likelihood is affected will vary among strandings. To be able to assess survival likelihood, we must first understand what we mean by it.

In your own words, please explain what survival likelihood means to you

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In your opinion what factors have the potential to affect survival likelihood of stranded cetaceans?

Please list all factors that you think of

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What observable/measurable indicators do you suggest are most useful to assess the survival likelihood of stranded cetaceans?

These indicators can be both animal based (e.g. coat/fur condition) and non-animal based (resource/ environmental e.g. available habitat).

Where possible please be specific e.g. do not use broad terms such as "behaviour" without specifying particular behaviours that may be observed.

Please list all indicators that you think of

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Thinking about all the current information available regarding cetacean strandings, please score how useful the information is for you to be able to assess survival likelihood.

(0= Not useful at all/ no information, 10= Very useful/ all information needed is available)

If you feel that you are not familiar enough with cetacean literature please choose "Not Applicable"

	Not Applicable 0 1 2 3 4 5 6 7 8 9 10
1	

Please tell me about any discrepancies in the information currently available for assessing survival likelihood of stranded cetaceans e.g. if you feel there is useful information for assessing survival likelihood in relation to one specific area, whilst for another there is not any information at all

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In your opinion what is currently the most significant knowledge gap, which if addressed would improve the ability to assess survival likelihood of stranded cetaceans?

If you feel there are not any gaps in knowledge please put "N/A"

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Please provide additional comments on what survival likelihood means to you when considering stranded cetaceans.

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Please provide all additional comments relating to survival likelihood here

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End of Block: Default Question Block

Appendix 3 Questionnaire 2 of Delphi method: Chapters 2 and 3

Start of Block: Default Question Block

Assessing welfare and survival in stranded cetaceans- Round two
<u>Welcome back!</u>
Thank you very much for participating in this study. In this second round of the Delphi survey, I provide you with a summary of all answers provided in the first round, along with follow-up questions.
Project Description
Cetacean strandings are global phenomena that have been occurring for centuries. Research suggests that these events are occurring more frequently due to climate change and anthropogenic activities. Strandings may involve one animal alone or many animals (mass stranding).
Costly and logistically challenging attempts to 'rescue' live stranded cetaceans are often undertaken. Yet there is limited information regarding the success of such efforts, and the effects of stranding and human intervention on both the welfare and survival of individuals remains poorly understood.
To address this knowledge gap, this research project implements the Delphi technique. The Delphi method is an iterative surveying technique which relies on a panel of experts. In the first round experts answer open unstructured questions, and these are then reviewed in the second round. The reviewing of answers is crucial to the success of a Delphi survey. Therefore, **you can still participate in this second round even if you did not complete round one.**
In the first questionnaire key factors that may affect the welfare and survivorship of stranded cetaceans, and potential observable/measurable indicators to assess welfare state and likelihood of survival at cetacean strandings were suggested. This information has been used to inform the design of this second questionnaire.
In this study a stranded cetacean is a wild whale, dolphin or porpoise that has "run aground" <u>alive</u>. A stranding event is considered as the time the animal first comes ashore until it either dies or is re-floated. Any events (e.g. natural or human) that occur whilst the animal is ashore should be considered as part of the stranding event.

This second round contains 18 questions and should take approximately 30 minutes to complete. It must be submitted by Friday 16th April 2021.
I am looking forward to receiving your responses and would like to thank you for your valuable input and time. If you have any questions, please do not hesitate to contact Rebecca M Boys r.boys@massey.ac.nz
By clicking next you are indicating that you have read the information sheet and give your consent to take part.

Region of work

○ Africa

○ Asia

○ Central America

○ Europe

○ North America

○ Oceania

○ South America

Please choose the field of **expertise** that most aligns with you:

○ Cetacean expert (including cetacean conservation and biology)

○ Animal welfare expert (including animal welfare science, welfare/animal ethics)

○ Cetacean expert with knowledge and/or focus on welfare

○ Animal welfare expert with knowledge and/or focus on cetaceans

○ Veterinarian

○ Other (please specify): ____

What is your **current** field of **work**?

____

Welfare

The questions on this page relate to the welfare of stranded cetaceans.

Stranded cetacean: Whale, dolphin or porpoise that has 'run aground' alive
Stranding event: Time from when the animal comes ashore until it dies or is re-floated. The event includes any natural and human based events that occur during a stranding.

In the previous survey I asked you to tell me what animal welfare means to you and additionally what it means when considering stranded cetaceans.

Some suggestions were provided and your responses have been collated into themes. Below are some of the most common themes.
Please indicate for each of the themes the **level of importance** you think the feature has in **assessing** the **welfare/well-being** of stranded cetaceans.

You can give the same level of importance to multiple themes.

0= **No importance** for assessing welfare
5= **Some importance** for assessing welfare
10= **Great importance** for assessing welfare

	0 1 2 3 4 5 6 7 8 9 10
Physical state and wellbeing, health, injury and disease status	
Animal’s experience/perception of situation, mental or psychological state or well-being, affective states or feelings	
Pain and suffering, distress, stress or fear	
Ability to live in normal/natural social and environmental conditions or habitat	
Appropriate decision-making about re-floating or euthanasia, and targeted rescue/re-floatation efforts to prioritize animal welfare	
Normal, natural or wild behaviour	
Treatment and care by humans, including during stranding response	
Sufficient food and water	
Physical comfort/discomfort	
Normal physiology and homeostasis	
Overall wellbeing or Quality of life	
Human activities in environment	

In the previous survey I asked what knowledge gaps could be addressed that would improve the ability to assess the welfare of stranded cetaceans. Your responses have been collated into themes. The most commonly mentioned knowledge gaps are presented here.

Please score your agreement on whether increased knowledge of each theme would improve our ability to assess the welfare of stranded cetaceans.

0= Filling this gap **would not improve** our ability to assess stranded cetacean welfare
10= Filling this gap **would greatly improve** our ability to assess stranded cetacean welfare.
If you feel that you do not have the knowledge to score a particular gap please tick "Don't know"

	Don't know 0 1 2 3 4 5 6 7 8 9 10
Post release monitoring to understand survival, outcomes or success of re-floatation	
Collection and documentation of empirical data to assist triage/ decision-making	
How to make decisions about when and how to euthanise stranded cetaceans	
Lack of information, education and awareness for potential responders about if, when and how to respond	
Effects of species, animal size and features of the stranding (geographical location and duration) on welfare	
Ability to diagnose internal injuries ante-mortem, including capture myopathy	
Ability to assess physiological indicators and recognise deviations from normal/baseline	
Ability to assess what animals feel or their mental state	
Understanding the health and disease status of the animal	
Lack of specialist/ expert advice and consultation from those with field experience and veterinarians	
Assessment and interpretation of indicators of neurological state and responsiveness/sensibility	
Ability to assess body condition	
Causes of stranding and how to prevent stranding	
Ability to interpret stranded cetacean behaviour in terms of welfare state	
Understanding social support and communication among animals	

In the previous survey I asked what the welfare issues are at cetacean stranding events. Your responses have been collated into themes. The most commonly mentioned issues are presented below.

Please score each of the following issues based on **how badly it might affect welfare** of stranded cetaceans

0= This will **not** affect welfare
5= This will have a **bad** affect on welfare
10= This will have a **severely bad** affect on welfare

If you feel that you do not have the knowledge to score a particular issue please tick "Don't know"

	Don't know
	0 1 2 3 4 5 6 7 8 9 10
Inappropriate human intervention, poor handling, responder training and experience, and public pressure influencing decisions	
Pain and suffering due to physical injury or trauma caused by stranding, particularly substrate	
Stress, fear, distress or pain caused by human presence, interactions, noise	
Effects of gravity, body weight, pressure on animal's organ function and physiology and causing internal injuries and pain as a result of not being supported by water	
Fear, stress, distress or helplessness at being unable to move or help themselves	
Fear and stress at being in a strange, novel environment	
Separation from conspecifics/social group, including mother-calf separation	
Suffering, stress and anxiety associated with stranding	

Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun	
Feasibility of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety	
Physical damage, stress, pain and thermal discomfort due to overheating, hyperthermia, heat stroke and hypothermia	
Fear and pain from predation	
Delays to deciding on euthanasia to relieve suffering	
Weather and environmental conditions	
Nutritional stress, poor body condition	
Animals suffering from illness, disease and underlying health conditions	
Difficulty breathing, inhalation of water	
Effect of species biology, resilience and stranding type on welfare outcomes	
Pain and its management	

Regarding the same potential welfare issues, please tell me **how much knowledge** you feel is available to **assess** how the **issue may affect** stranded cetacean **welfare**.

0=Knowledge is **insufficient**
5=**Some** knowledge is **present**
10=Knowledge is **complete**

If you feel that you do not have the knowledge to score a particular issue please tick "Don't know"

	Don't know										
	0	1	2	3	4	5	6	7	8	9	10
Inappropriate human intervention, poor handling, responder training and experience, and public pressure influencing decisions											
Pain and suffering due to physical injury or trauma caused by stranding, particularly substrate											
Stress, fear, distress or pain caused by human presence, interactions, noise											
Effects of gravity, body weight, pressure on animal’s organ function and physiology and causing internal injuries and pain as a result of not being supported by water											
Fear, stress, distress or helplessness at being unable to move or help themselves											
Fear and stress at being in a strange, novel environment											
Separation from conspecifics/social group, including mother-calf separation											
Suffering, stress and anxiety associated with stranding											
Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun											
Feasibility of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety											
Physical damage, stress, pain and thermal discomfort due to overheating, hyperthermia, heat stroke and hypothermia											
Fear and pain from predation											
Delays to deciding on euthanasia to relieve suffering											
Weather and environmental conditions											
Nutritional stress, poor body condition											
Animals suffering from illness, disease and underlying health conditions											

Difficulty breathing, inhalation of water	
Effect of species biology, resilience and stranding type on welfare outcomes	
Pain and its management	

Please tell me about any barriers to assessing how these issues effect welfare.

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Page Break

In the previous survey I asked you to suggest observable/measurable indicators to assess the welfare of stranded cetaceans. Your responses have been collated into themes. The most commonly mentioned indicator themes are presented here.
Please indicate the **value** that you think **each indicator has for assessing welfare state** of stranded cetaceans.

Please ensure that you are scoring how good an indication of welfare state each indicator is, not how practical these are to measure. A question on ease/practicality of measurement for the indicators comes next.

0= **Little**/no value
5= **Some** value
10= **Great** value

If you feel that you do not have the knowledge to score a particular indicator please tick "Don't know"

	Don't know										
	0	1	2	3	4	5	6	7	8	9	10
Abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering											
Respiration rate and character/effort											
Signs of physical trauma, injuries and wounds											
Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness											
Animals skin condition such as sunburn, peeling, cracking or blistering											
Body condition or nutritional status											
Weather, ambient temperature, sea and tidal conditions											
Animal age based on length/weight, and reproductive status											
Vocalisation rate and type											

Swimming ability and orientation when returned to water	
Core/internal body temperature	
Length of time stranded and number of re-strandings	
Heart rate and rhythm	
Presence and behaviour of pod members	
Measurement of blood parameters and serum/plasma chemistry	
Availability of resources including equipment	
Bleeding/fluids/mucus from orifices	
Signs of illness and disease	
Amount of human interaction and knowledge of responders	
Distance to animal’s natural habitat type	

Regarding the same proposed indicators, please indicate **how easy/practical each indicator is to measure** during a stranding event.

0= **Difficult** to measure
5= **May be measurable** depending on skills/equipment available
10= **Easy** to measure

If you feel that you do not have the knowledge to score a particular indicator please tick "Don't know"

	Don't know										
	0	1	2	3	4	5	6	7	8	9	10

Abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering	
Respiration rate and character/effort	
Signs of physical trauma, injuries and wounds	
Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness	
Animals skin condition such as sunburn, peeling, cracking or blistering	
Body condition or nutritional status	
Weather, ambient temperature, sea and tidal conditions	
Animal age based on length/weight, and reproductive status	
Vocalisation rate and type	
Swimming ability and orientation when returned to water	
Core/internal body temperature	
Length of time stranded and number of re-strandings	
Heart rate and rhythm	
Presence and behaviour of pod members	
Measurement of blood parameters and serum/plasma chemistry	
Availability of resources including equipment	
Bleeding/fluids/mucus from orifices	
Signs of illness and disease	
Amount of human interaction and knowledge of responders	
Distance to animal's natural habitat type	

Please tell me about any barriers to measuring these indicators of welfare.

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For the proposed indicators below, please use your judgement to suggest the mental (affective) **experience/feelings** that may be inferred from observing the indicator.

For example, food-seeking behaviour could be used to infer the negative experience of hunger. Likewise, spending time near a preferred conspecific may be used to infer feelings of safety.

You can provide multiple suggestions for each indicator and you can suggest the same feeling/state for multiple indicators.

- Elevated respiration rate ____
- Reduced respiration rate ____
- Abnormal respiratory character ____
- Agitated movements ____
- Arching ____
- Thrashing ____
- Fluke slapping ____
- Tensing/straining ____
- Abnormal body posture ____
- Fin movement ____
- Head swinging ____

○ Tremors/shivering ____

○ Injury/Trauma/Wounds ____

○ Reduced stimuli/reflexes ____

○ Poor skin condition ____

○ Poor body condition ____

○ Abnormal swimming movements
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○ Elevated stress hormones ____

○ Abnormal blood chemistry ____

○ Abnormal haematology ____

○ Vocalisation: rate, character
____

○ Elevated body temperature ____

○ Bleeding/fluids/mucus from orifices
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○ Elevated heart rate ____

○ Abnormal heart rhythm ____

○ Presence of disease or illness
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Please provide any additional comments about welfare here

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Survival

The questions on this page relate to the survival of stranded cetaceans.

Stranded cetacean: Whale, dolphin or porpoise that has 'run aground' alive. Stranding event: Time from when the animal comes ashore until it dies or is re-floated. The event includes any natural and human based events that occur during the stranding.

In the previous survey I asked you to tell me what survival likelihood means to you and additionally what it means when considering stranded cetaceans.

Some suggestions were provided and your responses have been collated into themes. Below are the most commonly suggested themes.

Please indicate for each of the themes the **level of importance** you think the feature has in **assessing** the **survival likelihood** of stranded cetaceans.

You can give the same level of importance to multiple themes.

0= No importance for assessing survival likelihood
5= Some importance for assessing survival likelihood
10= Great importance for assessing survival likelihood

	0	1	2	3	4	5	6	7	8	9	10
Animal returns to normal life and full functioning in its natural environment											
The chance that the animal survives after stranding											
Animal does not die of stranding related injuries or damage											
Animals health condition, disease and illness status											
Animal returns and socially re-integrate with its conspecific group/pod											

Animal is able to respond and cope with natural conditions to ensure its survival	
Animal survives after refloating	
Animal returns to pre-stranding life and health status	
Survival is affected by species and size	
Animal alive 1 month after stranding	
Animal alive 1 year after stranding	
Animal does not restrand within days of refloat	
Animal alive 6 months after stranding	
Animal’s body condition	
The number of re-stranded animals	
Response of animal when refloated	
Avoids suffering	
Cause of stranding still present	

In the previous survey I asked what knowledge gaps could be addressed that would improve the ability to assess survival likelihood of stranded cetaceans. Your responses have been collated into themes. The most commonly mentioned knowledge gaps are presented here.

Please score your agreement on whether increased knowledge of each theme would improve our ability to assess the survival likelihood of stranded cetaceans.

0= Filling this gap would not improve our ability to assess stranded cetacean survival likelihood
10= Filling this gap would greatly improve our ability to assess stranded cetacean survival likelihood.

If you feel that you do not have the knowledge to score a particular gap please tick "Don't know"

	Don't know
	0 1 2 3 4 5 6 7 8 9 10
Lack of post release monitoring to measure survival outcomes	
Lack of normal/baseline blood parameters and profiles	
Lack of data for species-specific survival	
Lack of knowledge on the links between survival and welfare	
Ability to determine presence of myopathy	
Ability to diagnose diseases and infections on the beach	
Lack of knowledge about causes and prevention of strandings and effects of local ecosystem changes	
Lack of trained and skilled responders	
Ability to assess body condition and blubber thickness	
Lack of data on species distribution	
Lack of data on the effects of conspecifics presence on survival	
How to make decisions about when and how to euthanise stranded cetaceans	
Ability to triage current state/condition	
Ability to assess internal body temperature	
Lack of knowledge about hearing impairments	
Lack of standardised protocols to follow	
Lack of knowledge of treatments and their effectiveness	
Lack of knowledge on the links between external assessments and pathology	

In the previous survey I asked what factors have the potential to affect stranded cetacean survival likelihood. Your responses have been collated into themes. The most commonly mentioned factors are presented below.

Please score each of the following factors based on how badly it might affect survival likelihood of stranded cetaceans

0= This will not affect survival likelihood
5= This will have a bad affect on survival likelihood
10= This will have a severely bad affect on survival likelihood

If you feel that you do not have the knowledge to score a particular factor please tick "Don't know"

	Don't know
	0 1 2 3 4 5 6 7 8 9 10
Feasibility and speed of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety	
Length of time stranded and number of re-strandings	
Weather and environmental conditions, including tides	
Physical injury or trauma caused by stranding	
Animal suffering from illness, disease and underlying health conditions	
Separation from conspecifics/social group	
Animal age based on length/weight and reproductive status	
Effects of gravity, body weight, pressure on animal's organ function and physiology and causing internal injuries and pain as a result of not being supported by water	
Body condition and nutritional status	

Availability of appropriate and timely human intervention and handling, responder training and experience	
Geographical location of stranding and being out of habitat or range	
Effect of species biology on survivorship	
Cause of stranding still present	
Stress, anxiety and associated conditions caused by stranding	
Presence of predators and scavengers	
Difficulty breathing, inhalation of water	
Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun	
Substrate/terrain at the stranding location	
Abnormal movements and reduced limb function	
Animal awareness and neurological status	

Regarding the same factors that have the potential to affect stranded cetacean survival likelihood, please tell me how much knowledge you feel is present to assess how the factor may affect the survival likelihood of stranded cetaceans.

0=Knowledge is **insufficient**
5=**Some** knowledge is **present**
10=Knowledge is **complete**
If you feel that you do not have the knowledge to score a particular factor please tick "Don't know"

	Don't know
	0 1 2 3 4 5 6 7 8 9 10
Feasibility and speed of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety	
Length of time stranded and number of re-strandings	
Weather and environmental conditions, including tides	
Physical injury or trauma caused by stranding	
Animal suffering from illness, disease and underlying health conditions	
Separation from conspecifics/social group	
Animal age based on length/weight and reproductive status	
Effects of gravity, body weight, pressure on animal's organ function and physiology and causing internal injuries and pain as a result of not being supported by water	
Body condition and nutritional status	
Availability of appropriate and timely human intervention and handling, responder training and experience	
Geographical location of stranding and being out of habitat or range	
Effect of species biology on survivorship	
Cause of stranding still present	
Stress, anxiety and associated conditions caused by stranding	
Presence of predators and scavengers	
Difficulty breathing, inhalation of water	
Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun	

Substrate/terrain at the stranding location	
Abnormal movements and reduced limb function	
Animal awareness and neurological status	

Please tell me about any barriers to assessing how these factors affect survival likelihood.

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In the previous survey I asked you to suggest observable/measurable indicators to assess the survival likelihood of stranded cetaceans. Your responses have been collated into themes. The most commonly mentioned indicators are presented here.

Please indicate the **value** you think each **indicator** has for **assessing** stranded cetacean **survival likelihood**.

Please ensure that you are scoring how good an indication of survival likelihood each indicator is, not how practical these are to measure. A question on ease of measurement for the indicators comes next.

0= **Little**/no value
5= **Some** value
10= **Great** value
If you feel that you do not have the knowledge to score a particular indicator please tick "Don't know"

	Don't know										
	0	1	2	3	4	5	6	7	8	9	10
Signs of physical trauma, injuries and wounds											
Body condition and nutritional status											
Respiration rate and character/effort											
Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness											
Animal age based on length/weight and reproductive status											
Measurement of blood parameters and serum/plasma chemistry											
Presence of pod members and social re-integration											
Animal's skin condition such as sunburn, blistering/integrity or desiccation											
Swimming ability and orientation when returned to water											

Length of time stranded and number of re-strandings	
Abnormal movements and behaviours including arching, thrashing, shivering, movements of pectoral and caudal fins	
Signs of illness and disease	
Weather, ambient temperature, sea and tidal conditions	
Availability of resources including equipment	
Number and experience/knowledge of responders	
Distance to animal’s natural habitat type	
Core/internal body temperature	
Bleeding/fluids/mucus from orifices	
Species biology and response to stress	
Heart rate and function	

Regarding the same proposed indicators please indicate how easy/practical each indicator is to measure during a stranding event.

0= **Difficult** to measure
5= **May be measurable** depending on skills/equipment available
10= **Easy** to measure

If you feel that you do not have the knowledge to score a particular indicator please tick "Don't know"

	Don't know										
	0	1	2	3	4	5	6	7	8	9	10

Signs of physical trauma, injuries and wounds	
Body condition and nutritional status	
Respiration rate and character/effort	
Animal’s level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness	
Animal age based on length/weight and reproductive status	
Measurement of blood parameters and serum/plasma chemistry	
Presence of pod members and social re-integration	
Animal’s skin condition such as sunburn, blistering/integrity or desiccation	
Swimming ability and orientation when returned to water	
Length of time stranded and number of re-strandings	
Abnormal movements and behaviours including arching, thrashing, shivering, movements of pectoral and caudal fins	
Signs of illness and disease	
Weather, ambient temperature, sea and tidal conditions	
Availability of resources including equipment	
Number and experience/knowledge of responders	
Distance to animal’s natural habitat type	
Core/internal body temperature	
Bleeding/fluids/mucus from orifices	
Species biology and response to stress	
Heart rate and function	

Please tell me about any barriers to measuring these indicators of survival likelihood.

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Please provide any additional comments about survival likelihood here

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End of Block: Default Question Block

Appendix 4 Categories of concepts, knowledge gaps and concerns for welfare and survival likelihood: Chapter 2

Table A4.1. Themes of welfare characterisation based on reflexive thematic analysis of expert opinion from questionnaire 1, transcribed as intelligent verbatim

Final theme	**Original terms**
Physical comfort/discomfort	It means the animal is overall comfortable; Freedom from discomfort; Physical comfort and health; Minimal or absence of discomfort; Animal well-being is the status of discomfort in an animal's perception; Comfortable as possible; Physical problems (thermal and physical discomfort); Widespread negative welfare impacts in all domains when a cetacean is stranded
Physical state and wellbeing, health, injury and disease status	The summary state of an animals physical well-being; Animal welfare is the sum effect of an animal's experiences on its physical well-being; It means the animal is overall healthy; The prevention of harm, the need to be protected from injury and disease; Animal need to be in health; Not subjecting an animal to physical harm, and to eliminating or minimising such harm if it has occurred naturally; Freedom from injury and disease; A good/healthy physical state of an individual; Without injury ; An animals welfare encompasses its physical well-being; These terms refer to the physical health of the animal; Well-being refers to physical state of the animal; Whether the individual is sick or injured; The identifying of an animals normal, healthy state; The physical health and welfare of an animal; An animals welfare refers to its well-being, health and condition physically; It refers to the health of animal (physical); The ability of an animal to meet its physical needs; Physical point of view; Putting the animals' health as a priority; Health status; The welfare of an animal relates to its physical health; Health and natural functions of the animal; Health; Animal welfare is concerned with the physical health of an animal; The state of the animal, based on its health but also physical state, reflected by its overall quality of life; Welfare includes physical wellbeing; Positive welfare is a state of physical wellbeing i.e. The absence of injury; Physical state; Wild animal biology and health; A condition of perfect body; Minimise any further injury or deterioration in condition; The state of being (physical) of an individual or group/population of animals as it relates to quality of life; Physical elements for cetaceans; Proxy measures of health; Some level of compromised health; Chronic and

	debilitating diseases; Should consider their physical status; Physical state health problems e.g. Low oxygen; The state of the animal, physically; Widespread negative welfare impacts in all domains when a cetacean is stranded
Animal’s experience/perception of situation, mental or psychological state or well-being, affective states or feelings	Status of discomfort in an animal's perception; Sum effect of an animal's experiences of its physical well-being; Animal welfare is the sum effect of an animal's experiences on its mental well-being; Animal's perception of the world and self; Not subjecting an animal to psychological harm, and to eliminating or minimising such harm if it has occurred naturally; No perceive route of escape or release; A good/healthy mental state of an individual; Safety (no fear/distress); Animal welfare is the experience an animal has of its own life; Ensuring that animals do not suffer; An animals welfare encompasses its mental/psychological well-being; These terms refer to the mental health of the animal; Well-being refers to the mental state; What he/she is experiencing psychologically/emotionally; The mental health and welfare of an animal; An animals welfare refers to its well-being mentally; It refers to the health of animal (mental); The ability of an animal to meet its mental needs; Animal welfare means how an animal feels including its mental state regarding its situation; Well-being - the status, when no health related aspects or impacts from past experiences pose stress on an animal; The welfare of an animal relates to its mental well-being; Assessing the affective aspects; Animal welfare is the quality of an animal's subjective experience which include a balance of pleasant and unpleasant mental states; Animal welfare is about the feelings an animal experiences; Animal welfare is concerned with the mental feelings of an animal; Welfare includes mental wellbeing; Mental state; A condition of perfect mind, psychological health; Ability of an individual animal to feel suffering or distress; Psychological elements for cetaceans; Animal experiences positively or negatively valenced states and emotions; The balance of positive and negative affective states experienced by an animal; The experience an animal has of its own life; Psychological status; Mental state; Welfare state of any stranded cetacean can be considered as compromised since they are experiencing a life-threatening situation; Difficult to understand or know when an animal is in pain or how much, effects of drugs on cetaceans are limited, on the dangers, and how useful they are; It is difficult to determine if they are stressed or in pain, or aware, unless there are obvious signs, but I suspect that there are not always obvious signs; Minimise stress; The state of the animal mentally; The state of animal according to the animal; The animals mental experiences (i.e. How they are 'feeling', which may be positive or negative); Mental impacts of conspecifics and impacts on conspecifics - i.e. For social species,

	this is a significant impact to consider, for solo animals the presence of humans might have more of an impact for example; Widespread negative welfare impacts in all domains when a cetacean is stranded
Normal, natural or wild behaviour	The summary state of an animals behavioural well-being; Behaviours; Express natural behaviour; Normal behaviour patterns; Ability to express natural behaviours; Normal behaviour; Proxy measures of behaviour, often directly measure valence (aversion or attraction to events or stimuli); Able to live according to the needs of your species; Ability of an animal to successfully breed; Ability to carry out its "normal" repertoire of behaviours; Ability to behave naturally; Widespread negative welfare impacts in all domains when a cetacean is stranded; Able to live the life that they are most adapted to; The right to live their life according to nature´s rules, conditions and challenges; Ability to carry out typical species specific or species appropriate functions
Overall wellbeing or Quality of life	Overall quality of life; State of being (physical) of an individual or group/population of animals as it relates to quality of life; Summary state of an animal’s physical well-being; Sum effect of an animal's experiences on its physical well-being; The state of being (emotional) of an individual or group/population of animals as it relates to quality of life; Quality of life and mechanism of death are often overlooked
Normal physiology and homeostasis	The summary state of an animals physiological well-being; Normal biological and physiological processes; Animal welfare/well-being refers to the capacity of an animal to maintain their homeostasis; High breathing rate means the animal is stressed; Proxy measures of physiology; Welfare in ecology needs to be context dependent, and although stranded cetaceans might have poor welfare, how do non-stranded cetaceans die and how does that compare to strandings; Prevent drying damaging skin, eyes, overheating, dehydration; Special physiology designed to cope with life in various parts of the sea; Widespread negative welfare impacts in all domains when a cetacean is stranded
Pain and suffering, distress, stress or fear	Not in any form of distress; The need to be protected from pain, suffering; The terms deal with pain and suffering that an animal may perceive; Pain, suffering; Free from pain or intense stress; Freedom from fear and distress; Minimal or absence of pain, anxiety and stress; Ensuring that animals do not suffer; Animal well-being is the status of fear, distress, pain, in an animal's perception; Condition that reflects the animals degree of pain and suffering; Without pain, or suffering including stress; Animal welfare is mostly a state of no suffering and minimum stress from psychological point of view; Additional or unusual suffering;

	Minimising or avoiding pain and mental stress; Freedom from undue pain; Stress levels; Being able to live without pain, fear, having a positive state of mind; Free from pain, fear and distress; Minimize pain and suffering; Animal living with no pain, no stress; Relates to if the animal is suffering; Relieve stress pain or inflect stress pain; Reducing/eliminating undue stress (physical/environmental) on animals; Positive welfare is a state of psychological wellbeing i.e. The absence of unnecessary suffering, pain; Ability of an individual animal to feel suffering or distress; Minimise suffering and stress; Low stress condition; The state of being (emotional) of an individual or group/population of animals as it relates to quality of life, pain and suffering; Ensuring that an animal is not distressed or otherwise suffering; As with all species, the important thing is to reduce suffering as much as possible; It mainly means to do what we can to not cause or prolong suffering in an animal; Minimize suffering; High welfare is often described in terms of constraints the animal has to be free from, re the various domains models; Brief experiences of fear or pain may not affect welfare overall - these states have survival value; Assistance must be provided to alleviate their suffering, to prevent and care for sun burns, to avoid stress due to the presence of large numbers of people, to avoid thoughtless actions and avoid unnecessary suffering
Ability to live in normal/natural social and environmental conditions or habitat	Able to get back in the water; Out of habitat, unfamiliarity with the environment; Separation of calf from dam; Able to live the life that they are most adapted to; Animals welfare encompasses its social well-being; Environmental conditions (shelter, feed, etc;); The right to live their life according to nature´s rules, conditions and challenges; Ensuring key 'needs' are provided (environment, appropriate social contact etc); Ability to carry out typical species specific or species appropriate functions, or ability to return to that state if temporarily compromised; Being able to live without shelter; Natural habitat; A condition of perfect social health; Freedom of living in their habitat free of boat disturbance and fishing net, quiet and safe environment, etc; "stress free" life with environmental enrichment; "out of habitat"; Achieve the most natural and comfortable situation for the animal to approximate conditions; Returning to the free-ranging social group; Lack of ability to move back into its normal environment; That means to me that a stranded animal is alive; Basically animal welfare means ensuring an animal has all its needs met to survive; Critical for the individual's prospects for rehabilitation and return to the ocean; Ability to make adaptations when these are compromised; Survival rate; The animal is in such a condition that it is able to be saved; In respect of cetaceans, this is how long has it been stranded, how long since salvage began, condition of animal etc;; The ability of an animal to cope with its environment; Welfare - positive expectation on the future well-being of an animal; Ability to cope with the environment in which it which it finds itself;

	How it lives and dies; Assessed with respect to their prognosis for post-rescue survival; Considering the long term state of the animal; The time it strands to the end of its life (whether it is refloated and goes back to live its life in the wild or if it is rehabilitated); Either it is returned to the sea with a reasonable chance of survival or that the animal is euthanized in a way that causes it minimal distress; In locations where rehabilitation facilities exist, it should be clear that an animal taken to such a place will be returned to the sea or euthanized; Swift return to the water and release with the minimum intervention, for suitable candidates; Stranding of large cetaceans is unfortunately mostly killing for the animal; It also depends on the species; But in general I think for smaller cetacean the more aspects of well-being are relevant; Tolerance of different species is critical here - in terms of ability to survive stranding and have positive outcomes; Determining whether returning the animal to it natural habitat can/should be attempted
Sufficient food and water	Freedom from hunger and thirst; Good nutrition; Ability of an animal to successfully forage; Sufficient food and water supply; Ensuring key 'needs' are provided (food, water); Being able to live without lack of food, water; Freedom of living with plenty of food
Appropriate decision-making about re-floating or euthanasia, and targeted rescue/re-floatation efforts to prioritize animal welfare	Determining whether returning the animal to it natural habitat can/should be attempted; Extends, where necessary, to euthanasia; The desire to help often exceeds the ability to do so appropriately, leading to wrong welfare decisions being made; The correct decision-making process whether to try and refloat or to euthanize; I do wonder if sometimes we are doing more harm than good by activating such intense rescue efforts for live strandings; Refloating animals who strand again and again until they die, for example, seems unnecessarily cruel; I realize SOME cetaceans will be rescued successfully, but perhaps more effort should be made to determine when, where, and under what circumstances success is more likely and only respond to THOSE strandings with an intensive rescue effort; Other strandings, where the cetacean(s) is/are likely to die should perhaps be left alone; Ensuring that welfare/well-being of the animal is clinically put first, above personal feelings and motives, to make sure the right thing is done for that animal whether it is refloated or euthanised; While I am convinced that humans can help animals in stressful situations, this needs to be targeted, it must be seen with extreme caution for the future of the population due to genetic deterioration and possible long-term effects; Respect the animal's decision to run aground, Returning it to the sea many times goes against animal welfare; Doing what is right for the animal and not buckling under pressure to "just do something urgently"; Make sure what we are doing

	is in the best interest of animal welfare and not for the sake appeasing the public or stakeholders; It means using the evaluation parameters we have at our disposal to make good judgement calls about the suffering of an animal and the likelihood that refloating will be associated with a good welfare outcome; This depends not only on the immediate welfare of the animal but also on the circumstances of the stranding, such as environmental conditions, resourcing, location of stranding and species involved; The welfare of the animal should be objectively assessed; Many NGO's or personalities who claim to be experts on marine mammal strandings give advice to first responders, not on objective information or with the welfare of the animal in mind but based on animal rights belief; Consideration of the well-being of the individual above all else and making decisions about release or euthanasia with this in mind; Lack of medical and management knowledge in many areas; Professional attention with medical and biological decisions; Sometimes release an animal is not the better way of attention; Especially with large whales, euthanasia is a difficult task, however especially important due to the often-hopeless situation; Hence, more research and developments should focus on humane euthanasia options for different (large) whale species in different situations; Every individual should not have to endure unnecessary suffering and that euthanasia is chosen over refloating where the individual's viability is deemed low; Euthanasia needs to be in consideration for every situation; Emphasis is put on the physical and some individuals are euthanised as it is deemed 'better' for them when in truth a decision has been taken without all the facts ; I hate that some people feel that euthanasia is not an action that take's an animal's welfare into account; In my opinion, a stranded animal is best served and most humanely treated when it is euthanized; If appropriate and possible euthanasia to minimise suffering; Intensive management that these animals can get when stranded and what a significant stressor that is, on top of the stress of the stranding itself; If and how they can be mitigated to enable a successful refloatation and release -at what point are there perhaps impacts that can't be easily corrected meaning that the cetacean will continue to experience negative impacts following refloatation and release
Human activities in environment	Good welfare involves cetaceans being able to live without human impacts; Human activities; Investigate the relationship that human activities have on the health of different species and their ecosystems
Treatment and care by humans, including	The way in which the animal is dealt with by people trying to help it (whether they are trained rescuers or not) can positively or negatively affect the animal depending on what is being done; How they are treated/cared for; To assist the animal; How we as humans should act towards animals and how we take care of them so that their quality of life is not compromised, or if

during stranding response	compromised, is mitigated appropriately; Best possible care and holding of an animal; If there is human intervention, some appreciable change in the behaviour or demeanour of the animal, reduced levels of stress, calmness, change in respiratory rates; Assistance must be provided to alleviate their suffering, to prevent and care for sun burns, to avoid stress due to the presence of large numbers of people, to avoid thoughtless actions and avoid unnecessary suffering; I think that the amount of time the animal(s) is/are stranded is extremely important when assessing welfare impacts and how quickly they can be helped by humans; To protect from environmental conditions, sun, wind, animals; Sufficient and necessary care for the stranded animal; Consideration for how we as humans treat animals should be included when considering animal welfare/well-being; I.e., they should be treated with respect, responsibly and humanely and to also uphold their dignity; Deal accordingly to ethic needs in wildlife; Impacts of conspecifics and impacts on conspecifics - i.e. For social species, this is a significant impact to consider, for solo animals the presence of humans might have more of an impact for example; Intensive management that these animals can get when stranded and what a significant stressor that is, on top of the stress of the stranding itself; If and how they can be mitigated to enable a successful refloatation and release -at what point are there perhaps impacts that can't be easily corrected meaning that the cetacean will continue to experience negative impacts following refloatation and release

Table A4.2. Themes of welfare knowledge gaps based on reflexive thematic analysis of expert opinion from questionnaire 1, transcribed as intelligent verbatim

Final theme	**Original terms**
Ability to assess what animals feel or their mental state	What they are thinking when high and dry on the beach; The ability to measure the degree to which a cetacean feels fear or distress when attended by a group of humans during a stranding; Little is considered from a mental state; Assess the animals stress and reduce this; Our aim is to keep the stress levels to a minimum during a rescue and always keep this in mind when deciding the next step; No easy mechanism to quantify the welfare impact of external environmental stressors on the stranded animal- to enable, for example those strategies which are most likely to calm, or exacerbate, stress in a stranded animal; There is much more information available on assessing their physical condition than their mental condition, and the impact of the stranding on the animal psychologically; Stress levels & exhaustion; Regarding mental wellbeing: Since we cannot discern a “normal” stressor response from actual distress in most animals, it is difficult to discern “healthy/natural” stress from distress by just endocrinologic measurements; Hence, improving this branch of research, though quite difficult, appears quite important to me; I believe having a degree of empathy for these animals is extremely important, to try and understand what they are going through, and use that to drive a compassionate response which takes the animals physical AND mental/social needs into consideration; Gap in knowledge of how impacts in the different physical domains manifest themselves in cetaceans
Post release monitoring to understand survival, outcomes or success of re-floatation	A comprehensive examination of post-stranding release success by species; More knowledge of the survivability of animals re floated would be useful; More extensive use of satellite tags would help; Fate of refloated and released animals; Survival post release; Post release survival; Better understanding of the outcomes for animals that are refloated and released and the circumstances that lead to the best long-term outcomes; Lack of knowledge of survival rates and thorough assessments of operational responses that can influence the outcomes; Post-rescue survival; Tagging; Post-release monitoring; As with most wildlife rescue projects, post-release monitoring is a significant knowledge gap; Survival rate post live stranding and release; Techniques and post release monitoring for large whales; Success of animals that have been "refloated"; Better understanding of the outcome for refloated individuals under a range of scenarios; Satellite tagging and post-release monitoring to gauge success of refloated and/or rehabilitated cetaceans; There is a loud contingent of the public and the professional world that believes refloating stranded cetaceans without

	post-release monitoring constitutes a successful rescue; Without context (species, stranding time, condition, etc;), this is an inappropriate assumption; Survival post refloating of individuals in a mass stranding event; Satellite telemetry to monitor success of refloatation or return to the sea is limited; More survival post stranding studies (using satellite tracking etc) are required; Data on survival following re-floating; Some welfare compromise is acceptable if measures taken result in welfare improvement and post-rescue survival, but there is very little information available on whether rescued animals stay rescued, or if they simply disappear, and ground-truthing assessments made while they are stranded; I also cringe at 'successful' rescue being declared when no post-release monitoring has been conducted; It may be a successful re-floating, but it does not mean an animal survived nor is necessarily the most humane action to take; Availability of accounts of successful rescues; Survival rate post release; Post-release monitoring is also limited;; Assessing if a stranded animal survives after release; We have now purchased 8 tags to tag stranded cetaceans so we have the ability to track them after release; Physiologic consequences of stress and potential short and long implications on whale health and survivability, post release sequelae impact on welfare of the animal (locomotion, secondary consequences to release, malignant hyperthermia, myoglobinuria, metabolic acidosis); Stress during the handling, success of release and sustained success of the individual released to the wild; Chance of survival for given species/distances from suitable habitat/ body conditions; Documentation at stranding and follow up data would help
Lack of information, education and awareness for potential responders about if, when and how to respond	A lot of people do not know how to properly respond to marine mammal strandings; Techniques for moving large whales without causing damage and with minimal suffering; Not a lack of potential methods - more a lack of capacity and opportunity (when animal is so obviously compromised) to apply them, and sometimes observant public resistance to 'interference' - the public just usually want a positive outcome through 'rescue'; Training on animal health assessment undertaken without emotion; How far is it reasonable to transport a stranded animal either for refloat or to a facility for further assessment/treatment?; The information is quite unorganised and often deteriorated towards being "animal friendly" i.e. Biased towards that making the animal survive in whatever condition is superior to either a natural death, or euthanasia; "Help" in general needs to be defined in terms of animal welfare and especially "animal-welfare" organizations are quite bad about that; Info available directs responders to immediately refloat if environmental conditions are right or refloat to another site; The assessment of welfare must be done in an objective approach taking all ethical aspects into consideration; Because cetaceans are large mammals and often get a lot of public exposure there is a desire for us to 'interfere' with a natural process; Should we do this?; We know that some animals do not survive or have been left by pods to die -

	this needs to be highlighted - e.g. Old males, any male not in a mass stranding, subadult Sperm Whale males; We should be able to necropsy any whale dead at a stranding to continue the learning; There are limited resources, especially given that many of the species that strand are not considered to be endangered or threatened; Much education and awareness work is needed
Lack of specialist/ expert advice and consultation from those with field experience and veterinarians	There is not much-specialized staff working on this in my country; Ability of assessing the welfare of a stranded cetacean is depending on the expertise of the veterinarians and biologists involved; The quality of knowledge is crucial for the level of understanding on welfare; Better consultation with species-specific experts and those who have field experience would also help; Lack of specialists in veterinary medicine; Having access to it and working in an environment that allows for relevant information to be used in decision making; Better consultation with species-specific experts and those who have field experience; Stranding response profession has been diluted by organizations most interested in welfare, and least interested in conservation; This results in an individual animal focus rather than a population focus, dilutes available resources, and confuses public messaging regarding conservation vs welfare; Limited facilities and expertise
Ability to assess physiological indicators and recognise deviations from normal/baseline	Better harmonisation and publication of basic measurable physiological indicators, e.g., baseline heartrate, breathing; Know the normal haematological and serum biochemical parameters for most species; Physiological responses; Blood profiles; Access to quick haematology and biochemistry results to inform on welfare is often missing; Suitable thermistor probes are often not available; Breathing rates it can be difficult to access 'normal' breathing rates for different species; Taking body temperature; There is a lot of info on clinical diagnostics that may need to be taken by a vet but not more general indicators that could be used by a lay person or biologist for example; Available blood parameters is limited; Blood and stress parameters; Physiologic consequences of stress and potential short and long implications on whale health and survivability, post release sequelae impact on welfare of the animal (locomotion, secondary consequences to release, malignant hyperthermia, myoglobinuria, metabolic acidosis); Lack of baseline data for a number of species; Internationally-supported published range of parameters measurable on the shore which indicate the condition of the stranded animal

Ability to assess body condition	Assessing true body condition in a live stranded animal beyond profile shape - i.e.: measuring blubber thickness, accurate weight vs body length and girth; Knowledge gap for deep-diving species (beaked whale mainly), which tend to live strand often (at least in EU) but difficulties in the assessment of things like their nutritional status; Body condition
Ability to diagnose internal injuries ante-mortem, including capture myopathy	Assessment of the extent of muscle damage due to grounding is also not easy to assess, clear and measurable indicators would be a decision aid in such difficult situations; A global gold standard protocol for assessment with clear diagnostics particularly no way to diagnose barotrauma or depth related injuries in deep diving species such as beaked whales in situ during stranding (not retrospectively through necropsy and analysis); Hearing loss; Not visible injures but special diagnostic techniques on the beach can help to know if euthanasia can be performed quicker or rehabilitation can be performed; Indicators of internal injury; Captive studies useful for indicators of pain, wound/disease relative to affective state; Health check on every whale before release and a significant % had hearing loss; Almost all of these whales restrand so they now euthanise all these with a massive reduction of restrands; Data on capture myopathy is limited; Clinical and pathological lesions in live stranded cetaceans; Timely detection of capture myopathy
Understanding the health and disease status of the animal	Fast and reliable, if possible non-invasive, monitoring methods of the actual underlying physical health; Observations from visual inspections can be misleading and might not align with the animal's internal condition, hence a terminally ill individual might be refloated due to no obvious deterioration in body condition and/or external injuries; Understanding the health of the individual; Lack of baseline data for a number of species, provided you are dealing with stranded cetaceans, which - by definition - are not healthy; Internationally-supported published range of parameters measurable on the shore which indicate the condition of the stranded animal and whether a refloat is likely to be successful and perhaps extended to consideration or rehabilitation (where this is possible); Indicators of disease or infestation; Captive studies useful for indicators of pain, wound/disease relative to affective state; Ability to diagnose common findings such as diseases like morbilli, brucella and capture myopathy, and understanding at what point an animal with the above may not be able to survive; Welfare of the rest of the pod or population of the animal or species, especially in the case of releasing an animal that is possibly sick (potentially carrying a disease that can infect others)
Ability to interpret stranded cetacean	Better harmonisation and publication of basic measurable movement; More information on assessing the animal's behaviour; Current information on assessing stranded (and for that matter, any) cetacean welfare, it seems to me, relies overmuch on indicators PEOPLE can identify and identify WITH; As long as a cetacean is not cringing, whining, tucking in its tail, flattening its ears, shivering,

behaviour in terms of welfare state	looking mangy, matted, or emaciated and so on, a person will tend to consider the animal "okay;" Cetaceans obviously don't exhibit any of these poor welfare signs; It's hard even to tell that a cetacean is in pain when it has an obvious injury - its demeanour is often stoic even when it must be in significant pain; In general, I think the field suffers from a lack of "translation" - the ability to translate what cetaceans are "feeling" into indicators that humans can easily recognize (e.g., can easily identify in terrestrial mammals); General interpretation of behaviour reflecting stress or poor physical condition; The link between observed indicators/behaviours and welfare outcomes
Assessment and interpretation of indicators of neurological state and responsiveness/sensibility	Better harmonisation and publication of basic measurable pupillary responses; Apart from the difficulties with physical assessments, the mental state cannot be assessed at all; Some clinical diagnostics are difficult to access when the stranded cetacean is submerged e.g. Eye responses to blinking and pupil; Indicators of sensibility; Neurologic assessment seems to be questionable at times, with some misinformation and/or diverging opinions about what qualifies as an obtunded animal; Neurological diseases and approach even medical and biological
Understanding social support and communication among animals	Cetacean communication is currently not well understood - sometimes cetaceans that are live stranded can be very vocal and at some point in the future when we know more perhaps there may be a way to understand whether the vocalisations they are producing are positive or negative in nature, or even more specific than that; Vocalisation rate and stress; Role of social support; Role of social support from other animals on the beach and post-release
Collection and documentation of empirical data to assist triage/ decision-making	Triage of a cetacean's current state; General standardised categorization of welfare status, based on empirical evidence to help those attending strandings to triage with more confidence; No measurable way to assess what to do with a live animal, especially if deciding on whether to refloat or rehabilitate; Such as a flowchart one can follow; Lack of baseline data for a number of species, provided you are dealing with stranded cetaceans, which - by definition - are not healthy; Internationally-supported published range of parameters measurable on the shore which indicate the condition of the stranded animal and whether a refloat is likely to be successful and perhaps extended to consideration or rehabilitation (where this is possible); Not visible injures but special diagnostic techniques on the beach can help to know if euthanasia can be performed quicker or rehabilitation can be performed; Cetaceans don't

	give you much to go on and it is often difficult to communicate to the uninitiated the significance of signs which in other species would be less critical to welfare; Especially for large cetaceans the clinical examination of the animal is difficult to be performed; Increases the challenge of assessing the degree of suffering of a stranded animal; Not enough information on how to assess whether an individual has the capacity to be rehabbed and returned to the wild; Treatment options and effectiveness of treatments; Comprehensive documentation of stranding events and responses are required to better assess efficacy and outcomes; There are differences between US and European efforts which may benefit from working to make them more universal and compatible; Very poor documentation at stranding and follow up data; The process of death is poorly understood in cetaceans and a better understanding of indicators for progression towards death could be very useful for triage on the beach; Welfare of the rest of the pod or population of the animal or species, especially in the case of releasing an animal that is possibly sick (potentially carrying a disease that can infect others); Gap in knowledge of how impacts in the different physical domains manifest themselves in cetaceans
How to make decisions about when and how to euthanise stranded cetaceans	Efficacy of euthanasia methods and when to implement them; The right time for euthanasia (attempts) is often difficult to determine and the reasoning might not be understood/accepted by the public, which can be difficult for the team on the ground; Dosages for euthanasia of large whales? Proper/standardized needles for euthanasia injection in different species; More information about euthanasia and perhaps some international standards would be helpful; Euthanasia can be an appropriate welfare outcome; Any agency considering training in marine mammal rescue needs to remove emotion and add euthanasia to the mix; Euthanasia is not a welfare issue and should be considered as an action that should be taken to relieve any suffering caused by stranding - especially when attempts to refloat the cetacean are or are likely to be ineffective and/or would involve very welfare impactful activities/actions; Organisations that use euthanasia should have clear decision-making policies and not make snap decisions, especially for large whales (given that euthanasia is more challenging due to uncertainties regarding dosage/delivery); Better understanding of indicators of death and progress towards death; The process of death is poorly understood in cetaceans and a better understanding of indicators for progression towards death could be very useful for triage on the beach; What are appropriate humane indicators to use to determine when euthanasia should be used

Causes of stranding and how to prevent stranding	Causes of strandings (recognising that there are likely to be many); Better knowledge of human-related environmental conditions specific to a region (e.g., seismic exploration, shipping traffic, intensity of commercial fishing) would help to determine their potential contribution to stranding events and thus suggest means of decreasing the occurrence of these events; Better understanding of why they strand - particularly for mass strandings - might help to either prevent or mitigate strandings; Lack of understanding on reasons for stranding in the first place; Lack information about the trends in strandings in many areas
Effects of species, animal size and features of the stranding (geographical location and duration) on welfare	Species and individual animal differences; It is difficult to establish standards to evaluate the welfare for all species of stranded cetaceans due to the biological variety of different animals; Understanding the behavioural needs in rehabilitation of larger or deep diving animals; Many have the rehab of small cetaceans, dolphins and porpoises down but there is a need to understand how best to provide care for larger species at a stranding location and for rehabilitation; The particular species involved, and within each species its size/age/gender are all likely to be important variables; Also, duration of stranding and geography; It is unlikely that a "one size fits all" protocol can be established; Assessment of welfare is not necessarily related to the location in my opinion, but more to the type of stranded animal (odontocete vs mysticete); I think that geographic location is huge and that managers and the public expect that what works in one area with one set of species should work elsewhere; Species differences; Data limited, particularly, with live stranded whales and larger species; Risk assessment about which kind of strandings, in which locations, are most likely to respond favourably to rescue and go from there; Not easily transferrable to large stranding events of large whales, especially in areas with limited facilities and expertise; More known about some species than others

Table A4.3. Themes of welfare concerns based on reflexive thematic analysis of expert opinion from questionnaire 1, transcribed as intelligent verbatim

Final theme	**Original terms**
Suffering, stress and anxiety associated with stranding	Stress from stranding process; Stress reduction through palliative care (protection from the sun, keeping the skin wet, placing the animal in the prone position and, if possible, floating); Stress; The stress of the stranding itself on the animal psychologically; Stress of stranding; Stress -including related to the stranding; Shock; Stress associated with the event (prior to coming ashore); Minimise stress; Stress inflicted on animal by circumstances; Keeping the animal's stress level to a minimum; Keep the animal calm; Anxiety; Anxiety/fear due to stranding; Distress; Stress/distress; Mental impacts; Immediate impacts of anxiety; Suffering
Effects of gravity, body weight, pressure on animal’s organ function and physiology and causing internal injuries and pain as a result of not being supported by water	Weight of organs leading to pain, fluid accumulation and haemodynamic dysfunction; Cramp, metabolic acidosis, and the torsional and pressure forces from no longer being supported by the water; Physical damage/pain caused by gravity; Keeping the animal floating; Pain due to pressure necrosis; The animal is feeling the effects of gravity; Impact of pressure; Physical external injury by own body (i.e. Weight, thrashing); Physical internal injury by own body weight; Being on a solid surface and not in the water - the different organs can be compromised due to the weight of the body and for this reason different organs cannot receive enough oxygenation for example; Physical pain as a result of being on land; Development of organ failure (compressive pressure, lack of oxygen) and pain/discomfort associated with that; Pain from gravitational forces in absence of buoyancy; Organ failure; Stress related to diminishing oxygen levels; Organ pressure; Internal physical injury associated with the effects of gravity on internal organs; Cardio-vascular function; Compression of internal organs dependent on size and location; Discomfort (from low to extreme) [e.g., from exposure to gravity, such as pressure on sternum], blood pooling / hormone build-up [from lying on their side/exposure to gravity]; Comfortable as possible prior to and during assessment and before possible refloat; This may mean righting it, removing any undue pressure on its body (possibly by digging a suitable 'cradle' in soft substrate or

	using rescue pontoons); Pain from being out of water (organs, muscles); Pain due to capture myopathy; Capture-myopathy from being on beach or if transported; Muscle myopathy; Discomfort; Dyspnoea caused by weight of body on a rib cage not designed to support the weight of the animal's body; Length of time the animal has been stranded has to be of importance from the perspective of both unnatural pressure on the animal's body and stress; Effects of gravity on internal organs; Physiological; Physical and health impacts; Environmental impacts of being out of the water
Fear/anxiety and social stress caused by witnessing conspecifics in distress	Fear, from conspecifics alarm calls; Psychological stress caused by death or injury to conspecifics; Anxious vocalization from conspecifics; May be a significant individual from the social group whose loss would have wider implications; Stress related to seeing other conspecifics stranded; Social stress awareness of distress in others of the group; Concern for conspecifics; Stress/anxiety from social aspects [e.g., witnessing (including hearing) others suffering; Emotional contagion - see social companions suffering; Death of pod members; Other individuals affected by its stranding or its absence or death; Presence of other stranded and swimming conspecifics
Compromised hearing	Hearing compromised [short-term or long-term issues may arise e.g., barking dogs, helicopters may cause trauma]
Cause of stranding still present	Was the stranding human-caused or natural; Same factors that caused stranding are still potentially present (e.g., noise); Reason for stranding may be unknown e.g., are there already environmental/health/behavioural reasons that have contributed to stranding
Keeping animal alive to enable re-floatation	Keeping the animal alive; Survival possibilities; Dying processes; Cetacean survival; Keeping alive on shore; Assessing the probability of survival if refloating is attempted (health assessment)
Dehydration	Dehydration; Ill-health - dehydration; Dehydration if stranding prolonged; Dehydration internal; Dehydration internally from lack of water to drink; Thirst; Unable to maintain hydration

Disorientation, loss of balance, inability to swim	Loss of balance; Disorientation/disturbed balance to inner ear [e.g., from lying on their side], disorientation [i.e., disorientation/disturbed balance can be very mentally taxing and require time to recover from this], location-specific disorientation [associated with moving an individual - such as when surf conditions are such that it is unsafe to release at stranding location and the animal(s) are moved to another location]; Disorientation; Inability to swim; Evaluating animal's cognitive state/coordination for the ability to be held in shallow water or temporarily maintained in nearshore holding pens
Out of habitat	Access to open water; Natural habitat, out of habitat situation such as beluga in VA; Proximity of animal's natural habitat (e.g., normally a pelagic species but stranded miles up a river)
Entanglement	An entangled animal may be under additional duress; Entanglement
Weather and environmental conditions	Weather conditions; The weather may not be conducive to assisting an animal (e.g. Stormy, high seas); Environmental e.g. Safe operation for people, weather, forecast; Air temperature/weather conditions; Tides for both risk to rescuers and also to aid decision-making on treatment of animal; Ensuring protection/shielding the animal from any harsh elements/ environmental changes; Effects of the environment (non-human e.g. Heat, sea state)
Delays to deciding on euthanasia to relieve suffering	Poor decision-making leading to delays in best practice management or inappropriate decisions re management - through ignorance or through unwillingness to proceed with strategies perceived as controversial e.g. Euthanasia; In cases where return to the sea and treatment in captivity are not possible, euthanasia can be used to shorten suffering; Euthanasia; Inappropriate attempts at euthanasia; When to reach a decision with regards to euthanasia; Species some more or less suitable for humane destruction; Whether euthanasia may be ethically a better option to prevent unnecessary and protracted suffering from cetaceans that are not viable due to health and condition issues; Waiting too long to euthanise the animal; Helping the animal does not necessarily means that the animal survives, Not survival at all costs!; Ability to euthanize; Will releasing, pushing off an animal, potentially cause it more pain and

	suffering, is doing nothing or euthanasia the more humane option, how best to answer that question; Is euthanasia the most humane option?; Decision on euthanasia VS; Lifetime in captive rehabilitation (no or low chance of release); Time to death; Determining when humane euthanasia is an option and whether it can be humanely and safely administered; Do everything medically possible so that the animal does not suffer, including euthanasia; Releasing/refloating animals that are not suitable for release (i.e.; Too young, permanent disability, etc) or forcing animals back out to the sea even if the animal is obviously weak or even if it is re-stranding
Animal exhaustion	Exhaustion; Tiredness [particularly when event lasts more than a few hours - this is a factor on the beach and after release - particularly if the latter is into strong currents or into surf conditions or rough seas]
Eye condition	Eye damage, drying; Eye strain from exposure to sunlight, sand/wind in eyes
Inappropriate human intervention, poor handling, responder training and experience, and public pressure influencing decisions	Early first responder actions which are inappropriate due to ignorance and lack of guidance; Disproportionate value put on the opinions of unqualified participants in making decisions (e.g., vocal volunteer groups; Veterinarians without experience in cetacean strandings); Releasing/refloating animals that are not suitable for release (i.e. Too young, permanent disability, etc) or forcing animals back out to the sea even if the animal is obviously weak or even if it is re-stranding; Cetacean expertise and coordinating this, possibilities for recovering on sight; Inappropriate handling, first aid and treatment, Inappropriate refloatation, Inappropriate carrying and transport, Inappropriate attempts at rehabilitation; Dogs; Human interference/interactions; Responses of the public; Coordinating activities of organisations, The press, Volunteers, Cetologists and Vets; There has been a tendency to refloat cetaceans due to public perception and pressure without justification via clinical assessment; Early release leading to further stranding and dislocation of family group, being towed by their tails as shown in whale rider; Being poorly handled especially with machines; Number of assistants and how many trained; Correct handling of the animal, training of the experts at site, experience of helpers; Maximum duration of handling, appropriateness of measures, public opinion; Human rescue attempts, especially

	when poorly managed; Knowledge and experience of response team; Human interactions; Trauma of being handled by humans; Presence of humans and their activities, Activities aimed at moving the cetacean back into water may cause increased physical discomfort and increase chance of injury; Degree of physical handling by humans (including treatment); How a successful and respectful handling and dealing with a stranded cetacean is conducted; Ensuring that intervention is clearly justified and carefully planned, Determining what is best for the animal rather than for the humans involved; Injuries from rescue [particularly when rescue coordinator is inexperienced or refuses to implement species-specific protocols], injury from transport [particularly when species-specific protocols are not implemented]; Assessment of condition is essential, so that appropriate decisions can follow, trained people in attendance and preferably under expert veterinary supervision; Issues around interventions e.g. Human attempts to refloat or euthanasia; Treatment by humans (stressful and potentially pain inducing); Is returning the animal back to the wild or transporting the animal to a rehab centre in the individual's or population's best interest "just because we can, doesn't always mean we should"; Do not touch the animal too much, If it kept in water help it to float; Short and long term quality of life (e.g. Rehab vs refloat, rehab releasability, failure to thrive, etc;); Human/animal interactions; Effects of the human environment (e.g. Human presence, handling, infrastructure etc); Presence of other animals e.g. Dogs on beach; Impacts of recovery attempts, and impacts of refloatation
Stress, fear, distress or pain caused by human presence, interactions, noise	Stress at being surrounded and approached by humans; Suffering from people mishandling the animal during stranding events; Stress from human interaction; Fear from human intervention; Physical or psychological stress caused by inappropriate human interventions; Overstimulation from people, dogs, etc; Excessive human activity and physical interactions with beach cast animals; Distress to animal on approach or attempted manipulation of the animal; Dogs; Human interference/interactions; All experiences while stranded (including the attendance on the animal by people) undoubtedly increase the perception of pain, discomfort, fear, and distress; Fearful (e.g. Exposure to people); Distress by the presence of people; Are humans attending them causing additional stress (well-meaning members of the

	public, for example); Direct interaction from people; Stress from being surrounded by people; Too many people making too much noise; Extra suffering when trying to rehabilitate an animal in poor conditions with little possibility of survival; Stress caused by close interaction with humans during a rescue; Unnaturally close proximity of and manipulations by humans; Perception of humans that are trying to help as threats whose proximity causes distress/fear; Perceiving human intervention as danger; Stress related to potential human contact; Disturbance from human interference and unnatural interaction with humans; Fear and stress resulting from human interactions, Fear, stress, pain resulting from human interventions; Pain animal suffers from care received, stress inflicted on animal by rescue efforts/treatments; Is it worth the stress on the animal to push it back out when it will just wash ashore again; Responses to human intervention; Distressing the animal beyond the distress caused by the stranding itself; Stress from the rescue [e.g., too little 'comfort' given, close proximity to humans and equipment]; Keeping people away from the animal; Minimizing any extraneous disturbance, including keeping people and dogs away; Treatment by humans (stressful and potentially pain inducing); Minimizing abrupt changes and intrusions to the animal; Mental impacts
Human welfare or safety, distress at not being able to help	Human welfare- distress and potential harm to people directly experiencing from these events, and the feeling they want to help but can't; Societal welfare- these events can be used to suggest issues with planetary health, and that can lead to wider number of people feeling stress and unease; Protecting the welfare of people who might not be cognisant of their own safety (from sea conditions / weather / zoonoses)
Animals suffering from illness, disease and underlying health conditions	Suffering from illnesses; Treatment of illnesses; Morbidity; May be ill; Poor health; Impact of any previous conditions the animal has which may have resulted in the stranding e.g. Parasitic bronchopneumonia or meningitis; Individual has an illness that can be treated; Health and condition issues; Suffering from disease; State of animals; Possible health issues driving stranding; Health and

	situation of the animal; Health parameters; Disease; Emerging diseases; Physical and health impacts; Negative impacts on health
Pain and suffering due to physical injury or trauma caused by stranding, particularly substrate	Trauma from the beaching event and subsequent manipulations; Suffering from injuries; Serious injury from prolonged periods out of water; Pain from trauma; Impacts of environment; Treatment of injuries; Physical damage/pain caused by physical abrasion; Pain due to trauma; Distress, pain, physical trauma incurred with the injury; Physical injuries; Injuries; Physical trauma; May have major or minor dermal abrasion or wounds; May be significantly injured (e.g. Ship strike, entanglement); Injured; Impact of any injuries resulting from the stranding itself which could be significant e.g. Severe wounds and fractures; Impact of any previous conditions the animal has which may have resulted in the stranding e.g. Injury; Individual has an injury that can be treated; Physical external injury by external factors; Suffering from wounds; Pain from injuries that lead to the stranding; Damage from wave action especially over rocks; Abrasion and soft tissue trauma from resting on a substrate; Pain - injury; Evidence of wounds; Trauma from stranding; Physical discomfort associated with being stranded and prolonged contact with surface of the land and risk of physical injury e.g. Abrasions, damage to fins; Stress related to injuries sustained during stranding; Avoid more lesions; External damage (wounds, oyster beds); Injury from stranding or other factors (i.e. Cause of stranding); Physical injury from running aground, external injury from being ashore for extended time; Pectoral fins trapped compression, Beaching damage cuts scrapes, stress, Teeth jaw damage, Damage from tail flailing; Injuries from the substrate [e.g., sharp rocks/shells etc], injuries from surf [e.g., rolling in surf can damage scapula-humerus joints], longer-term health implications from the event [e.g., an injury may impact mobility or a stranding may exacerbate a trauma that was already present prior to the stranding]; If the animal is in rolling surf if possible move it out of the surf - not possible for large animals; Minimize sources of repeated physical trauma; Physical pain due to trauma from ground/rocks; Comfort Position/location (sand rocks); Substrate the animal is lying on; If sharp rocks this can cause damage to the animal; Substrate also needs to be considered - e.g., if

	animal stranded on a rocky shore, consider moving it; Stranding-related injury; Physical and health impacts
Nutritional stress, poor body condition	Starvation; Nutritional condition; Condition of animals; Inability to feed; Starvation (in cases where stranding is associated with emaciation); Nutritional stress - lack of food; Body condition; Hunger [particularly during extended events, or for very young calves who would normally nurse frequently] [NOTE: hunger also results in potential dehydration]; Hunger; Poor body condition; Undernourishment; Unable to maintain nutrition
Fear, stress, distress or helplessness at being unable to move or help themselves	Fear and stress from being unable to move or remove itself from the situation; Unable to exercise any normal behaviours; Fear of being "trapped"; Stress consider their extreme vulnerability and lack of ability to help themselves; Helplessness through unable to move; Impact (physical and mental) on the stranded animal which is unable to respond; Inability to escape predators and humans; Obstruction of movement; Distress at not being able to move and dyspnoea; Distress at inability to move away from humans; Stress related to lack of ability to move back into water; Mental issues, like anxiety or stress of being in a life-threatening situation; Out of habitat - not able to move, swim, behave naturally; Behavioural impacts; Mental impacts; Unable to perform normal behaviours
Strange noises	Hearing strange noises; Noise; Acoustically, the situation is unusual and distressing, as the animal's ears are persistently in air, not in water; Noise from dogs, helicopters; Stress related to loud noises / vibrations in the ground [e.g., barking dogs, helicopters, vehicles driving too close/too fast near the animal(s)]; Keep noise to a minimum; Noise; Too many people making too much noise;
Not given enough time to recover at re-float before release	Not enough time to 'recover' given so unable to 'cope' (mentally and physically) [cetaceans should be given a chance to stretch their muscles, flex their bodies, recover their balance, orientate to the location, re-establish connections with conspecifics (physically and acoustically), before being released], upon

	return to the water there may be mental anguish/stress related to re-joining group/maintaining group/seeking food/returning to deep water; Impacts of refloatation
Pain and its management	Pain; Minimizing animal pain; Minimize pain; Pain animal suffers from stranding; Pain management; Suffering
Parasites	Parasites
Pathogens from humans	Transmitting pathogens to the stranded animal; Compromised health from exposure to pathogens not normally exposed to [e.g., a human rescuer may have a dermatitis condition and not be wearing gloves]
Pollution	Pollution
Fear and pain from predation	Fearful exposure to other animals such as birds; Fear of predation; Predation; Pain from antemortem scavenging; Potential exposure to predators/ scavengers; External damage from scavengers; Injuries from animals [e.g., birds pecking eyes, pecking at skin]; Presence of other animals e.g., sharks
Feasibility of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety	Resources available and how best to mobilize in an attempt to release an animal; Location where the animal is found may be inaccessible or not feasible for returning the animal to the water or moving it to a location where it will not be injured (e.g., waves on rocks); Suitable rehab facility nearby? (Ideally this would be a rehab centre or sanctuary with veterinarians who can assess and treat the individual and are motivated to get him/her back with his/her social group as soon as possible; Only under the most extreme circumstances should an individual be held in a concrete tank permanently and every effort should be made to get that individual back in the ocean either free-ranging or in a sanctuary); Location, time of day, remoteness, access to resources, access to experienced personnel, likely duration and resource balance, numbers, presence of other cetacean species that impede rescue efforts, presence of sharks, presence of blood/carcasses in water; Not enough people to keep the animal comfortable; Location; Safety of all people handling the animals; Available utilities; Responder safety; Ability to

	monitor animal(s) post release; Decision on refloating/release VS; Rehabilitation; Experience of success to rehabilitate or refloat; Is appropriate expertise and equipment available and can it reach the animal in a reasonable time?; In the event of group stranding, refloating numbers of individuals may be appropriate and a suitable strategy will be needed for this; Can animals be moved safely by authorized personnel and are appropriate resources available; Effects of the human environment (e.g. Human presence, handling, infrastructure etc); Impacts would depend on how long it was stranded; Impacts of recovery attempts, and impacts of refloatation
Difficulty breathing, inhalation of water	Finding it hard to breathe; Respiratory distress; Difficulty breathing; Water over blowhole; Drowning by returning tide; Difficulty breathing/slow suffocation; Drowning as tide comes in; Impaired respiration; Difficulty in breathing/dyspnoea caused by weight of body on a rib cage not designed to support the weight of the animal's body; Respiratory function; Rolling in surf can create situations where inhalation of water is unavoidable, stress from hyperventilation (or the opposite) from rapid breathing; Stress-breathing rate; Inspiration of water; Dyspnoea
Ability to assess whether animals will re-strand	Ability to accurately determine extent of stranding and potential restranding events; Is this a group stranding? Will the presence of others from the same pod/school keep individuals coming back?
Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun	Physical pain due to trauma from sunburn, skin dehydration; Environmental exposure (e.g. Sunburn), hyperthermia; Possibilities for shelter; Desiccation; Sunburn; Impact of desiccation; Burns due to sun; Effects of sun on skin (drying, sloughing of skin); Pain from blistering; Sunburn; Very sunny conditions possible sunburn; Dehydration external for epidermis, sunburn; Skin damage from sun and wind, drying; Dehydration [externally on skin and for eyes]; Sun can damage the skin very quickly so we use the blanket to protect the skin; Getting the animal shade from the sun where appropriate; And keeping it cool; Environmental impacts of being out of the wate

Separation from conspecifics/social group, including mother-calf separation	Separation from conspecifics and/or social group; In the case of social pelagic species, distress at being separated from conspecifics; Social isolation/separation; Distress could be caused by not having companions if it is a social species; Separation from its family members- even more pronounced for the more socially complex species; Proximity to other animals (if mass stranding/mother-calf pairs especially); Family or social group in the vicinity that he/she can be released to; Mental Stress, due to separation from pod; Dependent young, animals milling offshore; Loss of contact with conspecifics; Stress from being separated from calves and other relatives; Loss of conspecific social contacts; Loss of contact with other whales, especially young; Social stress - isolation from group; Loss of ability to perceive sounds normally through being out of water - can't communicate with conspecifics and sounds/vibrations out of water causing disorientation/fear; Stress and fear - at isolation; Separation from pod members; Possible separation from conspecifics; Cetacean being separated from their pod/social group and the repercussions of that if they are able to be rescued and released; Potential psychological trauma of being separated from calves or other conspecifics; Stress/anxiety from social aspects [e.g., separation from social network/offspring/parents/family members]; Emotional distress (e.g. Separation from conspecifics); Loss of contact with social companions; Physical separation from conspecifics, loss of social group/knowledgeable members of group; Safe access to conspecifics or mother/calf bond if present; Mixed or single species stranding; Separation from pod members; Other individuals that rely on it, Other individuals affected by its stranding or its absence or death; Presence of other stranded and swimming conspecifics; Age; Unable to responded to calls from socially or maternally dependent calves; Separation maternally dependent calves and mothers who have lost calves; May have a dependant young still at sea; Animal size/life stage of the animal(s) (e.g. Dependent calf); Age/size; Age of animal - a neonate without its mother will not be viable but mothers can be searched for; Proximity to other animals (if mass stranding/mother-calf pairs especially); Dependent young stress from being separated from calves and other relatives; Loss of contact with other whales, especially young; Potential psychological

	trauma of being separated from calves or other conspecifics; Safe access to conspecifics or mother/calf bond if present; Pregnancy
Effect of species biology, resilience and stranding type on welfare outcomes	Species (some being much more resilient that others); Species, the biology of the animal; Mixed or single species stranding; Type of cetacean stranding - single, family, mass, toothed, Baleen; Mass vs; Single stranding
Length of time stranded	Danger of death from prolonged periods out of water; Return to the sea as soon as it is viable using best practices to avoid suffering; Length of time stranded; Time since stranding; When did the animal/animals strand i.e. How many tides; When did salvage begin; Time of response; Resolve the situation as soon as possible; Maximum times we allow the animal to be out of water based on size and species; Length of time the animal has been stranded has to be of importance from the perspective of both unnatural pressure on the animal's body and stress
Physical damage, stress, pain and thermal discomfort due to overheating, hyperthermia, heat stroke and hypothermia	Physical damage/pain caused by overheating; Hyperthermia (occasionally hypothermia); Overheating & sun; Impact of heat on the body when stranded out of water, Heat Stroke; Temperature - The temperature inside the water and outside are completely different which will also influence the welfare of the animal; Hypothermia/hyperthermia; Overheating; Hyperthermia; Stress related to thermal discomfort; Internal physical injury associated with overheating; Temperature; Frostbite and other associated issues [in locations where temperatures/winds are very cold]; Hyperthermia - when a whale or dolphin is out of water they tend to overheat so we need to keep them cool by covering them in a sheet and keeping them wet; Ensuring the animal can thermoregulate properly; Environmental impacts of being out of the water
Fear and stress at being in a strange, novel environment	Panic at being on land, seeing strange sights; Distress at being out of its element; Suffering of the stranded animal from being outside their habitat; Fear from the unusual nature of the event; Visual stimuli; Unknown outcomes; Non immersion; Return to sea; Being ashore is an unusual situation that is typically life-threatening; Emotionally, the animal will be fearful, as everything that happens while

	ashore will be unusual and possibly completely novel, which coupled with the stranding itself will undoubtedly result in fear; Fear of novel objects including people; Distress by the circumstances leading to the stranding; Fear of alien environment; Being in a strange environment - this is a stressful event which can be detected through physiological measurements such as cortisol or endorphins and thus it is known that it also has an emotional component; Mental stress at being out of water and threats such as people being around; Unfamiliar environment; Unknown area (where stranded); Stress related to being in unfamiliar environment; Psychological trauma associated with being in extremist; Stress/anxiety from being ashore [i.e., inter alia all the compromised welfare issues listed above that may manifest itself in physical ways such as hormones, but also may manifest themselves mentally and as such compromise the way in which the individual can cope with recovery]; Its previous experiences; Physiological; Mental impacts

Table A4.4. Themes of survival likelihood characterisation based on reflexive thematic analysis of expert opinion from questionnaire 1, transcribed as intelligent verbatim

Final theme	**Original terms**
Animal returns to normal life and full functioning in its natural environment	The likelihood that an animal will return to a normal life with conspecifics; Being fit enough to return to effective function back in the ocean - a compromised animal will likely have prolonged suffering if not able to function; The likelihood that a cetacean will swim away from a stranding and return to an independent life in the wild; Survival likelihood is the probability that the animal will recover to function fully (swim, feed and reproduce); A stranded cetacean returning to the ocean and living the rest of its natural life with no long-term effects from the stranding event; The probability to persist (and thrive i.e. Reproduce and return to a 'normal' life i.e. Wild in natural habitat) after a stranding incident; The ability to return to a pre-stranding life and have a "normal" life and reproductive expectancy; The possibility to survive stranding and carry on a normal life again; The capability of an animal to recover to its normal healthy conditions in order to be able to survive on its own in the wild; Living to an average lifespan for that species in that situation/country/environment; Able to survive in the same way as other unstranded members of that species; Breeding normally after stranding; Probability of an animal that has

	been refloated returning to normal behaviours and not restranding within the days following a stranding; Animal resumes typical behaviours and life history strategies when refloated; Potential to return to a normal physiological state; Stranded animal will not only swim away but also continue to function as part of a population and contribute to the population's success (e.g. Reproduce); Survive and function out in the wild with little to no physical or behavioural deficiencies; Will it be able to make it's migrations? Will it be able to feed? Will it be able to mate, carry a calf a calf, give birth?; Chances of living a normal or close to normal life in the wild; Individual will survive for long enough to return to its natural habitat and resume normal feeding/breeding/migration behaviour; Ability to return to the wild and resume a productive and adaptable lifestyle, Survivability includes the ability to forage, defend against predators, be accepted and maintained within an appropriate social structure with conspecifics, breed, and shelter; Return to the sea of the animal without returning to beach itself again, and able to hunt and swim in a proper way; Long-term survival means that the animal re-joined its group, is reproducing and ensuring that its population survives; Long and full life; Recommencing natural behaviours in the natural environment; Number of cases retrieved to the wild and which go back to their normal social group and/or habitat and survive for at least a month to several months post stranding event; Individual will survive for long enough to return to its natural habitat and resume normal feeding/breeding/migration behaviour; Home range similar to previous; Recommencing natural behaviours in the natural environment
Animal returns to pre-stranding life and health status	The likelihood that the animal can return to the same or similar status in the wild to its pre-stranding status; Probability that animal will recover to its pre-stranding state of health with no change between pre- and post-stranding likelihood in its daily point probability of death; Survival likelihood means the potential for individuals to reach the survival rates that were applicable prior to the stranding (e.g. Survival of juveniles may be lower than adults in line with general survival rates); The ability to return to a pre-stranding life and have a "normal" life and reproductive expectancy; Likelihood of the individual being able to continue life as it was 'before' the stranding
Animal survives after re-floating	The probability that the animal will live following refloat; How likely an animal is to survive after a refloat (not die as a result of the stranding); The probability of an individual stranded cetacean being successfully refloated; Animal resumes typical behaviours and life history strategies when refloated; Whether there is a chance the animal may survive given the

	circumstances - i.e. how long ashore, how many tides, temperature, species; Is the animal able to survive once released?; Just surviving the initial refloating event and then dying at sea without anybody noticing is clearly not related to a positive survival likelihood; Chance of being refloated; How likely it is for an animal at a stranding event to survive if refloated and released
The chance that the animal survives after stranding	That the animal will most likely survive; How likely it is for an animal to survive after being ashore for a given period of time; Probability and physical ability of an individual to live out its full lifespan following a certain event; The chance that an animal will survive in the midterm future; Survival probabilities for an animal to survive after a live stranding; The possibility to survive stranding and carry on a normal life again; How likely the animal is to survive; Probability of survival; Can we return this animal to the sea with a good chance of survival; The chance of that cetacean going on to have long term survival
Animal does not die of stranding related injuries or damage	Must survive long enough to overcome the stranding event, that is, not to die after days or weeks as a result of problems caused by the stranding; That the animal lives out the full length of its normal life AND is not encumbered by physical or other damage; How likely an animal is to survive after a refloat (not die as a result of the stranding); A stranded cetacean returning to the ocean and living the rest of its natural life with no long-term effects from the stranding event; Does not die a few weeks later from organ damage or physical injuries sustained during stranding or rescue efforts; Probability that the stranding event will not ultimately result in the death of the animal; Dying due to injuries suffered as a result of stranding and efforts to refloat; Animal was able to survive any trauma, injury or impacts of the stranding event; Animal that is rescued (refloated or rehabilitated) and released, will survive in the wild until dying due to sources unrelated to the original cause of the stranding event or sequelae of the stranding event; Long-term survival and an eventual death unrelated to the stranding event; The chance of that cetacean going on to have long term survival (i.e. survival not shortened due to the stranding event) following refloatation

Animal does not re-strand within days of being re-floated	If re-stranding occurs immediately and within a few days, the likelihood of survival is lower than in an animal that may swim into deeper waters; Probability of an animal that has been refloated returning to normal behaviours and not restranding within the days following a stranding; Successfully refloated and not restranding in the immediate future
Animal’s body condition	Good body condition; Muscle condition are sub optimal we will elect to euthanise the animal
Animal’s health condition, disease and illness status	In cases where stranding is suspected to be a product of pre-existing illness, I feel that the stranding event underpins low survival likelihood and these animals should be euthanised e.g. Neurological signs prior to stranding; Refloated/released based on the information on the animal's health/condition; Survival likelihood involves the health conditions of an animal that enable it to return to the sea and survive; Survival likelihood has a lot to do with whether the individual has a life-threatening illness; All other possibilities need to be considered on a case by case basis; Sick animal has bad survival expectations; No obviously significant clinical disease or injuries; Animal without brucellosis
Animal is able to respond and cope with natural conditions to ensure its survival	The capability of an animal to recover to its normal healthy conditions in order to be able to survive on its own in the wild; Extent to which the stranding event affected the animal's ability to maintain responses that ensure/enhance survival; How well an animal can cope with its natural conditions and anthropogenic pressures given its current health and mental state; Survive and function out in the wild with little to no physical or behavioural deficiencies; Will the animal survive and thrive? Will it be able to make its migrations? Will it be able to feed? Will it be able to mate, carry a calf a calf, give birth?; Old enough to be self-sufficient or obvious potential mother around; Ability to return to the wild and resume a productive and adaptable lifestyle; Return to the sea of the animal without returning to beach itself again and able to hunt and swim in a proper way
Animal alive 1 month after stranding	The probability the animal will be alive one month after the stranding event; Percentage of individuals who survive a pre-defined time; So here, it would be something like the % of animals surviving for 1 day/1 week or one month after stranding; Number of cases retrieved to the wild which go back to their normal social group and/or habitat and survive for at least a month to several months post stranding event; Survival is a long term outcome - not just the ability to swim away short term

Animal alive 6 months after stranding	Likelihood that a cetacean will swim away from a stranding and return to an independent life in the wild for at least the next six months, anything less may mean the animal has been in distress that entire time and then strands again/dies; Ability of animal to survive for extended time (months) after refloated
Animal alive 1 year after stranding	Surviving long term; Long-term viability in the population following re-floatation; Animal reaching benchmark milestones (such as living past a certain timeframe - for some studies this is listed as weeks, for others a year); Chance that the cetacean will survive for a year post refloating
Animal returns and socially re-integrate with its conspecific group/pod	The likelihood that an animal will return to a normal life with conspecifics; The probability to persist (and thrive i.e. Reproduce and return to a 'normal' life i.e. Wild in natural habitat) after a stranding incident; Potential to re-join a pod; Stranded animal will not only swim away but also continue to function as part of a population and contribute to the population's success (e.g. Reproduce); Number of cases retrieved to the wild which go back to their normal social group and/or habitat and survive for at least a month to several months post stranding event; Individual will survive for long enough to return to its natural habitat and resume normal feeding/breeding/migration behaviour; Social re-integration, independent (and cooperatively) foraging; Survivability includes the ability to defend against predators, be accepted and maintained within an appropriate social structure with conspecifics, breed; Long-term survival means that the animal has re-joined its group, is reproducing and ensuring that its population survives; Survival in the wild of an individual as a viable member of its society
Response of animal when re-floated	Response of the animal when reintroduced to shallow water
Survival is affected by species and size	Survival likelihood depends in general on the size in combination with the species of the animal; Size, fully beached large sperm, beaked and bottlenose whales unlikely viable; Tolerance of different species is critical here - in terms of ability to survive stranding and have positive outcomes

The number of re-stranded animals	% of stranded cetaceans back on the beach in the near future after a refloat
Avoids suffering	Survival likelihood should allow to avoid unnecessary sufferings and to refloat animals that have more chances to survive

Table A4.5. Themes of knowledge gaps relating to survival likelihood based on reflexive thematic analysis of expert opinion from questionnaire 1, transcribed as intelligent verbatim

Final theme	**Original terms**
Ability to determine presence of myopathy	Determining presence of cardiomyopathy in the live animal; Pathophysiology of capture type myopathies in stranded cetaceans; Increased knowledge on capture myopathy; Ability to diagnose common findings such as capture myopathy
Lack of data for species-specific survival	More solid evidence on the role of species in stranding survivorship; We need baseline or normal blood values for the different species of cetaceans; Lack of parameters for blood tests in many species; Post stranding survival by species; Extrapolate that a certain species or an animal in a certain condition (length of being drydocked, blood parameters) is not worth saving, while others (that might have previously been deemed unworthy) are; There is no international standard protocol for this (is that a 'knowledge gap'? Feels like it is - and whilst it would probably need to be species-specific with some regional aspects - this would be useful; Outcomes vary dramatically by species and location; One good example of predicting survivability is the case of *Kogia* sp. in the USA where most rehab facilities no longer attempt rehab with these animals as a species because of poor survivability in rehab to release
Lack of normal/baseline blood parameters and profiles	We need baseline or normal blood values for the different species of cetaceans; Lack of parameters for blood tests in many species; Short and long term clinical chemistry and endocrine disturbances associated with standings; Extrapolate that a certain species or an animal in a certain condition (length of being drydocked, blood parameters) is not worth

	saving, while others (that might have previously been deemed unworthy) are; Blood profiles; Blood parameters; Lacking information of prognostic indicators from blood analysis; Blood profiles
Lack of post release monitoring to measure survival outcomes	More use of satellite tags in re floated cetaceans; Decent post-release survivability data; Post stranding survival by species; Satellite telemetry; Post release monitoring; Lack of reliable outcome data; Long-term survival from chronic impacts; Better knowledge of outcomes of stranding events; Satellite tag monitoring of animals post release to assess survival after strandings; Lack of knowledge of survival rates and thorough assessments of operational responses that can influence the outcomes; Studies of survival post stranding to prove that its low; Post-rescue survival; Tagging; Putting telemetry devices on all animals released; Lack of data on what happens to the animal after it leaves the beach is an issue; Important to monitor animals after release; Techniques and post release monitoring for large whales; Post release monitoring of small cetaceans, and beyond just location data, additional data is needed (dive data, behaviour); Lack of data on the outcome of most re-floatations; Lack of clear and measurable method to assess survival likelihood; Information on post-stranding movements of the animal; A lack of tracking and information on the survival of past releases; There is a paucity of information in this area due to relatively few examples other than anecdotal information found from specific response groups to a localized area i.e. Mote Marine Lab in Sarasota FL has a good record of the success rate of animal's they have rehabilitated and released in the Gulf of Mexico but there needs to be a more global coordination of these efforts with regional specific considerations; One good example of predicting survivability is the case of *Kogia* sp. in the USA where most rehab facilities no longer attempt rehab with these animals as a species because of poor survivability in rehab to release; Little data on survival of single stranded odontocetes post refloating; We don't tag enough animals so we have no idea if the actions and decisions we took on the beach 'worked' or not; Post release survival; Without suction tagging or other method to monitor the swimming pattern, range and detection of foraging activity, it is difficult to assess the impact of stranding on individual or mass strandings; Number of rescued animals to the number that can be monitored for knowledge gain; Don't think we have good knowledge of whether animals survive post release from most strandings; We make decisions based on health assessments and logistics, but don't have the follow through to see the results, unless the animal restrands; Telemetry or tagging to prove survival after refloating, particularly long-term i.e. months to years (rather than days/weeks); Data on survival following re-

	floating; Very little post stranding data on which to assess this; Telemetry is often proposed as the main tool but clearly involves an increased level of stress for the animal; Information from tagged individuals and their post-release survival; Some individuals have been tagged after stranding to assess post-release survival; Lacking knowledge on the survival of the animals after releasing; With little or no data to confirm whether refloating has been successful, information on survival probability seems like "educated guessing"; Very few case studies and many involve tagging the animals, which adds another layer of stress and can compromise the individuals; Limited information available to assess survival likelihood; Proper documentation of individuals at strandings, including species-specific identification features (e.g., eye patches of orca, callosities of southern right whales)
Ability to assess internal body temperature	Internal temperature
How to make decisions about when and how to euthanise stranded cetaceans	Whether it is more humane to euthanise or provide palliative care, which might prolong the animal's life (and thus its suffering)
Ability to assess body condition and blubber thickness	Measuring blubber thickness/weight vs length/girth
Ability to triage current state/condition	Triaging the current state would give an indication of whether an underlying condition might impact the cetacean’s survival chances
Lack of trained and skilled responders	Trained staff are not always available; A lack of skilled people who know; There is not a lot in literature or taught as a skill
Lack of knowledge about hearing impairments	Hearing loss

Lack of knowledge about causes and prevention of strandings and effects of local ecosystem changes	Changes in movements of their food sources, changes in water temperature, variations in main ocean currents, and/or other factors; The marine ecosystem is indeed extremely complex, but a better knowledge of this ecosystem could help to predict the pattern of future strandings; How to effectively predict and prevent mass strandings in different areas; Much to be understood about the cause of and impacts of strandings that we do not understand still
Ability to diagnose diseases and infections on the beach	Ability to diagnose common findings such as diseases like morbilli, brucella; Diagnostic on the beach of several diseases; Concomitant infections in a single animal, make the prognosis worse, therefore, availability of rapid tests that can be performed in the field are necessary to have a good idea of the medical status of the animal and have a better support for a medical decision
Lack of knowledge of treatments and their effectiveness	Treatment options and effectiveness of treatments
Lack of standardised protocols to follow	There is no international standard protocol for this (is that a 'knowledge gap'? Feels like it is - and whilst it would probably need to be species-specific with some regional aspects - this would be useful
Lack of data on the effects of conspecifics presence on survival	Think there's good literature on age-related issues (nutritionally dependent calves won't survive without a mother - adoption not being common and certainly not without a ready adopter waiting offshore!), but perhaps not on the need to have a pod of conspecifics nearby; It's common wisdom that this will help, but how much empirical data are available on that?
Lack of knowledge on the links between survival and welfare	General guidance on how survival and sustainability of animal welfare related release and possible prior rearing are; Survivability may be easier to consider than welfare as the physical condition of the individual is paramount in making this decision; Being able to assess the best animal welfare decisions and determining survival, pretty much need the same information and data; How negative impacts in the 5 domains influence survival; Links between observed indicators/behaviours and survival likelihood

Lack of data on species distribution	There may be reasonably good information available on some of the species at risk, particularly those of baleen whales. However, there is a lack of current knowledge on the spatial and temporal distribution of several species of toothed whales, particularly offshore species, recognizing the difficulty of gathering this kind of information
Lack of knowledge on the links between external assessments and pathology	Links between external assessment of cases and internal findings (linking pathology)

Table A4.6. Themes of survival likelihood concerns based on reflexive thematic analysis of expert opinion from questionnaire 1, transcribed as intelligent verbatim

Final theme	**Original terms**
Ability to forage once re-floated	Ability post release to feed, forage; Inability to find food; Hunger; Availability of food when re-floated
Stress, anxiety and associated conditions caused by stranding	Stress; Suffering and distress; How distressed the animal is made to feel; Minimal stress; Stress endured during the stranding event; Stress-related conditions, e.g., Cardiomyopathy; Stress and capture myopathy
Effects of gravity, body weight, pressure on animal's organ function and physiology and causing internal injuries and pain as a result of not being supported by water	Severe physiological problems; Compression of internal organs in large animals, with impaired blood circulation; Physiological damage that cannot be remediated; Stranded on one side; Physical internal injury by own body weight; Risk of pressure on organs for large species; How large is the animal - how 'crushed' might its organs be; Unseen physiological changes that impact upon on long-term survival; Impaired organ function (e.g., kidney damage from dehydration, shock, myoglobin, circulatory compromise from stress cardiomyopathy); Organ damage from gas emboli; Pressure of gravity on organs, damage to internal organs; Cardio- failure; Extent of stranding related trauma physiological; Development of cardiomyopathy, Development of skeletal myopathy; Cumulative physiological damage accrued by the process of stranding (e.g. capture myopathy); Stress and capture myopathy; Myopathy; Muscle damage leading to impaired swimming +/- scoliosis; Stress levels) at re-floating; Effects of capture myopathy
Compromised hearing	Hearing impairment that may have led to stranding; Damage to the hearing system
Abnormal movements and reduced limb function	Abnormal movements; Diminished limb or fluke function; Behaviour response
Bleeding/fluids/mucus from orifices	Any mucus around blow hole or coming out of mouth

Cause of stranding still present	The cause of the stranding; Whether the precipitating or inciting cause of the stranding persists or has been removed from the local environment; Reason for stranding; Why the cetacean stranded in the first place; Distance from causative agents (e.g., Seismic or acoustic military surveys); Cause of the stranding; Not attended to main reason of the stranding (hit by a boat, different pathogen infection)
Dehydration	Dehydration
Disorientation and swimming ability	Disorientation; Ability to swim
Distance/position of animal from sea	How far is the animal from water; The degree of the stranding i.e., how far up the beach
Weather and environmental conditions, including tides	Weather; Weather and tidal conditions; Air temperature; Magnitude of tidal changes and timeline between high and low tide; Low vs high tidal changes, water accessibility; Weather conditions, sea state; Favourable environmental conditions- for example, not hot and dry; External environmental conditions; Sun; Weather conditions; Water temperature and quality; Time of year; Weather/water conditions at the time of stranding; The weather conditions e.g. temperature and humidity; Release conditions; Air temperature, sun exposure, tides; State of tide; Weather/wind/surf/tide conditions; Weather conditions [temperature, storms, waves, tides etc]; Time of release [related to tides, current, visibility (water clarity and day vs night)]; Weather and sea conditions at refloat site(s); Environmental conditions and parameters; Tides, wind, currents, topography
Animal exhaustion	Exhaustion; Weakness
Eye condition	Eye damage leading to impaired vision
Genital condition	A prolapsed uterus

Geographical location of stranding and being out of habitat or range	Geographic and oceanographic features of stranding site; Conformation of coastline and water depth; Species range (vagrants less likely to survive); Circumstance of stranding (e.g. Native vs lost animal); Animal has appeared in a very unusual location (well outside normal habitat); Location of the stranding and factors that may have caused it to strand initially - beach configuration, high seas, etc; Habitat/geographic region; Location of stranding (remote area, complex topography etc); The species i.e. coastal versus a pelagic, deep sea, offshore species; Geography and area of release; Out of habitat range; Location of stranding - whether the animal is in its key habitat; Landscape; Geographic location; Location; Distance from normal habitat; Depth of stranding; We make sure the species is in its range - if a Beluga is found in the River Thames there is little chance it will survive in the English Channel so we need to assess how far the animal is out of its natural range to see if we can release it or not; Habitat that animal is returned to, or placed in, is appropriate to the animal's natural home range
Human activity in surrounding environment	Anthropogenic factors in the immediate environment
Availability of appropriate and timely human intervention and handling, responder training and experience	The knowledge and experience of the stranding team, presence of a veterinarian in the stranding team; Management of stranding response; The sooner animal welfare-people know when stranding is at hand, the sooner they can try to prevent the stranding; Appropriate assessment, treatment; Professional conduct; Responses by the public (inappropriate assistance/ appropriate assistance/ hindrance/ exploitation e.g.; For food, traditional medicine, distance and availability of experienced people, distance and availability of appropriate volunteers; A fast response from a team of experienced cetacean rescuers, with an experienced vet leading them through an assessment and decision making while they are supported in the correct way to look out for physical/mental/social welfare; available personnel with experience and expertise; Handling during stranding (appropriate); Persons which are trained and specialized to deal with animals in these type of situations; If already in human hand, it should be helped; Where/how they were introduced; Intervention of humans to release individuals back into the sea; Kind or degree of human intervention (including handling) received while stranded;

	Access to experienced stranding response team; The response from humans (good vs poor, timely vs untimely); Availability of expert rescue team; Release protocols [inter alia, were the animals given appropriate time to recover whilst in the water and not just shoved out to sea and herded offshore]; Risks posed by early intervention by inexperienced people
Distress and disturbance caused by human presence and interactions	Disturbance or distress from interaction with people and/or transportation
Animal suffering from illness, disease and underlying health conditions	Disease status; Predisposing illness; Pre-existing disease not necessarily predisposing to stranding likelihood; Evidence of disease; Pre-existing health at point of stranding; Infectious diseases; Health status of individual(s); Infection; Underlying health condition; Disease, Chronic disease; Severity of any illness; Illness; Weakened or present some type of disease; Diseases affecting the brain, systemic severe diseases (morbillivirus, herpesvirus, brucella); Condition when stranded; Health status of the animal as assessed by well-informed professionals; Health; Health status of animal at the time of stranding i.e. was ill-health the initial cause of the stranding; The baseline health status of the cetacean; The underlying health of the individual that stranded; Pre-existing conditions and overall health prior to the stranding event; Health status of the individual before stranding; It's overall health condition upon stranding; Health status in general; Immune response compromission; Chronic diseases or not approved medication for successful treatment
Physical injury or trauma caused by stranding	Severity of injuries suffered due to efforts to refloat; Traumatic injury; Evidence of trauma; Trauma; Fractures in the skull bones; Inflicted physical injuries (external or internal) by stranding event; Physical trauma (not recoverable); Existing injuries; Severity of any injury; Presence of injury; Injury; Physical external injury by external factors, Physical external injury by own body (i.e. Weight, thrashing); Injuries and overall condition and strength; Injuries sustained (both in stranding and returning to the sea); Wounds; What are the nature of its injuries; Presence of injuries; Obvious damage to animal e.g. Wounds; Injuries sustained during the stranding; Physical injury; Injuries; Soft

	tissue injury; Direct injuries; Condition (i.e. injuries); Evidence of significant trauma; Extent of injuries; Severity of injuries suffered due to stranding; Severity of injuries from stranding event; Health status as the result of being ashore; Severity of any injuries/blood loss; Badly injured; We look for any signs of damage to the animal - wounds; Injury type; Wounding; Physical ability where no injuries or impairments hamper the animal's ability to survive and the animal can feed, breed, shelter and protect itself; Extent of stranding related trauma physical
Helplessness due to being unable to move	Helplessness through inability to move
Animal age based on length/weight and reproductive status	Age; Age e.g. Maternal dependency; Size - larger = less likely to survive; Size of the animal/s involved; Whether the cetacean is maternally dependent; Age (very young and very old individuals less likely to survive stranding); Age/maternal dependency; Old age (some stranded animals that I have seen are old and diseased - possibly stranding as the last thing they do in their normal arc of life); Age class, size; Animal is fully maternally independent; Size/weight; Age/size of individuals; Age i.e. Mature versus immature (dependent); Age of animal/s; If the individual is maternally dependant and the mother is dead; Size; Life stage; The age of the individual; Weight; Age (neonate VS adult); Body mass; Size; Reproductive; Time from parturition
Animal awareness and neurological status	Neurological lesions; Neurologic disease; Full sensory awareness of its environment; Cognition and mental capacity of the animal to carry out those behaviours needed to thrive
Body condition and nutritional status	Prey availability; Body condition; Nutritional condition; Excessive thinness; Nutritional status, body condition (if emaciated, the reduced blubber may impede buoyancy); Severe emaciation (some stranded animals that I have seen are very thin); Condition (healthy, thin, emaciated); Poor body condition; Emaciation; Fat levels; Evidence of poor nutritional state - for example emaciated; Condition; Body condition - we need to be happy the animal is in moderate to good body condition;

	We use the lumbar muscle at the base of the dorsal fin to assess this: Concave is bad body condition - Convex is good; Nutritional state
Presence of parasites	Presence of parasites
Documenting animals on the beach for re-identification	If the animal was documented correctly on the beach so that it can be confirmed as resighted later - i.e., undocumented animals can't be confirmed as resighted and subsequent strandings cannot be confirmed as the same animal
Presence of predators and scavengers	Presence of reef, presence of sharks; Fear of predation; Predation; Presence of predators; Some injures may be due to predators; Avoid predators in post-stranding environment; Predators/scavengers
Feasibility and speed of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety	Speed of intervention (e.g. Stranding time, response time, etc;); How soon first responders arrived and gave emergency care to the animal from the time it stranded; Location; Location of stranding - access to stranding site; Availability of resources, location of stranding; An alert alarm system (peoples network) for stranding of cetaceans; Refloatation and rehabilitation; Availability of stranding network/responders and response equipment; Availability of boats, equipment; Availability of permitting authorities; Available resources; Ability to safely - or otherwise - mount a rescue effort; Ability to be moved to appropriate release site - if required, ability to stabilise animals, ability to manage other people, media coverage which may influence the ongoing level of resourcing, assessment of options; What medical assistance can be given; Assistance/treatment used on the animals; How much help do you have to get the animal back in the water; Access to well-managed human resources to attend to the stranded animal in a timely manner, access to at least temporary holding facilities for holding the animal under observation for a few days if necessary; If they were under human care for how long; The facilities and desire to assist; Stranding location (do animals need to be transported or can they be refloated on scene); Treatments, supportive care, and techniques to minimize stress and negative impacts of the stranding can help; Urban versus rural setting; Access to

	equipment such as stretchers/pontoons; Rehabilitation [none vs in a concrete tank vs in a sea pen as well as duration and social networking during rehabilitation - e.g., youngster removed from mother, siblings removed from pod]; Availability of equipment, accessibility of rescue site; Ability of responders to return the animal and any group members fully to the deep (or just into the waves); Time of the day the animal stranded; Ability to move animals into deeper water if needed; Speed of human response; Speed of intervention (e.g. Stranding time, response time, etc.)
Difficulty breathing, inhalation of water	Water aspiration; Breathing compromised due to compression of the lungs or ingestion of sea water; Drowning by returning tide; Abnormal respiration; Respiratory failure; We look for any signs of breathing difficulties
Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun	Sunburn; Loss of large portions of the skin; Whether it remained in water or was beached on sand i.e., Sunburn; Extensive skin damage (blistering, crabs, gulls) leading to body fluid loss; Too hot skin lesions; Damage to skin
Separation from conspecifics/social group	In the case of social species: presence of unstranded pod members in the vicinity; Ability to re-join social groups; Social structure of species; Proximity of conspecifics when released; If social animals, whether conspecifics are within the region; Irreversible separation from their pod/group; Socially independent; Presence of conspecifics, particularly for social species; Mental Stress, due to separation from pod; Whether other group members are present for a gregarious species; Having lost the pod/relatives; Whether the animal has been separated from its pod or whether it is able to return to its group; In a mass stranding, the survival of conspecifics might be important too; Dependent calf or juvenile that does not successfully re-join dam or conspecifics; Loss of social group/social cohesion; Loss of social contacts with conspecifics; Likelihood that a single stranded animal will be able to re-join its pod; Social behaviour; Personality; Presence/absence of other individuals and relatedness to them - especially if they are stranded too or remain stranded; Social group/species (those animals known to live individually will have higher chances of survival when retrieved alone, than those

	known to normally live in family or social groups); The survival of conspecifics, particularly senior pod members perhaps; Social factors; Strength of social bonds with pod mates or dependence on pod mates; Social dependency; Number of animals stranded; The number of animal/s involved; Single or multi species stranding; With group or alone; Numbers of simultaneously stranded animals; Proximity/survival of pod members; Proximity/condition of likely mother if unweaned calf
Effect of species biology on survivorship	Species; Species - especially social pelagic vs more solitary species (the latter having higher survival likelihood); The species of the animal; Species involved; Species-specific protocols applied or not
Length of time stranded and number of re-strandings	Duration of stranding; Length of time ashore, particularly important in large cetaceans; Length of stranding event; Stranding duration (the longer stranded the worse the chances of survival); Period of time out of the water; How long it has been out of the water; Minimal length of time stranded; Length of time stranded; Time since stranding; How long an individual has been stranded for (and size of species; How long has the animal been out of water; How long they were stranded and how long it took to refloat them; Number of tides ashore; Time ashore; Time spent on the beach; Amount of time on beach; Time between stranding and release; Length of event; How long they were stranded for; Length of time stranded; The time that the cetacean was found after stranding; Stranding length; The time between stranding and release; Time on the beach; Time on land; Time spent ashore; Time from stranding to assessment, treatment, refloatation; Duration that the animal(s) were on the beach [extended periods may contributing factors, but extended periods have occurred and animals have survived, so this is one of a matrix of factors]; The time it has been on the beach; Time between stranded and return into the water; Number of previous refloat attempts
Substrate/terrain at the stranding location	Geography of stranding location (beach versus rocks); The nature of the terrain the animal strands on; Location substrate; Substrate type (rocky/sandy shore?); Substrate
Too hot/hyperthermia	Hyperthermia; Heat Stroke; Too hot hyperthermia

Fear of novel environment	Fear of alien environment
Duration and severity of impacts	Severity and duration of negative impacts in all 4 physical domains; Severity and duration of negative impacts in any of the physical domains during reflotation; Severity of event

Appendix 5 Linear Discriminant Analysis (LDA): Chapter 2

All categories provided for scoring in the second round are shown on each LDA figure. The first two axes of the LDA were used to provide a visual representation of differences and similarities among expertise in relation to the major categories within each of the topics.

For each LDA figure, arrows show the direction of the gradient of larger scores, and the length of the arrows is proportional to the correlation between the variable (category) and the ordination (data points). Longer arrows in the same direction as the ordination of a particular expertise group, indicate that the group generally scored the category higher than the overall average. Whereas longer arrows in the opposite direction of the ordination of a particular expertise group, indicate that the group generally scored the category lower than the overall average. Ellipses were plotted to aid in the visualisation of expertise group scores. The ellipses indicate the 95% tolerance region of data points within each expertise group, estimated by fitting a bi-variate normal distribution to the covariance matrix of each expertise group. In some cases, the data for a particular expertise group were insufficient, therefore the ordination is plotted but there is no ellipse to indicate the 95% tolerance region.

Overall, there was substantial overlap among the expertise groups for all categories within each topic, with little correlation observed between expertise group and categories. However, in some cases there were slight trends that could be identified visually. Where slight trends among expertise groups for each topic could be identified, these are interpreted in the results sections below.

Characterising concepts of stranded cetacean welfare and survival

A LDA was performed, and the first two discriminant axes accounted for 72% of the variation (Figure A5.1). The results of this showed that there was substantial overlap among expertise groups with little correlation between particular expertise groups and certain variables (categories). Although the 'Other' expertise was grouped more on the negative side of LD2. Some generalised trends seen on the LDA suggest that 'cetacean expert (including cetacean conservation and biology)' (n = 16) were less likely to score 'physical state and wellbeing, health, injury and disease status' (PhysState) as important for characterising welfare than the 'animal welfare expert with knowledge and/or focus on cetaceans' (n = 3). In contrast, the 'animal welfare expert (including animal welfare science, welfare/animal ethics)' (n = 9) were less likely to score 'Normal physiology and homeostasis' (Physiol) as important for characterising welfare, whereas 'veterinarian' (n = 20) were more likely to score this variable as important for characterising welfare.

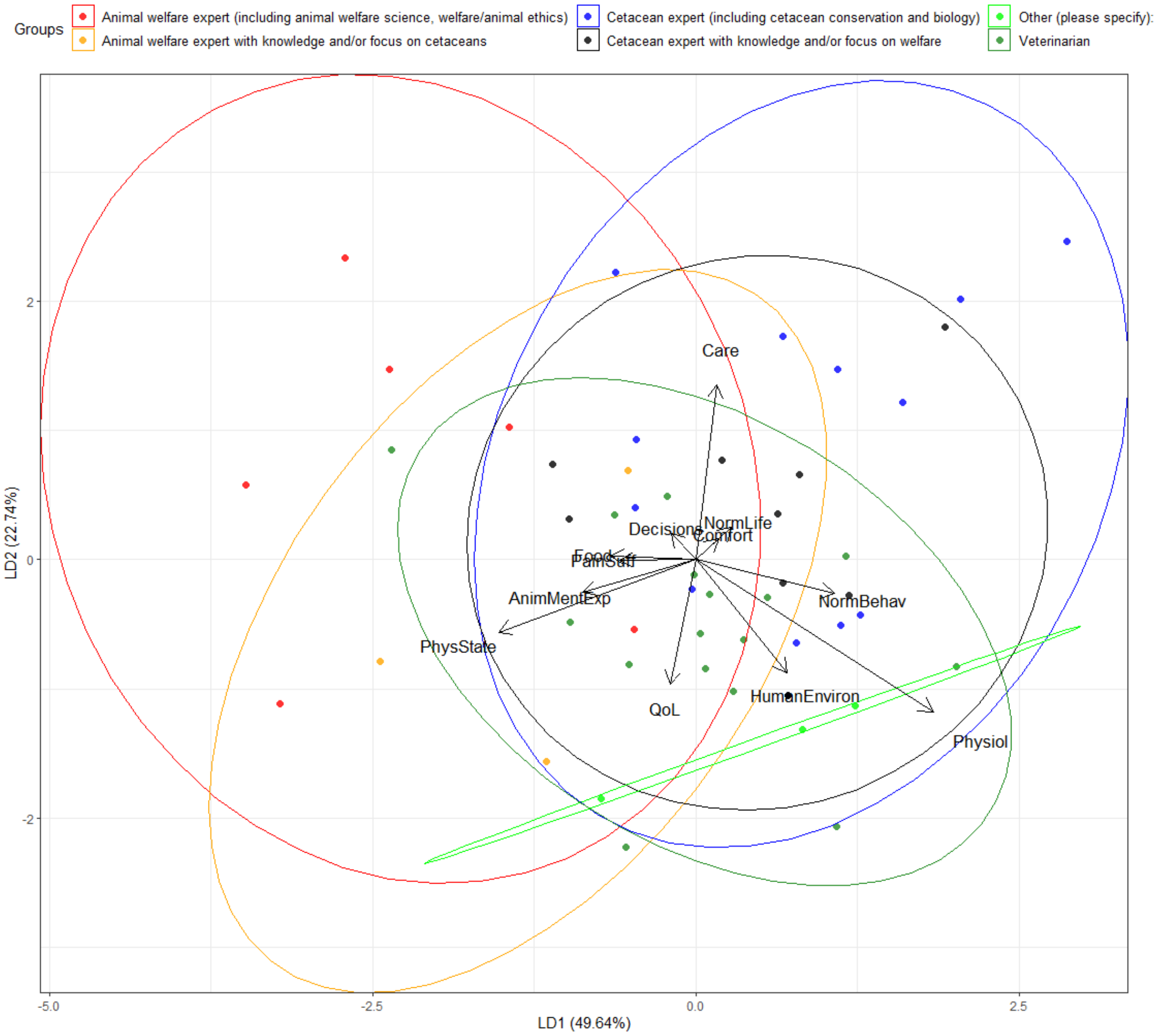

Figure A5.1. Biplot of the linear discriminant analysis of category scores for the topic characterising welfare, which attempts to find axes that discriminate among expertise groups. Category key: PhysState: Physical state and wellbeing, health, injury and disease status; AnimMentExp: Animal's experience/perception of situation, mental or psychological state or well-being, affective states or feelings; PainSuff: Pain and suffering, distress, stress or fear; NormLife: Ability to live in normal/natural social and environmental conditions or habitat; Decisions: Appropriate decision-making about re-floating or euthanasia, and targeted rescue/re-floatation efforts to prioritize animal welfare; NormBehav: Normal, natural or wild behaviour; Care: Treatment and care by humans, including during stranding response; Food: Sufficient food and water; Comfort: Physical comfort/discomfort; Physiol: Normal physiology and homeostasis; QoL: Overall wellbeing or Quality of life; HumanEnviron: Human activities in environment.

In terms of survival, the LDA of the first two discriminant axes accounted for 72% of the variation (Figure A5.2). The LDA showed overlap among all expertise groups. However, it showed that ‘animal welfare expert (including animal welfare science, welfare/animal ethics)’ (n = 9) grouped more on the negative side of LD1 and were more likely to score ‘Animal survives after re-floating’ (SurviveRefloat) highly for characterising survival. In contrast, ‘veterinarian’ (n = 20) were less likely to score that variable as important for characterising survival, and instead scored 'Animal alive 1 month after stranding' (X1mnth) as important for characterising survival.

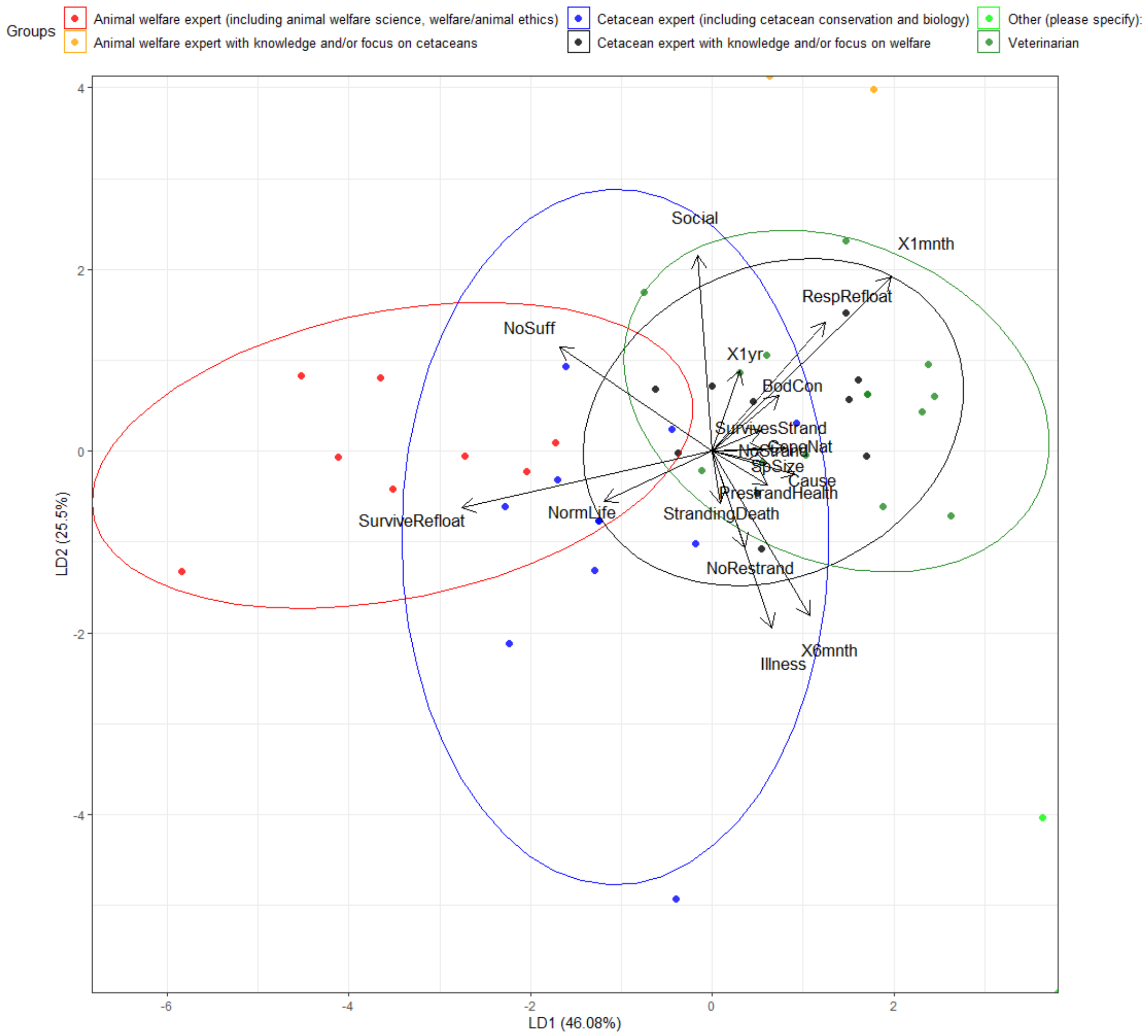

Figure A5.2. Biplot of the linear discriminant analysis of category scores for the topic characterising survival, which attempts to find axes that discriminate among expertise groups. Category key: NormLife: Animal returns to normal life and full functioning in its natural environment; SurvivesStrand: The chance that the animal survives after stranding; StrandingDeath: Animal does not die of stranding related injuries or damage; Illness: Animals health condition, disease and illness status; Social: Animal returns and socially re-integrate with its conspecific group/pod; CopeNat: Animal is able to respond and cope with natural conditions to ensure its survival; SurviveRefloat: Animal survives after re-floating; PrestrandHealth: Animal returns to pre-stranding life and health status; SpSize: Survival is affected by species and size; X1mnth: Animal alive 1 month after stranding; X1yr: Animal alive 1 year after stranding; NoRestrand: Animal does not re-strand within days of re-float; 6mnth: Animal alive 6 months after stranding; BodCon: Animal's body condition; NoStrand: The number of re-stranded animals; RespRefloat: Response of animal when re-floated; NoSuff: Avoids suffering; Cause: Cause of stranding still present.

A total of 3.8% "Don't know" responses were provided in answer to this question for welfare, and which data imputation was undertaken. The LDA carried out found that the first two discriminant axes accounted for 70% of the variation (Figure A5.3). The LDA again showed substantial overlap among expertise groups, though the 'animal welfare expert with knowledge and/or focus on cetaceans' appeared slightly more differentiated. However, the variance among the group appeared larger and there were few data points (n = 3). 'Animal welfare expert with knowledge and/or focus on cetaceans' group appeared to score 'Ability to diagnose internal injuries ante-mortem, including capture myopathy' (InternInj) as less of a knowledge gap in contrast to 'cetacean expert (including cetacean conservation and biology)' (n = 16) that were more likely to score this category as an important knowledge gap. The 'animal welfare expert (including animal welfare science, welfare/animal ethics)' (n = 9) were more likely to score 'Ability to assess what animals feel or their mental state' (Feel) as a key knowledge gap.

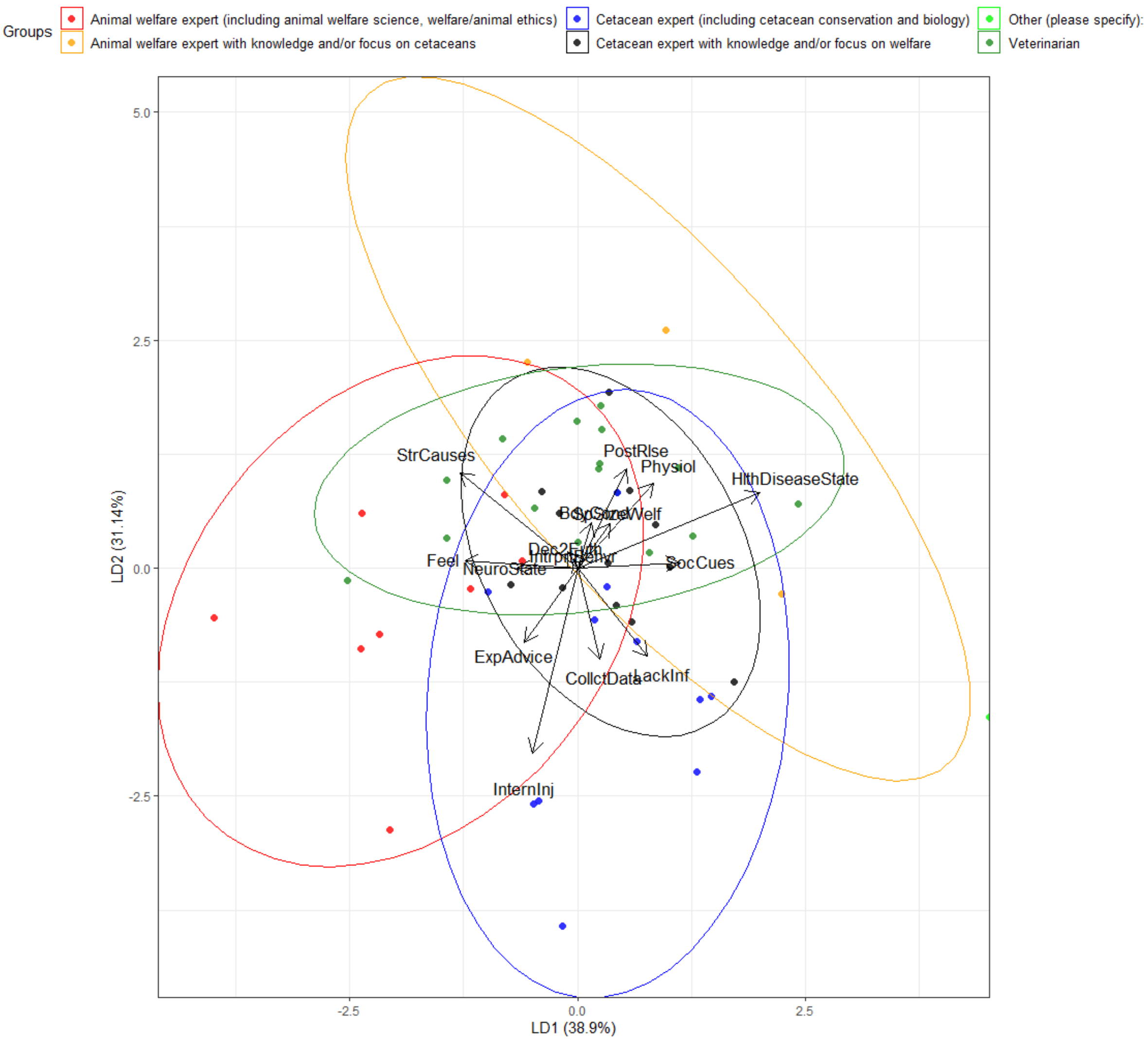

Figure A5.3. Biplot of the linear discriminant analysis of category scores for the topic on welfare knowledge gaps, which attempts to find axes that discriminate among expertise groups. Category key: PostRlse: Post release monitoring to understand survival, outcomes or success of re-floatation; CollctData: Collection and documentation of empirical data to assist triage/ decision-making; Dec2Euth: How to make decisions about when and how to euthanise stranded cetaceans; LackInf: Lack of information, education and awareness for potential responders about if, when and how to respond; SpSizeWelf: Effects of species, animal size and features of the stranding (geographical location and duration) on welfare; InternInj: Ability to diagnose internal injuries ante-mortem, including capture myopathy; Physiol: Ability to assess physiological indicators and recognise deviations from normal/baseline; Feel: Ability to assess what animals feel or their mental state; HlthDiseaseState: Understanding the health and disease status of the animal; ExpAdvice: Lack of specialist/ expert advice and consultation from those with field experience and veterinarian; NeuroState: Assessment and interpretation of indicators of neurological state and responsiveness/sensibility; BdyCond: Ability to assess body condition; StrCauses: Causes of stranding and how to prevent stranding; IntrprtBehvr: Ability to interpret stranded cetacean behaviour in terms of welfare state; SocCues: Understanding social support and communication among animals.

There was more uncertainty about survival knowledge gaps, with 11% “Don’t know” responses provided, for which data imputation was undertaken. In the LDA the first two discriminant axes accounted for 63% of the variation (Figure A5.4). Once again, the LDA found overlap among expertise groups, although the ‘animal welfare expert (including animal welfare science, welfare/animal ethics)’ group (n = 9) appeared to group slightly more on the negative side of LD1. They were more likely to score ‘Ability to diagnose diseases and infections on the beach’ (Disease) as an important knowledge gap. The ‘cetacean expert (including cetacean conservation and biology)’ (n = 16) scored ‘Lack of post release monitoring to measure survival outcomes’ (SurvivOutcome) as an important knowledge gap and scored ‘Lack of data for species-specific survival’ (SpSurvival) as less of a knowledge gap, which was in contrast to ‘cetacean expert with knowledge and/or focus on welfare’ (n = 12) who scored these categories inversely.

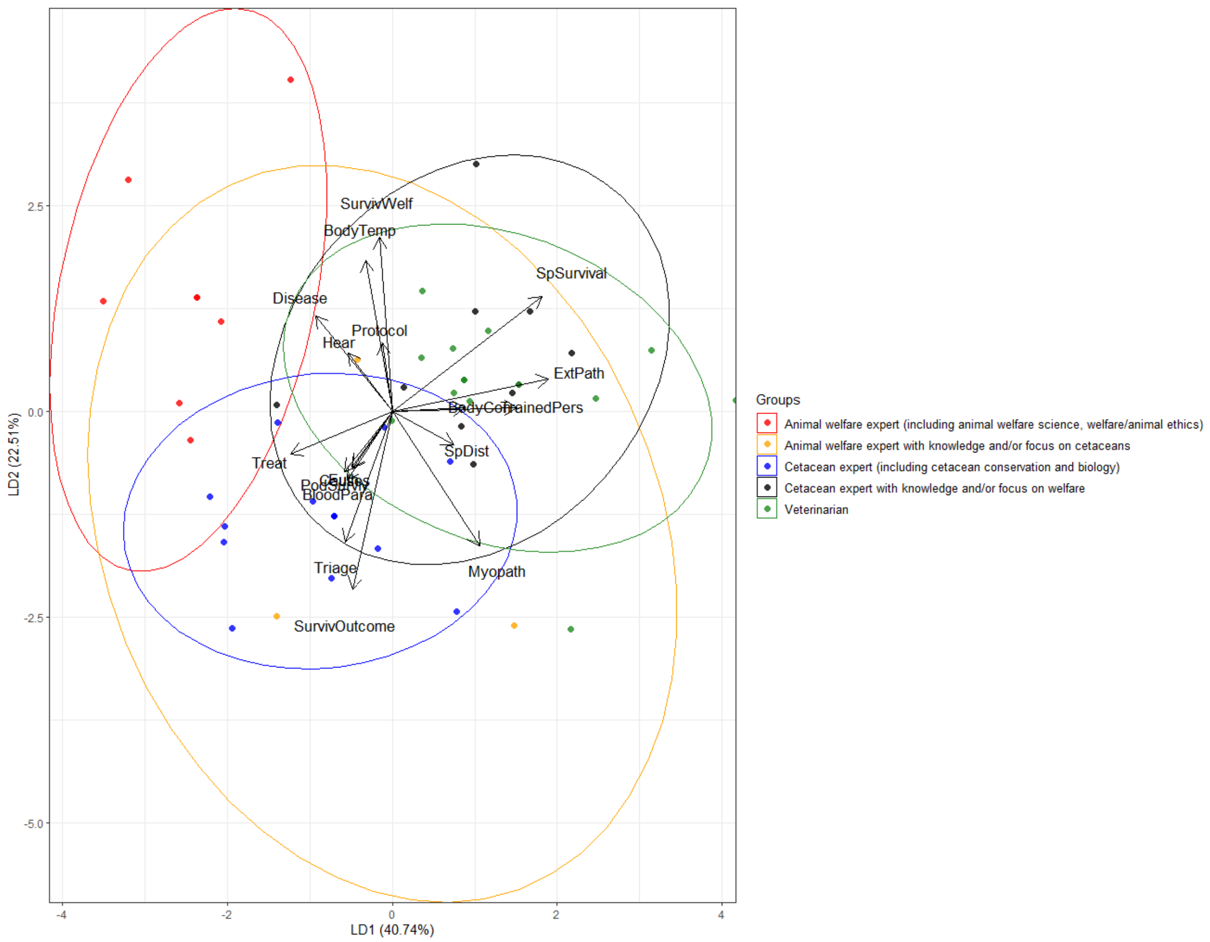

Figure A5.4. Biplot of the linear discriminant analysis of category scores for the topic on survival knowledge gaps, which attempts to find axes that discriminate among expertise groups. Category key: SurvivOutcome: Lack of post release monitoring to measure survival outcomes; BloodPara: Lack of normal/baseline blood parameters and profiles; SpSurvival: Lack of data for species-specific survival; SurvivWelf: Lack of knowledge on the links between survival and welfare; Myopath: Ability to determine presence of myopathy; Disease: Ability to diagnose diseases and infections on the beach; Causes: Lack of knowledge about causes and prevention of strandings and effects of local ecosystem changes; TrainedPers: Lack of trained and skilled responders; BodyCon: Ability to assess body condition and blubber thickness; SpDist: Lack of data on species distribution; PodSurviv: Lack of data on the effects of conspecifics presence on survival; Euth: How to make decisions about when and how to euthanise stranded cetaceans; Triage: Ability to triage current state/condition; BodyTemp: Ability to assess internal body temperature; Hear: Lack of knowledge about hearing impairments; Protocol: Lack of standardised protocols to follow; Treat: Lack of knowledge of treatments and their effectiveness; ExtPath: Lack of knowledge on the links between external assessments and pathology.

Identifying key concerns about stranded cetacean welfare and survival

There were 6% responses of “Don’t know” for this welfare question, for which data imputation was carried out. In the LDA undertaken the first two discriminant axes accounted for 70% of the variation (Figure A5.5). The LDA found that ‘animal welfare expert with knowledge and/or focus on cetaceans' (n = 3) appeared to group more on the positive side of LD1 and negative side of LD2. They scored 'Difficulty breathing, inhalation of water' (DiffBreathe) as a key concern for welfare, but scored 'Physical damage, stress, pain and thermal discomfort due to overheating, hyperthermia, heat stroke and hypothermia' (PhysDamage) as less of a concern. In contrast, 'veterinarian' (n = 20) appeared to score these two categories inversely. Experts in 'animal welfare expert (including animal welfare science, welfare/animal ethics)' (n = 9) scored 'Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun' (SkinDamage) as an important welfare concern, whereas 'cetacean expert (including cetacean conservation and biology)' (n = 16) scored 'Inappropriate human intervention, poor handling, responder training and experience, and public pressure influencing decisions' (InappInterv) as a more important welfare concern.

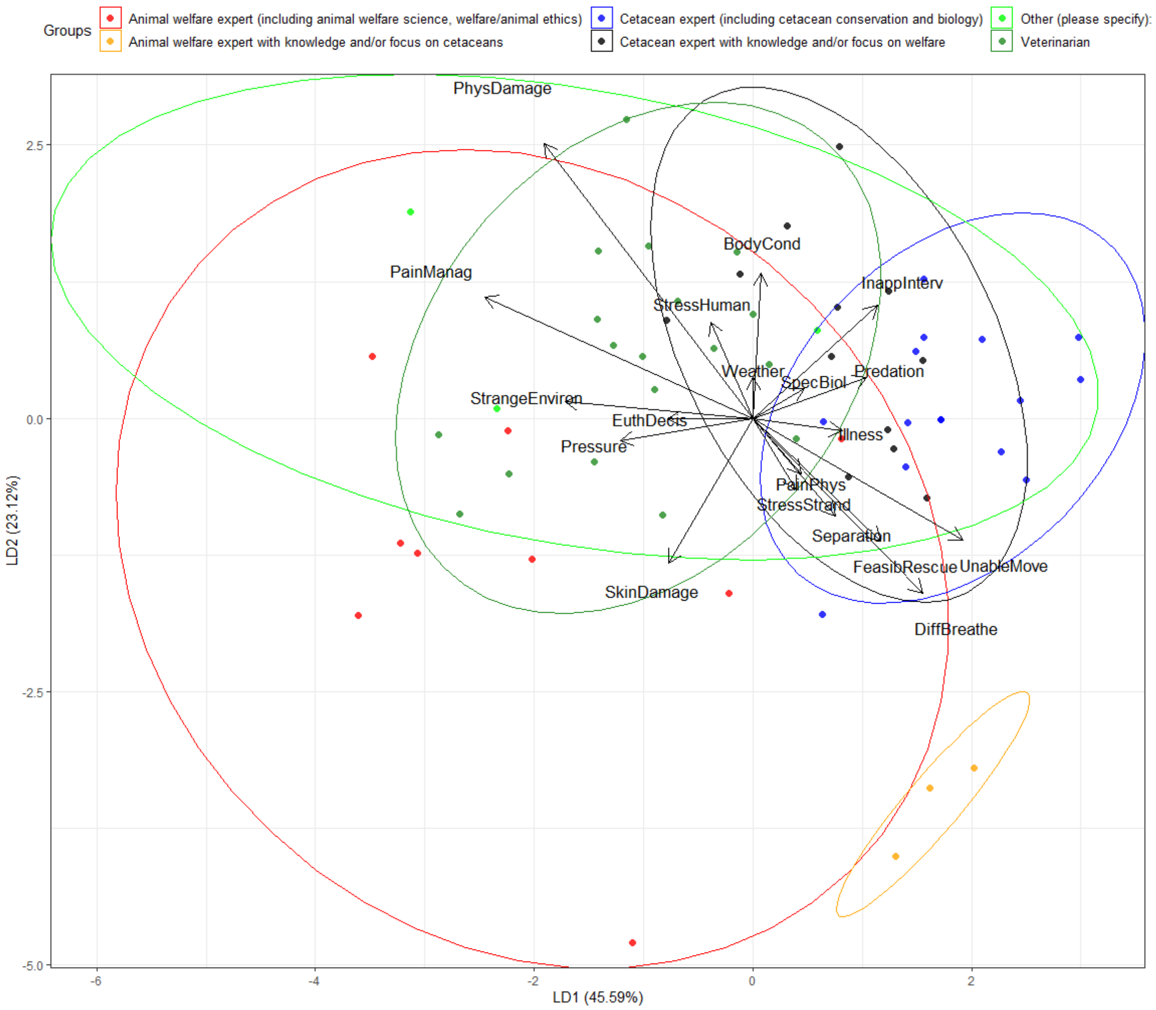

Figure A5.5. Biplot of the linear discriminant analysis of category scores for the topic on key welfare concerns, which attempts to find axes that discriminate among expertise groups. Category key: InappInterv: Inappropriate human intervention, poor handling, responder training and experience, and public pressure influencing decisions; PainPhys: Pain and suffering due to physical injury or trauma caused by stranding, particularly substrate; StressHuman: Stress, fear, distress or pain caused by human presence, interactions, noise; Pressure: Effects of gravity, body weight, pressure on animal's organ function and physiology and causing internal injuries and pain as a result of not being supported by water; UnableMove: Fear, stress, distress or helplessness at being unable to move or help themselves; StrangeEnviron: Fear and stress at being in a strange, novel environment; Separation: Separation from conspecifics/social group, including mother-calf separation; StressStrand: Suffering, stress and anxiety associated with stranding; SkinDamage: Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun; FeasibRescue: Feasibility of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety; PhysDamage: Physical damage, stress, pain and thermal discomfort due to overheating, hyperthermia, heat stroke and hypothermia; Predation: Fear and pain from predation; EuthDecis: Delays to deciding on euthanasia to relieve suffering; Weather: Weather and environmental conditions; BodyCond: Nutritional stress, poor body condition; Illness: Animals suffering from illness, disease and underlying health conditions; DiffBreathe: Difficulty breathing, inhalation of water; SpecBiol: Effect of species biology, resilience and stranding type on welfare outcomes; PainManag: Pain and its management.

For survival there were 7% responses of “Don’t know” and data imputation was undertaken. The first two discriminant axes in the LDA accounted for 73% of the variation (Figure A5.6). The LDA showed that ‘animal welfare expert with knowledge and/or focus on cetaceans’ (n = 3) grouped more on the negative side of LD1 whilst the ‘Other’ expertise grouped on the positive side of LD1. However, there was still overlap among groups. The ‘animal welfare expert with knowledge and/or focus on cetaceans’ scored variables ‘Substrate/terrain at the stranding location’ (Substrate) as an important concern for survival and scored ‘Presence of predators and scavengers’ (Predators) as less important, this was in contrast to the ‘cetacean expert (including cetacean conservation and biology)’ (n = 16) who scored these categories in the inverse. The ‘animal welfare expert (including animal welfare science, welfare/animal ethics)’ (n = 9) scored ‘Availability of appropriate and timely human intervention and handling, responder training and experience’ (AvailHuman) as an important survival concern but scored ‘Feasibility and speed of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety’ (FeasibRefloat) as a less important concern.

Figure A5.6. Biplot of the linear discriminant analysis of category scores for the topic on key survival concerns, which attempts to find axes that discriminate among expertise groups. Category key: FeasibRefloat: Feasibility and speed of rescue/re-floatation based on human and equipment resources, location of stranding, time of day, responder expertise and experience and human safety; Restrand: Length of time stranded and number of re-strandings; Weather: Weather and environmental conditions, including tides; Injury : Physical injury or trauma caused by stranding; Illness: Animal suffering from illness, disease and underlying health conditions; Separation: Separation from conspecifics/social group; Age: Animal age based on length/weight and reproductive status; Pressure: Effects of gravity, body weight, pressure on animal's organ function and physiology and causing internal injuries and pain as a result of not being supported by water; BodyCon: Body condition and nutritional status; AvailHuman: Availability of appropriate and timely human intervention and handling, responder training and experience; HabitatRange: Geographical location of stranding and being out of habitat or range; SpBiol: Effect of species biology on survivorship; Cause: Cause of stranding still present; StressStrand: Stress, anxiety and associated conditions caused by stranding; Predators: Presence of predators and scavengers; DiffBreath: Difficulty breathing, inhalation of water; SkinDam: Skin damage and associated pain due to sunburn, dehydration/desiccation occurring when out of water in sun; Substrate: Substrate/terrain at the stranding location; AbnormMov: Abnormal movements and reduced limb function; Aware; Animal awareness and neurological status.

Discussion of the agreement across expert disciplines

A secondary aim of this study was to look for differences in the way welfare and survival likelihood are understood, the associated key concerns and knowledge gaps, among expert respondents with different backgrounds. These data were collectively generated by an interdisciplinary panel of international experts in cetacean biology, medicine, and animal welfare science. This diversity was vital to ensure elicitation of both welfare and conservation focused factors since previous studies have found perspectives on relevant topics to be discipline-specific (Beausoleil et al. 2018; Clegg et al. 2021).

Interestingly, the findings revealed consensus among the varied expertise regarding how to characterise and understand the welfare and survival likelihood of stranded cetaceans. Despite almost half the participants reporting no knowledge of animal welfare and a third reporting only some knowledge, overlap among expertise for all categories was evident in the analyses, suggesting a lack of effect of expertise. Consensus was also evident among the expert panellists regarding the major knowledge gaps that need to be addressed and the key concerns that may affect stranded cetacean welfare and survival likelihood. Overall, this suggests that experts from the different backgrounds represented in this study, conceptualise the welfare and survival of stranded cetaceans similarly and have comparable concerns about these issues.

The experts in this study represent those disciplines that provide guidance and influence decision-making at strandings. Although unity among experts in this study was evident, management of stranding events has typically been focused on re-floating as many individuals as possible, reflecting a conservation focus. However, based on the results, it is clear that stranding management decisions should be undertaken based on scientific assessment of the animal, both in terms of welfare state and survival likelihood. This is particularly pertinent since welfare compromised individuals may experience prolonged suffering and may not survive, even if re-floatation is achieved (Sharp et al. 2014; Brownlow et al. 2015b; Dolman and Moore 2017; Marks et al. 2020).

Appendix 6 Indicator categories for welfare and survival likelihood and potential welfare experiences: Chapter 3

Table A6.1. Themes of welfare indicators based on reflexive thematic analysis of expert opinions from questionnaire 1, transcribed as intelligent verbatim. Themes found for both welfare and survival likelihood are in bold.

Final theme	Original terms
Ability to euthanise and how/when to make the decision	Assessment of euthanasia options if appropriate
Ability to remain upright and float	Disorientation and inability to maintain buoyancy; Righting reflex; Amount of body being supported (buoyancy) and cooled by water; Fail to remain upright; 'Righting response' when refloated; Ability to float 'upright' - problems with buoyancy? Is it tilting to one side? Unable to float?; Animal should be in an upright position to allow breathing with both lungs
Abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering	Abnormal movements like thrashing, arching of the body; Signs of pain - arching; Movement; Agitation can be indicators of pain or stress; Distress of animal (thrashing), hyperactivity, straining muscles, attempting to shift position in the substrate, attempting to release from substrate; Activity (trying to move, trashing vs laying still); Fluke slapping; Agitated movements; Thrash; Becoming agitated when approached or attempts made at refloating; Behaviour- are they demonstrating signs of psychological stress such as tremoring, slapping their tail flukes on the ground; Calm movements; Body movement (thrashing); Activity levels; Unusual behaviour that may indicate a neurological issue; Temperament (e.g. Agitated, anxious, excitable); Muscle movements (e.g. Tremors, arching, stiffness); Attempts to regain water - thrashing about; Unusual movements; Trembling/shivering; Flapping tail on beach indicates disquiet; Behavioural observations of normal vs. Abnormal behaviour; Behaviours indicative of fear; Movement, or lack of; Arching/shivering/shuddering behaviour (bad); Is animal attempting to remain in

	water; Frequency of attempts to move, right oneself, Frequency of tail/fin movement; Behaviour e.g. Attempts to move; Species specific behaviours; Behaviours such as thrashing; Physical movements e.g. Rapid movement of tail peduncle, agonal movement; Thrashing about is an obvious sign of distress; Wincing, thrashing or tensing behaviours; Attempting movement; Behaviour idiosyncrasies: arching, crunching, listing, tremors; Head swinging, idiosyncratic behaviour; Gnashing teeth; Behaviour including avoidance, stiffness, agonistic behaviour; Behaviour; Inactivity; Not to struggle overmuch; Lack of mobility
Amount and level of noise	Noise; Loud noises, people shouting loudly to each other during rescue or attendance activities; Noise level
Amount of human interaction and knowledge of responders	Amount of human interaction/presence on scene; Human resources; Experience with a range of scenarios is critical for effective responses; Elevated number of people around one individual, one anxious and stressed person may transfer more stress than several calm individuals; Ethical guide which includes all aspects of animal welfare; Number of people nearby (crowds); Presence of stranding responders for any treatment/ to protect from elements, presence of knowledgeable stranding responders (less likely to induce stress); Good management of stranding responders, including welfare and ethical frameworks; Observations of human interaction (not a welfare indicator but helps to define likely impacts on animal and welfare state of animal) e.g. Are they calm, skilled; Dogs
Animal age based on length/weight, and reproductive status	Age (juvenile/dependent calf vs adult); Estimated age, particularly in relation to weaning; Assessment of age particularly in regard to whether maternally dependent; Species and animals size, life stage (e.g. Maternally dependent calves); How mature is the individual, i.e., post-weaned?; Demographic profiles of dead and alive (e.g. Age/size classes); If an individual is weaned/mature or independent and the presence of mother if still dependent (average weaning length per species); Animal's relative age e.g. Young animal still dependent on its mother, but without the mother present, or juvenile versus fully grown adult; Animal size/weight; Weight of animal - heavier animal more likely to have difficulty breathing and experience

	distress caused by loss of support for body weight; Age - is it a neonate? (did it strand alone or with its mum?) Or adult?; Umbilicus/lingual papillae; Life history (e.g. Dependent calf); Species and size- larger species may be impossible to move in terms of response triage; If female, is she pregnant?; Reproduction; Calving success; Sexual behaviours
Animal is entangled	Entanglement minor to serious; Entanglements; Materials present or signs of entanglement which might indicate underlying wounds; Obvious entrapment or evidence of external trauma
Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness	Mentation - responsiveness to stimulation (e.g. Manipulation of mouth or tongue) indicating alertness and awareness vs non-responsiveness, blink response; Level of consciousness; Degree of liveliness of the animal; Assessment of muscle tone and reflexes; Attentive to its surroundings, reacting to movements/touch; Alertness, response to stimuli; Response to application of cooling/water/shade, response to refloatation; Response to stimuli (level of consciousness); Reacting appropriately to stimuli; Eye reflex; Nervous symptoms; Alertness; Diminishing responsiveness to stimuli; Diminishing muscle tone (e.g., sagging lips); Neurological signs (e.g., nystagmus, loss of blowhole, palpebral and other reflexes); Any evidence of severe depression indicated by loss of normal protective reflexes (e.g. Tongue withdrawal, palpebral and corneal reflexes, blowhole); Flinch/blink reaction; Responsiveness; Response to human presence; Reflexes pain, eye, movement; Lack of response to touch around the eye; Reflexes; Responses to touch/movement/noise, how alert the animal is; Degree of responsiveness to stimuli - such as reaction to humans handling it; Eyelid/blowhole reflexes/jaw tone, pupil reflex, menace response, young flipper reflex; Neurologic assessment; If the animal is immobile and unresponsive check reflexes e.g. Tap eye; Eye, blowhole reflex; Abr assessment; Not responding when approached or attempts made at refloating; Nystagmus
Animals skin condition such as sunburn, peeling, cracking or blistering	Physical assessment of skin condition, signs of exposure (e.g. Sunburn); Skin condition and hydration; Integrity and appearance of the skin (unbroken, smooth and shiny are indicative of good conditions); Skin condition; Skin damage; Cracked skin; Sunburn; Skin condition (signs of desiccation- peeling, cracking);

	Is there a skin lesion or abnormality?; Skin condition; Damage to skin; Extensive skin disease; Obvious damage to external skin; Blistering, freshwater skin disease; Dry skin should be minimised; Skin integrity of concern if sun or dryness induced blisters have started to appear; Skin condition sunburn, desiccation, live scavenging; Assessments of coat/skin; Skin conditions dry cracked; Skin marking damage especially in some species; Skin condition (wrinkles indicative of dehydration, sunburn, blisters); Physical condition including skin state and cleanliness
Availability of resources including equipment	Assessment of logistics of refloatation if appropriate; Assessment of access and transport logistics if rehabilitation appropriate; Equipment resources, Boats available; Resources and equipment to refloat and tow to suitable habitat; Distance to suitable release site if not at location of stranding; Resource availability (people, boats, safety gear, heavy equipment); Are there resources and appropriate facility available for rehabilitation?
Behaviour prior to stranding	Swimming behaviour before stranding; Observed behaviour prior to stranding; Pre stranding behaviours, circling potential infection
Bleeding/fluids/mucus from orifices	Evidence of blood from major orifices; Presence of deep bleeding from orifices; Bleeding from the ears or eyes; Bleeding from orifices; Mucus from blow hole; Mucus discharge from blowhole, presence of bleeding from blowhole; Presence of blood in body fluids (vaginal, anal, septum); Abnormal secretions; Bleeding or fluid discharge from body openings; Presence of froth in blowhole; Discharge from anywhere; Respiratory discharge; State of orifices
Blowhole condition	Blowhole function (closing properly between breaths); Blowhole condition; State of orifices
Body condition or nutritional status	Body condition; Body condition score; Nutritional status; Body conditions (animal well nourished, without showing signs of thinness like protruding bones); Assessment of hydration; Bcs; Body condition: emaciation; Overall body condition; Physical condition (roundness of torso); Overall body condition i.e. Emaciated or in a 'normal' body condition weight wise; Good, thin, emaciated; Body condition (slim);

	Body condition/emaciation; Body condition - body fat; Body condition based on the appearance of the epaxial muscle mass; Body condition (emaciated, thin, robust); Nutritional condition (blubber thickness (ultrasound?) Or assessment of external features which resemble this, like body shape); Loss of body condition, is it skinny; Overall physical condition - is it emaciated?; Body condition (signs of malnourishment); Body condition (shape or depth of blubber layer); Body score; Body condition (e.g. Nutritional status); Starvation; Body condition ("neck" or ribs visible); Body shape; Physical condition; Knowledge on cetacean in all the physical domains of nutrition
Capillary refill time	Capillary refill of the tongue to assess circulation; Capillary refill time
Colour and consistency of faeces	Diarrhoea; Defecation; Colouration and make up of faeces; Faeces description (foam, flatulence, greenish colour); Presence of urine or faeces and consistency/colour of both
Condition of teeth	Are their teeth normal?; Worn or broken teeth; Growths on teeth or beak; Teeth wear
Core/internal body temperature	Body temperature; Core temperature; Hyperthermia; Temperature; Hyperthermia/dehydration; Body temperature based on deep rectal temperature i.e., hyperthermia or hypothermia; Core body temperature; Temperature (e.g., increasing temperature); Internal temperature potentially measured through ocular temp, "hot spots" behind the dorsal fin which could potentially be measured to assess temp changes; Inner core temperature - measured by anal temperature probe - only used by vet
Distance to animal's natural habitat type	Species vs habitat/geographic region; Access to deep water habitat for pelagic species that have stranded in shallow water; Out of its regular habitat range; Species vs stranding location (e.g. Out of habitat animals, with long distances from their normal home range); Stranding location within or out of the habitat; Distance from habitat; Location to normal feeding ground coastal pelagic and coastline; Habitat (e.g. Offshore species in inland waters); Consider how far out of natural range animal may be; Available

	habitat- enclosure or temporary holding; Distance to suitable release site if not at location of stranding; Suitability of release site (rocky vs. Sandy vs. Muddy, beach/bank steepness)
Distance/position of animal from sea	Animal position in relation to shoreline (in water, hard on beach, in rocks, at bulkhead, etc.); Ability of animal to be placed back into water environment (are there obstructions or too many humans around); Distance from water source; Distance from the open sea
Eye behaviour	Possibly blink rate, iris diameter, % of sclera displayed; Signs of pain- closed eyes; Eye movements; Wide eyes; Open eyes; Eyes open or closed; Eye movement i.e., blinking and pupil dilation; Nystagmus
Eye condition/damage	Eyes; Damage to eyes; Obvious damage to eyes; Eye condition; State of orifices; Mucosal surfaces inc eyes
Genital condition	Eversion of penis; Genital condition; State of orifices
Hearing ability	Full functioning condition including the hearing/orientation; Abr assessment
Heart rate and rhythm	Heart rate; Pulse rate; Crt; Heart rate may go up (or down, which can signal some degree of catatonia); Heart rate and rhythm (tachycardia, loss of normal sinus arrhythmia); Heart rate and variability; Heartbeat
Human activity in surrounding environment	The presence of anthropogenic activities during or pre stranding (such as military activities or other sound-sources); Entanglement with human activities; Presence of military vessels
Length of time stranded and number of re-strandings	Refloating history (i.e. Whether animal has been unsuccessfully returned to the ocean already), duration of stranding; Length of time stranded, particularly in relation to body size; Approximate time of stranding (length of grounding); How long the animal has been stranded; Length of time stranded; Temporal and spatial aspects of the stranding, e.g. Duration of time that individuals have been ashore (although - some are very resilient to being ashore for extended periods); Length of time out of water; How many tides the animal/s have been stranded for; If the animals have been stranded for more than one tide; Estimated time

	since the animal came ashore; Length of time since stranding occurred; How long have they been stranded; Time ashore; Duration of stranding so far, number of times it/they stranded prior to the current stranding; Prior strandings, near strandings; Attempt to return to stranding site
Level of water surrounding animal that may provide support	Amount of water surrounding animal which may provide a degree of buoyancy/support; Amount of water they are submerged in if any; Depth of water where the stranding occurred relative to animal's size
Location of stranding and accessibility for responders	Location of stranding; The accessibility of the location to people and to equipment that may be needed; Geographical conditions, availability of help from humans, is there a suitable, accessible site for refloating?
Measurement of blood parameters and serum/plasma chemistry	Haematology (e.g. PCV); Blood measures (if taken or takeable), dehydration; Organ damage; Blood gas, lactate and electrolytes (e.g. Lactate, ph, pco2, etc); Complete blood count (e.g. WBC, etc); Oxygen levels e.g. Saturation in blood; Blood values if available and other ancillary diagnostic tools; Hydration status; Blood values; Blood indicators; Blood chemistry may provide some clues; Biochemistry (e.g. Urea, creatinine, muscle enzymes); Serum/plasma chemistry (e.g. CK, LDH, AST, BUN, Creatinine, Glucose, etc); Plasma chemistry indicators of organ function (by use of point of care analysers if available and if blood can be obtained)
Measurements of stress hormones	Measurements of blood cortisol, aldosterone, epinephrine and norepinephrine levels; Cortisol; Stress hormones (e.g., cortisol, aldosterone, epinephrine and norepinephrine, etc); Cortisol measures in exhalation samples or blood; Catecholamine and corticosteroid plasma levels; Blood parameters (stress leukogram), cortisol (saliva)
No movement/response, lethargic	Laying still; Movement, or lack of; Lethargy; Inactivity; Not to struggle overmuch; Lack of mobility; Lethargy can indicate that the animal is sick or debilitated; Lethargic

Post release monitoring	Telemetry
Presence and behaviour of pod members	Presence of other unstranded pod members in the case of social species; Presence and behaviour of conspecifics; The presence of other animals either stranded or in the water nearby; Is the pod or family nearby?; Presence/interactions of other individuals and/or other species (e.g. Interactions between pilot whales and offshore bottlenose dolphins at mixed stranding events); Presence or absence of other animals, being able to see/hear pod-mates may help to calm the individual however if it is a mother, hearing their young, or not hearing their young may cause increased stress; Reintegration with pod/social group; Distance between individuals (especially mothers and calves); Proximity of social group, presence of older animals in social group; Group/socialising, reintegration; Social needs; Social activities; Social considerations (e.g. Conspecific injuries, social species, etc.); Whether a species is gregarious or group forming and has stranded alone or with other group members/part of a pod; # of animals; Response to conspecifics e.g. Vocalisation
Presence of parasites	Presence of parasites, whale lice, barnacles; Skin parasites
Presence of predators and scavengers	The presence of predators; Signs of scavenging; Presence or risk of scavengers attacking; Predator presence
Presence of red tide/algal blooms	Red tide into the area
Ratio of live to deceased animals	Ratios of dead to alive
Respiration rate and character/effort	Respiratory; Respiratory rate; Respiration; Breathing rate and character and, depending on the animal's size, lung auscultation; Breathing rate and nature; Breath frequency and intensity; Assessment of respiratory rate and character; Increased or profoundly decreased respiratory rate, shallow respirations; Breathing rate; Respiratory; Indicators of distress - respiratory; Breathing rate may be unusual - too high or too low; Respiration rate is either very slow or very rapid; Respiratory rate and expiratory-inspiratory

	gap; Calming of breathing; Is respiration regular?; Breathing rates (elevated can indicate distress); Respiratory effort; Coughing, abnormal and respiratory rates; The animals breathing pattern; Abnormal respiration; Shallow laboured breathing, with wheezing and slow opening and closing of the blowhole; Rate of respiration; Breathing rate of concern if abnormally high for the species; Respiration rate and quality; Respiration rate and variability; Frequency of breathing; Compromised respiration; Breaths/minute; Breathing rate depending on species, fast stress but excessive breath holding is also bad; Breathing rate
Signs of illness and disease	Evidence of concomitant disease processes (both incidental and causative to stranding); Signs of illness/disease such as skin lesions; Presence of signs of illness and their severity; Are there obvious signs of a systemic illness?; External wounds or lesions that may indicate disease, pathogens; General health levels (any underlying disease); Extensive skin disease; Disease incidence; Health
Signs of physical trauma, injuries and wounds	Signs of physical trauma e.g. Wounds, fractures, breach of a body cavity; Severity of wounds if any; Extent of any trauma; Physical assessment of injuries; External injuries; Injuries; Abrasions or injuries; Visible injury, bleeding; Presence of injuries and their severity; Visible injury or a missing part of the body; Observable physical injuries; Bleeding from injuries; External wounds or lesions that may indicate serious injury; Presence of wound severity; Wounds; Obvious entrapment or evidence of external trauma; Injuries/cuts; Physical injuries, bleeding; Injuries - shark or orca bites, boat indicators such as propeller cuts, severe bruising, missing tail flukes; Impact bruising added to cuts ranging from lacerations to removal of parts, cookiecutter bites, other shark bites; Visible evidence of abrasion/bruising; Presence of injuries/trauma; Any external evidence of serious injury; External lesions (propeller marks, abrasions indicating significant struggle on beach/in surf); Obvious injury?; Number of abrasions, other wounds; Presence and extension of lesions; Wound assessment; Assessment of wounds/injuries; Does it have fresh wounds or debilitating injuries?; Injuries or ligatures, blood loss; Obvious injury's open wounds; Observable lesions (e.g. Wounds); Assessment of visible wounds including whether they are likely to be

	life-limiting/threatening/treatable on the shore or require a period of captive rehabilitation where that is possible; Wounds on body; Lesion assessment; Obvious injuries; Visible injuries
Smell of blow/breath	Does the breath have a putrid smell?; Breath overly smelly; The way it smells (bad odour vs normal bad odour!)
Species biology and response to stress	Whether the animal is a deep diving species; Assessment of species e.g. Coastal/pelagic, solitary/social; Species (native, migrating or uncommon; Solitary vs gregarious); Species, i.e., is this a species that is generally robust when interacting with humans (orcas) or is it a species that is known to have a strong acute stress response to being handled (vaquita)?; Species involved i.e. Coastal versus offshore species
Substrate/surface type at the stranding location	Substrate the animal is on; Environment- beach substrate; Rocky vs sandy location; The beach/land configuration - e.g. Sand, rocks, - etc; Environment- terrain (sand vs mud vs rocks); The surface the animal is on; Location of stranding e.g. If animal has stranded on a sandy beach or on rocks; Suitability of release site (rocky vs. Sandy vs. Muddy, beach/bank steepness; Nature of surface stranded on - fine sand probably better than coarse sand which is probably better than uneven rocks; The location of stranding (e.g. The substrate); Substrate at stranding location (rocks/sand/pebbles)
Swimming ability and orientation when returned to water	Swimming movement if in the shallows; Activity - is it swimming normally? Can it float upright or does it tilt to the side?; Assessment of behaviour when returned to water; Strong and controlled swimming response in water; How well can the individual swim or move around in the water; Mobility and strength of swimming; Orientation and ability to swim unassisted, uncoordinated swimming; Swimming then on the side and upside down; Ability to orientate, swim to avoid potential threats or reach optimal aquatic conditions and respond to presence of conspecifics/re-join social group; Swimming speed/diving behaviour - are they exhibiting baseline swimming/diving behaviours after being re-floated or are they somehow erratic?; Indications of neurological conditions swimming in tight circles in one direction; Can it swim on its own; Stereotypic swimming; Ability to feed; Way of swimming

Time of day	Time of day
Vocalisation rate and type	Vocalizing on land; Vocalisation; Intense vocalization can be indicators of pain or stress; Increased vocalizations with possible distress calls; Is the individual making contact calls or sounds of any kind?; Calls; Excessive vocalisation probably indicates they are looking for a baby; A change in vocalisation; Rate or power of vocalisations; Vocalisation rate
Vomiting	Vomiting
Weather, ambient temperature, sea and tidal conditions	Weather and oceanic conditions; Weather conditions tide and sea conditions; Light; Environmental conditions (e.g. Tide [dry-docked vs still slightly floating]; Hot vs cold ambient temperatures, sunny vs cloudy/rainy days; Weather conditions, especially sea state; Weather (heat, wind, cold, rain); The environment - temperature; Weather conditions; Heat; Wave/current speed, tidal conditions; Temperature, % cloud cover; Weather condition: rain, sun, temperature, tide and beach condition; Tides and weather; Surf/water conditions to get it off the beach; External temperature; Would the environmental conditions allow immediate refloating?; Weather/wind/surf forecast, tidal predictions; Protection from sun and wind which can cause drying out of skin and cause deep skin lesions that can cause infection; Shelter at stranding location (waves/sun/wind); Observations of environment including time of year, time of day, water temperature, air temperature; Environment

Table A6.2. Themes of indicators of survival likelihood based on reflexive thematic analysis of expert opinions from questionnaire 1, transcribed as intelligent verbatim. Themes found for both welfare and survival likelihood are in bold.

Final theme	**Original terms**
Ability to euthanise and how/when to make the decision	Assessment of euthanasia options if appropriate
Ability to remain upright and float	Stranded on one side; Regain their balance soon; Ability to float 'upright'; Ability to stay upright; Disorientation; Attempts to remain in water
Abnormal movements and behaviours including arching, thrashing, shivering, movements of pectoral and caudal fins	Ability to stir its tail; Body movement (thrashing); Behaviour; Abnormal movements; Arching/shivering/shuddering behaviour (bad); Behaviour such as thrashing; Behavioural indicators such as movement of pectoral or caudal fins; Gnashing teeth
Animal age based on length/weight and reproductive status	Age; Skinny juvenile with no mother in attendance; Assessment of age particularly in regard to whether maternally dependent; Estimated age; Animal age; Animal length; Age is an indicator - dependent calves separated from their mothers are unlikely to survive if refloated or released; Size/approximate weight; Being maternally dependant; Animal size/weight; Size, age; Weight; Length or proxies for age; Age (neonate vs adult); Reproducing; Sex
Animal is entangled	Deep entanglement
Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness	Blink response, blowhole function, response to stimuli; Level of consciousness; Appear aware of the environment; Cetacean attentive to what happens around it; Response to touch; Assessment of muscle tone and reflexes; Attentiveness; Severe non responsiveness - do not refloat a comatose animal; Responsiveness - level of activity when refloated, reflexes; Activity levels; Response to sound upon refloating e.g. Recognises sounds of

	conspecific vocalisations, recognises & avoids 'threat' sounds; Flinch/blink reaction; Responsiveness; Reflexes; Responses to touch/movement/noise, how alert the animal is; Activity or response of the animal; Neurologic assessment; Lethargy
Animal’s skin condition such as sunburn, blistering/integrity or desiccation	Skin condition and hydration; Integrity of the skin; Good skin condition; Skin integrity; Physical injuries to skin; Extensive, serious skin disease, extensive skin burns; Extensive skin damage (blistering, crabs, gulls) leading to body fluid loss; Skin condition (sunburn, desiccation); Assessment of skin; Skin condition
Availability of food and appropriate feeding behaviours once refloated	Appetite; Presence of appropriate food; Accessibility of food in local area once refloated; Species (and population) appropriate behaviours such as foraging [including aspects such as food-sharing etc]
Availability of resources including equipment	Assessment of logistics of refloatation if appropriate; Assessment of access and transport logistics if rehabilitation appropriate; Duration until a boat arrives; Resource availability in terms of appropriate equipment; Adequate resourcing i.e. People, equipment etc; How much help do you have to get the animal back in the water; Available assistance; Distance to suitable release site if not at location of stranding; Resource availability (people, boats, safety gear, heavy equipment); Facilities available; Shelter at stranding location (waves/sun/wind); Veterinary hospital available or basic infrastructure
Behaviour prior to stranding	Observed behaviour prior to stranding.
Bleeding/fluids/mucus from orifices	Presence of deep bleeding from orifices; Bleeding from orifices; Mucus from blow hole; Presence of froth in blowhole; Any signs of mucus
Body condition and nutritional status	Body condition; Body condition score; Well fed, with energy reserves; Good body conditions; BCS; Length:girth ratio; Body condition - if an animal is severely emaciated, for example, then likelihood of survival seems low; Good body condition; Nutritional condition; Physical condition (roundness of torso); Bloating; Girth or emaciation; Body condition: emaciated animals are less likely to survive; Poor body condition; Visual appearance externally; Emaciation; Energy reserves upon refloating - e.g. Food in GI tract, electrolyte balance; Level of body

	fat/condition; Body condition (emaciated, thin, robust); Nutritional condition (blubber thickness (ultrasound?) Or assessment of external features which resemble this, like body shape); Emaciated or not; Body condition - muscle mass; Assessment of hydration; Dehydration; Level of dehydration; Dehydration status
Capillary refill time	Circulation e.g., capillary refill tongue; Capillary refill time
Cause of stranding still present	Cause for the stranding been mitigated; Circumstance of stranding; Original reason (i.e., if will re-strand then poor survival)
Colour and consistency of faeces	Colouration and make up of faeces; Faeces description (foam, flatulence, greenish colour); Presence of urine or faeces and consistency/colour of both
Core/internal body temperature	Temperature; Internal temperature; Core temperature; Body temperature; Hyperthermia; Prolonged elevated body temperature; Internal ocular temperature
Distance to animal's natural habitat type	Location of releases; Geographic conditions; Habitat range - if an animal is found far from their normal habitat range, that may very well have contributed to their stranding and could play a role in them restranding; A beach or in-water features that allow an animal to be safely refloated and maintained until it can be moved to deeper water and released; Release into appropriate habitat (not refloating animals totally out of habitat); Habitat/geographic region; Close to natural habitat; Out of habitat range; Is habitat appropriate for the animal; Knowledge of spatial and temporal distribution of the population of the species involved; Suitability of release site (rocky vs. Sandy vs. Muddy, beach/bank steepness, wave/current speed, tidal conditions); Species vs stranding location (e.g. Out of habitat animals, with long distances from their normal home range); Is the stranding location within or out of the habitat; Is the animal in its natural home range; How far is the animal from water; Access to water
Distress	Level of distress

Eye behaviour	Eye movements; Nystagmus
Eye condition/damage	Physical injuries to eyes; Eye damage leading to impaired vision; Live scavenging -especially eyes and blowhole
Hearing ability	Hearing impairments; Hearing ability in odontocetes; Hearing impairment that may have led to stranding; Aep
Heart rate and function	Assessment of heart function; Heart rate; Cardio-vascular function-related parameters; Heart rate
Human activity in surrounding environment including sounds	Presence of many ships; The presence of anthropogenic activities during or pre stranding (such as military activities or other sound-sources)
Length of time stranded and number of re-strandings	Length of time ashore; Length of time stranded; Length of time spent distressed; Number of attempts at stranding if more than one then lower likelihood of survival; Time since stranding/report; Frequency of attempts to return to sea - these may decline with exhaustion etc; How long has the animal been out of water; Time spent stranded before refloating; Length of event; Time from stranding; Time out of the water; Time spent on the beach; Time on the beach since stranding; Duration of stranding; Number of strandings of the same animal
Location of stranding and accessibility for responders	Location of stranding; Distance from response station; Environmental features making it possible to reach, assess and move the animal to the water; Duration until land based team arrives; Time of day
Measurement of blood parameters and serum/plasma chemistry	Haematology ; Blood; Haematology (e.g. Pcv), blood parameters; Clinical examination; Development of blood markers for long term survival; Organ damage from gas emboli; Depressed blood oxygen levels; Blood values; Results of clinical investigation; Blood cell count; Blood parameters; Access to blood work machines; Blood indicators; Blood parameters such as liver and muscle enzyme levels; Serum chemistry; Biochemical serum exams; Biochemistry (e.g. Urea, creatinine, muscle enzymes); Chronic physiological damage; Impaired organ function (e.g., kidney damage from dehydration, shock, myoglobin); Circulatory compromise from stress cardiomyopathy

Measurements of stress hormones	Direct blood and tissue sampling to determine stress levels and muscle injury; Cortisol measures in exhalation samples or blood; Blood parameters (stress leukogram), cortisol levels (saliva)
Number and experience/knowledge of responders	Number of experts; The response team; Skilled operators who understand contemporary and appropriate rescue methods; Experience of rescue; Presence of knowledgeable stranding responders (less likely to induce stress); Available veterinary attention including amounts of necessary medicines; Number of volunteers; Duration until land based team arrives; Early and specialised assistance/treatment; Presence of stranding responders for any treatment/to protect from elements; Good management of stranding responders, including welfare and ethical frameworks
Post release monitoring	Long term follow up studies which provide empirical evidence for outcomes of individuals from a range of different scenarios which will help in this type of decision making; Resighting of the animal (confirmed with photo-identification or dna is the most reliable - tags do not last long enough for long-term monitoring); Resightings in areas of its home range where it had previously been documented (for that individual or conspecifics); Travel distances and average daily travel similar to previously documented travel distances for that individual or conspecifics, offspring of stranded individuals born and surviving to age-milestones; Post-release monitoring; Post release monitoring with satellite telemetry or resightings
Presence of parasites	Presence of parasites
Presence of pod members and social re-integration	Social pelagic species; Other conspecifics nearby; Interactions with pod mates; Presence of healthy pod members; Having nearby conspecifics; Presence of conspecifics; Presence of other individuals for mass stranding/social species; In a mass stranding whether conspecifics have survived or not; Dependent calf or juvenile that does not successfully re-join dam or conspecifics; Regroup with pod; Presence of others in the animals social group upon refloating; Presence of social group in the area and whether it returns to it; Presence/absence of other individuals and relatedness to them - especially if they are stranded too or remain stranded; Social needs of the species; Social unit proximity; Proximity to non-stranded conspecifics; Social reintegration with conspecifics, particularly

	with individuals it was seen with prior to the stranding (i.e., appropriate research prior to a stranding is required and all individuals at the stranding must be documented too); Proximity of social group , presence of older animals in social group; Group membership or alone; # of animals
Presence of predators and scavengers	The presence of predators; Predators/scavengers
Respiration rate and character/effort	Assessment of lung function; Respiratory rate; Respiratory count and quality; Breathing rate and character and, depending on the animal's size, lung auscultation; Breath frequency and intensity (large whales less than 1 minute between the breaths is a bad signal); Assessment of respiratory rate and character; Respiratory rate and pattern; Respiration rate; Breathing rate; Normal breathing rate; Abnormal respiration; Respiration rate and quality; Frequency of breathing; Respiratory condition; Respiratory rate; Breathing pattern; Breathing rate and quality if breathing
Signs of illness and disease	Disease condition; Animal healthy; Indication of infection or chronic disease; Apparent fitness; Are they chronically ill; Presence of disease; Signs of illness; Severity of illness; Signs of ill health; Health status of the animal; Health assessment; Health status of animal at the time of stranding i.e., was ill-health the initial cause of the stranding; Immune response-related parameters; General health levels (any underlying disease)
Signs of physical trauma, injuries and wounds	Evaluation of existing trauma/evidence of exposure; Extent of any trauma; Any trauma superficial; Physical injuries; Physical assessment of injuries; External injuries; Trauma; Number/severity of injuries; Severity of injuries; Presence of injury; Minor injuries; Observable physical injuries, bleeding from injuries; Injury i.e. Wounds, lesions; Severe wounds; What are the nature of its injuries; Injuries; Diminished limb or fluke function; Presence of injuries such as abrasions, fin damage; Displaying evidence of significant trauma; External lesions (propeller marks, abrasions indicating significant struggle in beach/on surf); Severity of injuries suffered due to stranding; No lesions; Wound assessment; Injuries sustained due to cause of stranding; Wounds/injuries; Injured

	or not; No visible injuries; Any traumas; Wounding; Wounds on body; Visible injuries; Severity of injuries suffered due to efforts to refloat
Species biology and response to stress	Species; Assessment of species e.g., coastal/pelagic, solitary/social; Species (e.g., different species react differently to manipulation during a live stranding)
Substrate/surface type at the stranding location	Substrate type; Animal position in relation to shoreline (in water, hard on beach, in rocks, at bulkhead, etc.); The location of stranding (e.g., the substrate); Substrate of the stranding location (rocks/sand/pebbles)
Swimming ability and orientation when returned to water	Movements after refloating; Swimming movements; Activity (i.e. Swimming, diving); Animal trying to swim strongly away; Assessment of behaviour when returned to water; How vigorous the animal is able swim; Observed porpoising behaviour; Orientation in the water column; Mobility; Ability to swim unassisted, orientation, disorientation; Muscle damage leading to impaired swimming +/- scoliosis; Swim energetically; Condition of animals - can they swim; Ability to navigate and swim purposefully upon refloating; Response to refloating - does the animal actively swim away or does it take some time to move away; Normal swimming pattern; Swimming in tight circles in one direction indicates neurological condition; Swim purposefully; Way of swimming; Swimming ability
Vocalisation rate and type	Calls; Vocalisations; Vocalisation rate
Weather, ambient temperature, sea and tidal conditions	Environmental conditions; Favourable environmental conditions at stranding site; Algal bloom; Weather conditions -storms, rough seas, temperature etc; Adverse environmental conditions; Weather conditions; Stranded at high or low tide - more difficult to refloat if stranded at high tide; Tides and weather, safe/accessible site for release; Air temperature, sun exposure, tides; External temperature; Weather/wind/tide/surf forecast

Table A6.3. All expert suggestions, transcribed as intelligent verbatim, of affective experience or cause of observed welfare status indicator from questionnaire 2.

Animal status indicator	**Suggested affective experience/cause of observed indicator**
Poor body condition	Systemic disease; Physiological compromise; Inappetence; Inability to forage; Loss of social support; Nausea; Sickness; Distress; Feeling unwell; Pain; Chronic energy deficit; Physical discomfort; Hunger; Discomfort; Pre-stranding hunger; Feeling ill; Malnutrition; Disease; Ribs seen defined skull shape numerous cookie cutter scars worn teeth; Pain and stress from an underlying health issue; Chronic unrelieved hunger; Loss of swimming strength; Stress; Illness; Infection; Decreased ability to regulate or respond to adverse environment; Negative; Chronic disease; Lack of food; Shows signs of disease or lack of food in this area; Trauma; Weakness; Lethargy; Emaciation from starving; Nutritional stress; Inability to cope in the wild; Emaciation; Injury; Exhaustion; Hunger and distress; Old age; Poor food availability; Chronic pain; Stomach disease; Pre-existing illness; Age; Overfishing; Separated from mother; Diseased/weakened; Old or health issues; Disorientation; Concomitant condition
Abnormal blood chemistry	Illness; Physiological compromise; Nausea; Sickness; Distress; Feeling unwell; Physiological pathology; Disease; Test done incorrectly (lysis) test machines not calibrated; Baseline for normal incorrectly inferred from other species; Stress; Feeling of ill health; Pain; Nausea; Stress/physical exertion; Pain; Feeling ill; Dizziness; Lethargy; Disease; Disease/Stress; Stressed or underlying health issue; Depends on the abnormality; Infection; Stress response; Physiological strain; Poor health; Negative; Malnutrition; We don't have blood testing on beach; Disease or illness; Physiological stress; Muscle damage; Dehydration; Depends on variable; Distress and/or pain; Poor physiological fitness; Approach of death; Muscle and tissue damage and degradation; Poor health; Could mean anything at all; Poor condition; Discomfort; Hepatic or kidney problem; Pre-existing illness; Stranding-related illness; Any disease; Fear; Feeling unwell; Tiredness; Stressed/diseased; May infer problems with internal organs and therefore assist in the euthanasia decision; Shock; Hunger; Thirst; Organ condition; Very dependent on what parameters are elevated and how much elevated by; And what the cause of that is for

	example renal azotaemia or severe hyperbilirubinemia may relate to nausea, pre-renal azotaemia may relate to thirst. But really most biochemical abnormalities would be indicators of welfare risk rather than reflective of a specific mental experience
Abnormal haematology	Illness; Shock; Trauma; Infectious disease; Stress; Physiological compromise; Nausea; Sickness; Distress; Feeling unwell; Physiological pathology; Disease; Test done incorrectly (lysis) test machines not calibrated; Baseline for normal incorrectly inferred from other species; Feeling of ill health; Pain; Nausea; Feeling ill; Dizziness; Lethargy; Disease; Disease/Stress; Stressed or underlying health issue; Depends on the abnormality; Infection; Stress response; Physiological strain; Unhealthy; Negative; Disease; Trauma; We can’t measure; Anaemia; Dehydration; Depends on variable; Stress and distress; Poor physiological fitness; Approach of death; Muscle and tissue damage and degradation; Could mean anything at all; Physical difficulty or poor condition; Pain associated with disease; Discomfort; Pre-existing illness; Stranding-related illness; Fear; Age; Exhaustion; Tiredness; Stressed or diseased; Usually signals underlying problem as major organ failure or disease; Hunger; Thirst; Concomitant condition; Depends what abnormality and severity, could be weakness if severely anaemic, otherwise unlikely any results would directly relate to a mental experience; Might be more likely to be an alerting factor; Depends on blood parameter
Abnormal heart rhythm	Shock; Hypo or hyperthermia; Fluid imbalances; Physiological compromise; Nausea; Sickness; Distress; Stress; Feeling of ill health; Pain; Discomfort; Fear; Pain; Confusion; Feeling ill; Dizziness; Lethargy; Disease/Stress; Stress and fear; Perhaps an already compromised individual; Hyperventilating from exertion or inability to inhale fully; Illness; Infection; Stress response; Physiological strain; Negative; Disease; Contextual - could mean many things; Exhaustion; Illness; Physiological stress; Underlying condition; Injury; Weakness; Distress and/or pain; Poor physiological fitness; Approach of death; Cardiac muscle and tissue damage; Changed calcium levels; Physical difficulty or poor condition; Stressed; Capture myopathy; Pre-existing disease; Panic; Animal may be slipping away; Stranded for an extended period; Circulatory collapse; Metabolic or thermal stress; Stress or

	cardiac disease; Hard to directly relate to a mental experience; Fear (but there are other physical factors that could cause this)
Abnormal respiratory character	Stress; Respiratory disease; Aspiration; Fluid imbalance; Distress; Effort; Feeling unwell; Pain; Disease; Adrenaline; Trauma; Physiological problem; Fear; Feeling of ill health; Discomfort; Confusion; Feeling ill; Dizziness; Lethargy; Disease/Stress; Stress and fear; Decompensating; Hypoxia; Illness; Infection; Stress response; Physiological strain; Distress or fear; Negative; Could be indicator of disease; Exhaustion; Physiological and/or behavioural stress; Shock; Weakness; Distress and/or pain; Gravity and non-water support; Approach of death; Injury; Physical difficulty or poor condition; Stressed or lung disease; Depends - can be stress; Can be compromised pulmonary health; Can be shock; Stressed; Increase above norm may signal stress that can be reduced; Decrease (other than when stress factors are relieved) may signal downturn in well-being; Often close to death; Depression; Possible pneumonia; Respiratory involvement; More likely breathlessness related to respiratory tract disease; Panic
Bleeding/fluids/mucus from orifices	Disease; Injury; Pain; Immunocompromise; Sickness; Distress; Feeling unwell; Trauma; Response to stranding; Physical discomfort; Feeling of ill health; Illness; Nausea; Internal injury/illness; Feeling ill; Dizziness; Lethargy; Signs of dying; Pain and stress; Pain from whatever internal structure is bleeding; Infection; Wounded; Physiological response; Negative; Heart failure; Could indicate internal injuries; Sickness; Weakness; Discomfort; Fear; Potentially serious internal injury or disease; Sick; Stress; Possibly pain; Distress and/or pain; Tissue breakdown; Pre-existing illness; Stranding-related illness - many discharges are normal; Feeling unwell; Suffering; Tiredness; Injured or diseased; Slight bleeding may be a result of stranding; Larger quantities may signal birth/miscarriage; Internal damage; Shock; Multi tide stranding; Sun/heat issues; Depression; Acute event; Hit by boat; Prompt death; Probably not directly associated with mental experiences in itself
Elevated heart rate	Stress; Hyperthermia; Pain; Fear; Distress; Adrenaline; Disease; Physiological compromise; Feeling of ill health; Anxiety; Confusion; Feeling ill; Dizziness; Lethargy; Disease/Stress; Stress and fear; Perhaps an already compromised individual; Exertion; Illness; Infection; Stress response; Physiological strain; Distress or fear;

	Negative; Stressed; Contextual - could mean many things from stress to hyperthermia; Discomfort; Physiological stress or potentially underlying heart condition; Injury; Tiredness; Distress and/or pain; Dehydration; Hyper or hypothermia; Blood calcium changes; Injury; Physical difficulty or poor condition; Stressed state or poor health condition; Shock; Decompensation; Exhaustion; Anxiety; Respiration difficulties; Shock; Close to death; Stress or cardiac condition; Very variable on its own; Very much depends on cause - can be sign of anxiety or other physiological causes or sign of disease primary cardiac, or secondary e.g. Hypovolaemia
Elevated respiration rate	Stress; Hyperthermia; Feeling unwell; Distress; Pain; Feeling of ill health; Anxiety; Feeling ill; Dizziness; Lethargy; Disease/Stress; Stress and fear; Hypoxia; Exertion; Illness; Infection; Fear; Metabolic strain; Distress or fear; Negative; Could be a stress sign; Contextual - could mean many things; Sickness; Discomfort; Physiological stress; Behavioural stress; Shock; Tiredness; Distress and/or pain; Gravity; Exposure; Metabolic activity; Injury; Disease; Physical difficulty or poor condition; Stressed; Compromised pulmonary health; Disease; Exhaustion; Stressed/hyperventilating; Animal may be too hot, feel threatened, or anxiety if in mother/calf duo; Stress responsiveness; Possible pneumonia; Water and sand in respiratory tract; Very variable on its own; Depends on cause- could breathlessness if related to respiratory tract disease, or can be caused by anxiety or other physiological causes (overheating and potentially fear)
Elevated stress hormones	Physiological compromise; Distress; Nausea; Sickness; Fear; The animal is stressed at the point the sample is taken; Stress; Feeling of ill health; Anxiety; Distress; Pain; Confusion; Chronic disease or stress; Disease/Stress; Pain and stress; Generalized stress; Illness; Infection; Prolonged stress; Distress or fear; Negative; Disease; Stress and trauma; Physiological stress; Anxiety; Distress and/or pain; Exposure; Inability to act; Stressed; Depends which other organ involved; Very variable unlikely to relate directly to a mental experience
Injury/Trauma/Wounds	Weakness; Defencelessness; Pain; Feeling unwell; Trauma inflicted- acute or chronic; Physical discomfort; Feeling of ill health; Distress; Stress; Discomfort; Fear; Disease; Often superficial; Pain and stress; Blood loss; Shock; Reduced situational awareness from low blood pressure and reduced blood flow to brain; Health;

	Negative; Need assessing before release; Poor body condition and illness; Inability to survive after release; Parasites/rocks/predators; Pain and distress; Physical trauma; Beaching; By caught; Boat impact; Predation; Shooting; Poor health; Pre-existing or stranding-related; Often painful; Suffering; In pain; May signify deeper internal injury; Depending on trauma may affect level of response; Location of stranding or shark bites; Several strandings or hit by a boat
Presence of disease or illness	Immunosuppression; Stress; Old age; Feeling unwell; Distress (impaired feeding/diving abilities); Low resilience; Physical discomfort; Pain; Distress; Discomfort; Feeling ill; Dizziness; Lethargy; Disease; Pain and stress; Depends on disease or illness; Body condition; Reduced ability to regulate or respond to adverse environment; Negative; Weakness; Need to be taken into account when deciding course of action; Sick; Weakness; Hunger; Moribund; Potential inability to survive in the natural environment; Depends on disease - malaise; Distress and/or pain; Presence of disease or illness; Ill; Tired; Chronic pain; Injury; Poor nutrition; Poor health; Pre-existing disease or stranding-related illness; Suffering; Feeling unwell; In pain/discomfort; Could affect nutritional status and general debilitation; Sick; Old or health issues; Depression; Fear; Cause of the stranding; Very much depends what that disease is e.g. Could cause pain, nausea, malaise, weakness, but it depends on disease
Reduced respiration rate	Shock; Depression; Tiredness; Giving up; Dive response; Neurological; Reduction in noxious stimuli; Regaining physiological control; Pain; Exhaustion; Level of consciousness; Feeling ill; Dizziness; Lethargy; Disease/Stress; Stress and fear; Perhaps an already compromised individual; Decompensating; Stress; Illness; Infection; Decreased ability to regulate or respond to adverse environment; Relaxed; Positive; Safety; Could be sign we are losing the animal; Contextual - could mean many things; Fear; Panic; Exhaustion and reduced condition; Onset of shock; Weakness; Possibly a dive response as the animal tries to flee; Gravity and non-water support; Approach of death; Declining stress/response to good care from responders or communicating with others in a mass stranding; Agonal state; Poor body condition; Or stressed; Depends; Apnoea >3 minutes usually indicates shock and cardiopulmonary collapse due to a dive reflex and catastrophic bradycardia; Animal may be

	slipping away - giving up or resting; Calm; Stranded for an extended period - not a good sign; Systemic collapse; Pneumonia; Organ compression; Hard to interpret on its own without other parameters; Unlikely to directly indicate a mental experience; Potentially dive reflex as result of fear
Reduced stimuli/reflexes	Shock; Trauma; Physiological compromise; Nausea; Sickness; Distress; Feeling unwell; Tiredness; Giving up; Masked by other stimuli; Low cognitive state; Test not done correctly; Stress; Pain; Feeling of ill health; Exhaustion; Level of consciousness; Feeling ill; Dizziness; Lethargy; Helplessness; Coma; Disease; Pain and stress; Perhaps an already compromised individual; Decompensating; Reduced situational awareness; Illness; Infection; Decreased ability to regulate or respond to adverse environment; Unaware; Negative; Severe disease; Animal is closing down or has died; Contextual - could mean many things; Numbness; Fear; Moribund; Losing consciousness; In state of shock; Weak; Injury; Emaciation; Weakness; The animal may be losing consciousness; Poor physiological fitness; Approach of death; Apathy; Poor condition; Stress (catatonia); Agonal state; Poor body condition; Depression; Disorientated/weak/diseased; Animal may be slipping away; Stranded for extended period; Neurological disease or neurological condition; It depends frustration if unable to move normally; Lethargy
Elevated body temperature	Hyperthermia; Exposure; Distress; Pain; Fear; Prolonged solar radiation exposure or muscular activity; Discomfort; Feeling of ill health; Illness or hyperthermia; Confusion; Feeling ill; Dizziness; Lethargy; Overheating; Disease; Only through sun; Stressed; Secondary effects from internal organ damage; Stress; Illness; Infection; Being out of water; Physiological response; Stress or unhealthy; Negative; Distress; Environmental conditions; Deep core temperature probes are important here; Overheating; Physiological stress; Needs water; Injury; Distress and/or pain; Exposure; No cooling of water; Metabolic activity; Physical difficulty or poor condition; Overheating due to stress or being out of water; Discomfort which can be severe; High environment temperature; Shock; Capture myopathy; Other pre-existing disease; Exhaustion; Heat trauma; Stressed/diseased; Overheating due to prolonged stranding or disease; Weather; Hot

Poor skin condition	Systemic disease; Trauma; Exposure; Feeling unwell; Pain; Physical discomfort; Hunger; Discomfort; Irritation; Disease; Pain and stress; Perhaps an already compromised individual; Fluid loss; Illness; Infection; Decreased ability to regulate temperature and protect skin barrier; Negative; Nutritional problems; Environmental conditions; May have been stranded for long period; Sunburn or sloughing skin; Poor body condition; Illness; Physiological stress; Dehydration; Emaciation; Possibly pain; Pain and distress; Physical trauma; Beaching; Predation; Sun; Wind; Sand blown; Chronic pain; Injury; Sunburn or infections; Pre-existing illness; Stranding-related illness; Suffering; In pain/diseased; Pain through disease or previous stranding; Possible health issues; Systemic illness; Several hours post strandings; Pruritus; Potentially pain
Abnormal body posture	Pain; Injury; Feeling unwell; Fear; Hard to assess given extremis of stranding event but likely negative; Physical discomfort; Discomfort; Distress; Feeling ill; Lethargy; Gravity; Muscle cramp; Disease; Stress and fear; Inability to correct situation; Stress; Illness; Infection; Being out of water/dissociation; Negative; Distress; We try and get animal upright to make animal more comfortable and makes breathing easier; Shock; Badly positioned; Weakness; Distress and/or pain; Gravity and non-water support; Muscle damage; Spine or stomach problem; Myopathy; In pain or injured; May be death throes or genuine attempt to get back to water; Bone issues; Stress possible multi tide stranding; Disorientation; Neurological disease or condition
Abnormal swimming movements	Pain; Disorientation; Weakness; Neurological illness; Loss of orientation; Neurological disease; Myositis; Cramp or strandings related postural cramp; Physical discomfort; Stress; Disorientation; Grief over lost conspecifics during stranding event; Injury/pain; Fear; Distress; Confusion; Feeling ill; Dizziness; Lethargy; Physical injury; Disease; Erratic thrashing lots of tail movements; Pain and stress; Perhaps an already compromised individual; Neurologic impairment or physical injury; Stress; Illness; Infection; Fatigue; Injury; Negative; Neurological problems; Could be neurological; Contextual depends on length of time spent not swimming and habitat; Distress; Excitement; Worry; Exhaustion; Physiological stress; Weak/lack of balance; Helplessness; Discomfort; Distress and/or pain; Voluntary escape efforts; Involuntary fitting & muscle activity; Approach of death; Injury; Something physically wrong; Physical difficulty or poor condition; Trauma with

	flipper or flukes or has some gastric problem; Capture myopathy; Shock; Desire to swim away; Tiredness; Disorientated; May signal an imbalance in internal fluid, with build-up on one side - need to rebalance either after prolonged period on beach on one side or a previous unknown stranding; May also infer internal damage or brain damage due to underlying illness (e.g. Meningitis); Multi tide stranding; Neurological disease or neurological condition; Hit by boat; Maybe anxiety; Confusion if not moving as intended
Agitated movements	Stress; Fear; Agonal movement; Effort to escape situation/keep people away; Anger; Hard to assess given extremis of stranding event but likely negative; Distress; Physical discomfort; Pain; Desire to escape - fear; Discomfort; Confusion; Feeling ill; Stress and fear; Agitation; Ineffectual escape attempts; Illness; Infection; Escape response; Responding to conspecifics; Distress or fear; Negative; Stress and discomfort; Behavioural stress; Helplessness; Anxiety; Distress and/or pain; Voluntary escape efforts; Frustration; 'Leave me alone'; Involuntary fitting & muscle activity; Approach of death; Anxiety; Stressed; Discomfort/stressed; Threat/defence; Too many rescuers; Seizures; Frustration or anxiety maybe; Possibly pain; Potentially fear
Arching	Agonal movements; Pain; Fear; Distress; Anger; Hard to assess given extremis of stranding event but likely negative; Physical discomfort; Desire to escape - fear; Stress; Discomfort; Confusion; Feeling ill; Contraction; Healthy and trying to free itself or a sign of pain; Hypoxia; Agonal; Escape response/fear; Negative; Normal sign of death throes; Illness; Extreme behavioural stress; Injury; Illness; Helplessness; Distress and/or pain; Escape efforts; Involuntary fitting; Approach of death; Poor internal condition; Uncomfortable or stomach disease; Shock; Muscle contractions due to catecholamine release; Myopathy; Disease; May be death throes or genuine attempt to get back to water; Shock; Dying; Neurological disease or neurological condition
Fin movement	Stress; Physical strength; Feeling unwell; Pain; Effort to escape situation; Desire to escape - fear; Anxiety; Fear; Distress; Movement; Healthy animal trying to free itself; Trying to rectify situation; Health; Discomfort; Negative; We allow pectoral fins to move and surround with water to help cooling; Contextual - could mean many things; Can be positive i.e. Strong swimming or panic or lack of movement; Flight response or potentially positive attempts to swim; Weakness; Discomfort; Escape efforts; Involuntary fitting; Voluntary signalling;

	Approach of death; Trying to move; Get away; Desire to swim; Trying to be back to water; If in water may infer determination to get back to deeper water, if out of water may do the same or signal distress; Responsiveness; Nothing specific; Alive
Fluke slapping	Stress; Aggression; Feeling unwell; Pain; Effort to escape situation/keep people away; Anger; Fear; Attempt to move away; Warning to other pod members; Muscular pain; Anger; Distress; Physical discomfort; Desire to escape - fear; Anxiety; Distress; Confusion; Feeling ill; Movement; Not an issue; Healthy and trying to free itself or a sign of pain and stress; Fight-or-flight response; Agonal; Illness; Infection; Escape response; Warning conspecifics; Safety; Negative; Stressed; Rapid violent fluke slapping is bad: Stress on land, excitement ready to leave while supported in water; Behavioural stress or potentially positive attempts to swim; Helplessness; Distress and/or pain; Voluntary escape efforts; Involuntary fitting & muscle activity; Approach of death; Communication; Social activity; Annoyed/discomfort/stressed; Anxiety due to a perceived threat; Desire to move into deeper water; Responsive; Shock; Dying; Usually when stranding last attempts at floating; Aggression; Threat; Neurological disease or neurological condition; Potentially fear or frustration
Head swinging	Stress; Pain; Panic; Agonal movement; Nausea; Sickness; Distress; Feeling unwell; Desire to escape - fear; Fear; Confusion; Disease; Usually along with rolling side to side; Healthy and trying to free itself or a sign of pain; Defensive; Illness; Infection; Escape response/fear; Confusion or fear; Negative; Neurological problem; Discomfort; Behavioural stress; Lost/lonely; Helplessness; Distress and/or pain; Poor physiological fitness; Approach of death; Over heat or mental problem; Stressed/disorientated; May show underlying damage to brain or be attempt to get back to water; Shock; Usually attempting to swim and gain stability; Aggression; Weakness; Neurological disease or neurological condition
Tensing/straining	Pain; Fear; Muscular cramp; Spinal shock; Distress; Physical discomfort; Desire to escape - fear; Pain/stress; Fear; Confusion; Contraction; Pain and stress; Perhaps an already compromised individual; Illness; Infection; Escape response/fear; Distress and pain; Negative; Neurological problem; Again bad sign; Discomfort; Stress; Behavioural stress; Distress and/or pain; Voluntary escape efforts; Involuntary fitting & muscle activity;

	Approach of death; Trying to escape; Stressed by the stranded state; Shock; Muscle contractions due to catecholamine release; Disease; Exhaustion; Extreme stress; May be death throes or genuine attempt to get back to water; Neurological disease
Thrashing	Stress; Agonal movement; Fear; Pain; Effort to escape situation; Avoidance behaviour; Antemortem muscular spasm; Desire to escape; Distress; Stress/pain; Distress; Confusion; Movement; Stress and fear; Panic; Escape response/fear; Distress or fear; Negative; Contextual - could mean many things; Agitation; Discomfort; Illness; Extreme behavioural stress; Helplessness; Distress and/or pain; Voluntary escape efforts; Involuntary fitting & muscle activity; Approach of death; Mental abnormality; Anxiety; Stressed; Shock; Panic; Desire to swim away; Annoyed/discomfort/stressed; Indicator of stress; Pain or when in water anxiety and desire to get to deeper water. May also be a reaction to any drugs given; Dying; Too many rescuers; Attempts to swim or maintain stability; Aggression; Interaction; Several strandings
Vocalisation: rate; character	Distress; Social isolation; Seeking support; Expression of fear; Feeling unwell; Physical discomfort; Pain; Desire to escape - fear; Stress; Worried about conspecifics; Fear; Confusion; Feeling ill; Lethargy; Group safety; Trying to communicate with any conspecific; Negative; Sign of stress; Contextual - from calf could mean fear, from adult could mean pain or aggression; Comfort; Discomfort; Illness; Behavioural stress; Excited/lonely/happy/interactive; Helplessness; Distress and/or pain; Communication; 'Doing all I can'; Signalling to pod members; 'Leave me alone'; Safety if communicating with others in a mass stranding; Calling for conspecific partners; Calling a family member; Disorientated/stressed; Anxiety - especially if a pod member of mother/calf pair; Responsiveness; Possible mother calf calls/family tie calls; Social isolation; Group nearby
Tremors/shivering	Hypothermia; Stress; Distress; Nausea; Sickness; Fear; Pain; Hard to assess given extremis of stranding event but likely negative; Mental distress; Overheating or hypothermia; Hyperthermia/hypothermia; Discomfort; Illness; Confusion; Feeling ill; Heat stress; Contraction; Stress and fear; Perhaps an already compromised individual; Decompensating; Infection; Negative; Neurological problem; Hypoglycaemia; Bad sign; Shock; Physical issues such as hypo or hyperthermia; Behavioural stress; Anxious; Chill; Distress and/or pain;

	Exposure; Metabolic activity; Body temperature abnormality; Stressed or low environment temperature; Likely catecholamine release - stress; Cold; Disease; Stressed; May be a reaction to changes in core temperature or stress related; Close to death; Weakness; Neurological disease or neurological condition; Potentially fear but may also be involuntary

Appendix 7 Linear Discriminant Analysis (LDA): Chapter 3

All categories provided for scoring in the second round are shown on each LDA figure. The first two axes of the LDA were used to provide a visual representation of differences and similarities among expertise in relation to the major indicator categories value and measurability.

For each LDA figure, arrows show the direction of the gradient of larger scores, and the length of the arrows is proportional to the correlation between the variable (category) and the ordination (data points). Longer arrows in the same direction as the ordination of a particular expertise group, indicate that the group generally scored the category higher than the overall average. Whereas longer arrows in the opposite direction of the ordination of a particular expertise group, indicate that the group generally scored the category lower than the overall average. Ellipses were plotted to aid in the visualisation of expertise group scores. The ellipses indicate the 95% tolerance region of data points within each expertise group, estimated by fitting a bi-variate normal distribution to the covariance matrix of each expertise group. Where data for a particular expertise group were insufficient, the ordination is plotted but there is no ellipse to indicate the 95% tolerance region.

Overall, there was overlap among the expertise groups for indicator categories in terms of value and measurability, with minimal correlation observed between expertise group and categories. However, in some cases there were trends that could be identified visually. Where these could be identified, they are interpreted in the sections below.

Indicator value

A total of 11% of the responses for the welfare indicator value were "Don't know", and data imputation was applied. The first two discriminant axes of the LDA accounted for 77% of the variation (Figure A7.1). Some generalised trends seen on the LDA suggest that 'cetacean expert (including cetacean conservation and biology)' (n = 16) were more likely to score 'swimming ability and orientation when returned to water' (SwimAbil) and 'abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering' (AbnormBehav) as highly valuable and 'respiration rate and character/effort' (Respirat) as less valuable for assessing welfare. This was in contrast to 'animal welfare expert (including animal welfare science, welfare/animal ethics)' (n = 9) who appeared to score the inverse and were only found grouped on the negative side of LD1. Whereas 'cetacean expert with knowledge and/or focus on welfare' (n = 12) were more likely to score 'measurement of blood parameters and serum/plasma chemistry' (BloodParam) as a high value indicator.

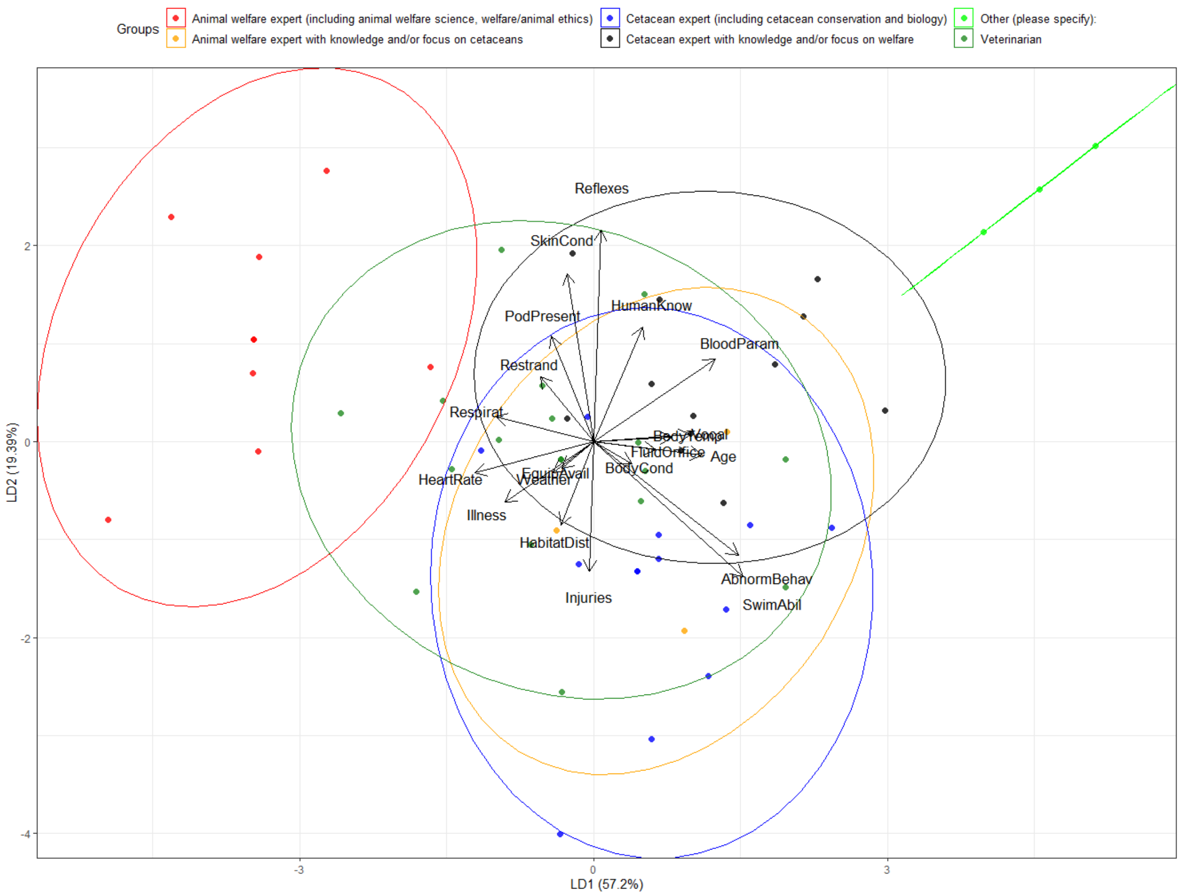

Figure A7.1. Biplot of the linear discriminant analysis of category scores for welfare indicator values, which attempts to find axes that discriminate among expertise groups. Category key: AbnormBehav: Abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering; Respirat: Respiration rate and character/effort; Injuries: Signs of physical trauma, injuries and wounds; Reflexes: Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness; SkinCond: Animals skin condition such as sunburn, peeling, cracking or blistering; BodyCond: Body condition or nutritional status; Weather: Weather, ambient temperature, sea and tidal conditions; Age: Animal age based on length/weight, and reproductive status; Vocal: Vocalisation rate and type; SwimAbil: Swimming ability and orientation when returned to water; BodyTemp: Core/internal body temperature; Restrand: Length of time stranded and number of re-strandings; HeartRate: Heart rate and rhythm; PodPresent: Presence and behaviour of pod members; BloodParam: Measurement of blood parameters and serum/plasma chemistry; EquipAvail: Availability of resources including equipment; FluidOrifice: Bleeding/fluids/mucus from orifices; Illness: Signs of illness and disease; HumanKnow: Amount of human interaction and knowledge of responders; HabitatDist: Distance to animal's natural habitat type.

A total of 9% of the responses for survival likelihood indicator value were provided as “Don’t know”, and data imputation was applied. The first two linear discriminant axes accounted for 67% of the variation (Figure A7.2). The LDA again showed overlap among expertise groups, though the ‘animal welfare expert with knowledge and/or focus on cetaceans’ and ‘animal welfare expert (including animal welfare science, welfare/animal ethics)’ appeared slightly more differentiated, with both only grouped on the negative side of LD1. The LDA suggested that ‘animal welfare expert with knowledge and/or focus on cetaceans’ (n = 3) were more likely to score ‘core/internal body temperature’ (BodyTemp) as highly valuable and ‘measurement of blood parameters and serum/plasma chemistry’ (BloodParam) as less valuable indicators of survival. In contrast animal welfare experts including welfare science and ethics (n = 9), were more likely to score ‘number and experience/knowledge of responders’ (KnowHuman) as highly valuable and ‘weather, ambient temperature, sea and tidal conditions’ (Weather) as less valuable indicators.

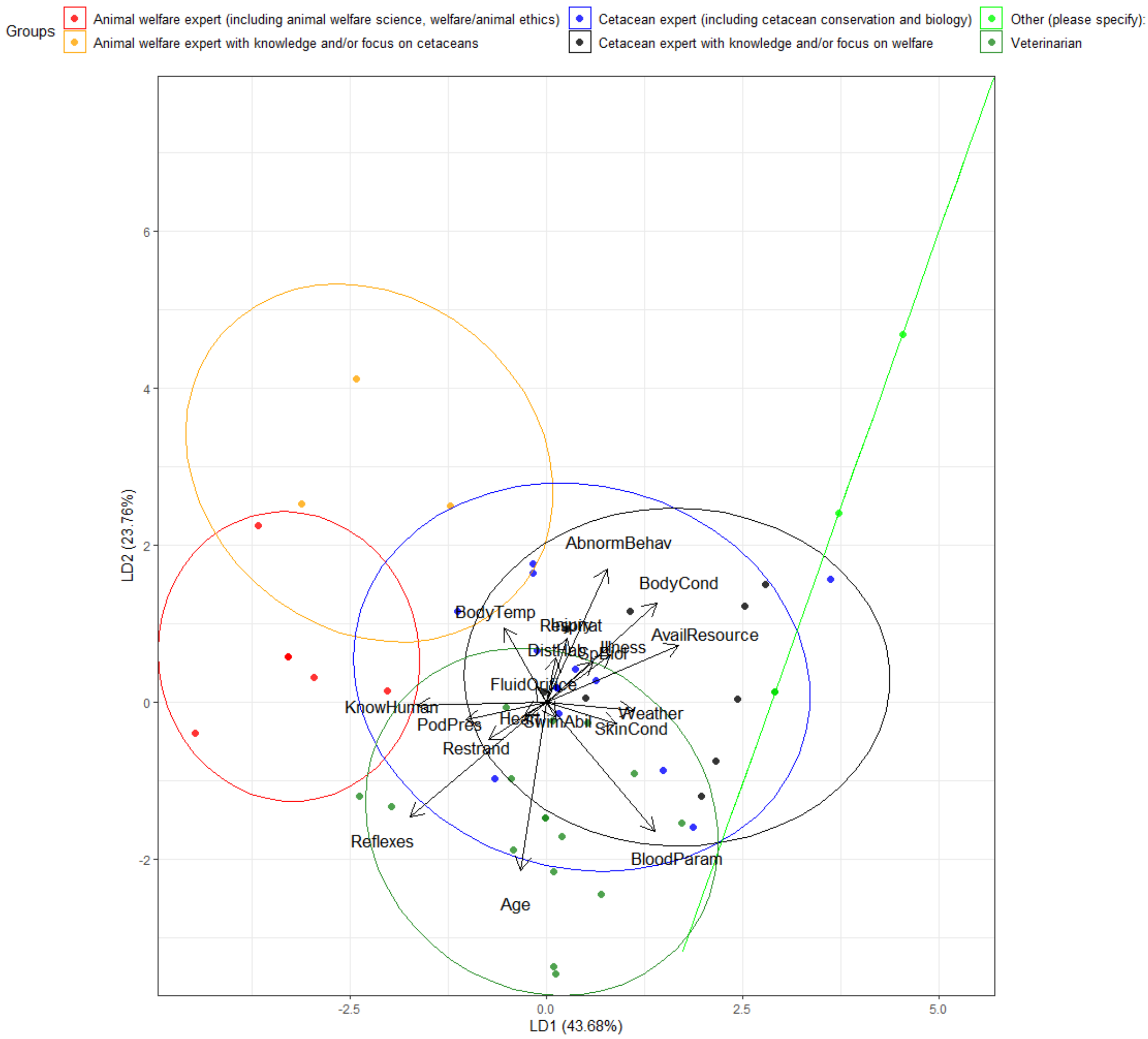

Figure A7.2. Biplot of the linear discriminant analysis of categories scores for survival indicator values, which attempts to find axes that discriminate among expertise groups. Category key: Injury: Signs of physical trauma, injuries and wounds; BodyCond: Body condition and nutritional status; Respirat: Respiration rate and character/effort; Reflexes: Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness; Age: Animal age based on length/weight and reproductive status; BloodParam: Measurement of blood parameters and serum/plasma chemistry; PodPres: Presence of pod members and social re-integration; SkinCond: Animal's skin condition such as sunburn, blistering/integrity or desiccation; SwimAbil: Swimming ability and orientation when returned to water; Restrand: Length of time stranded and number of re-strandings; AbnormBehav: Abnormal movements and behaviours including arching, thrashing, shivering, movements of pectoral and caudal fins;

Illness: Signs of illness and disease; Weather: Weather, ambient temperature, sea and tidal conditions; AvailResource: Availability of resources including equipment; KnowHuman: Number and experience/knowledge of responders; DistHab: Distance to animal's natural habitat type; BodyTemp: Core/internal body temperature; FluidOrifice: Bleeding/fluids/mucus from orifices; SpBiol: Species biology and response to stress; Heart: Heart rate and function

Indicator practicality

A total of 7% of the responses for welfare indicator measurability were provided as “Don’t know”, and data imputation was applied. The first two linear discriminant axes accounted for 67% of the variation (Figure A7.3). For welfare the LDA suggested that there was substantial overlap among expertise group scores of indicator practicality. However, it appeared that ‘cetacean expert (including cetacean conservation and biology)’ (n = 16) were more likely to score ‘core/internal body temperature’ (BodyTemp) as more easily measurable and ‘heart rate and rhythm’ (HeartRate) as less measurable. In contrast ‘cetacean expert with knowledge and/or focus on welfare’ (n = 12), were more likely to score ‘respiration rate and character/effort’ (Respirat) as more easily measurable. The ‘animal welfare expert (including animal welfare science, welfare/animal ethics)’ (n = 9) were more likely to score ‘abnormal movements and behaviours including arching, thrashing, shivering, movements of pectoral and caudal fins’ (AbnormBehav) as more easily measurable.

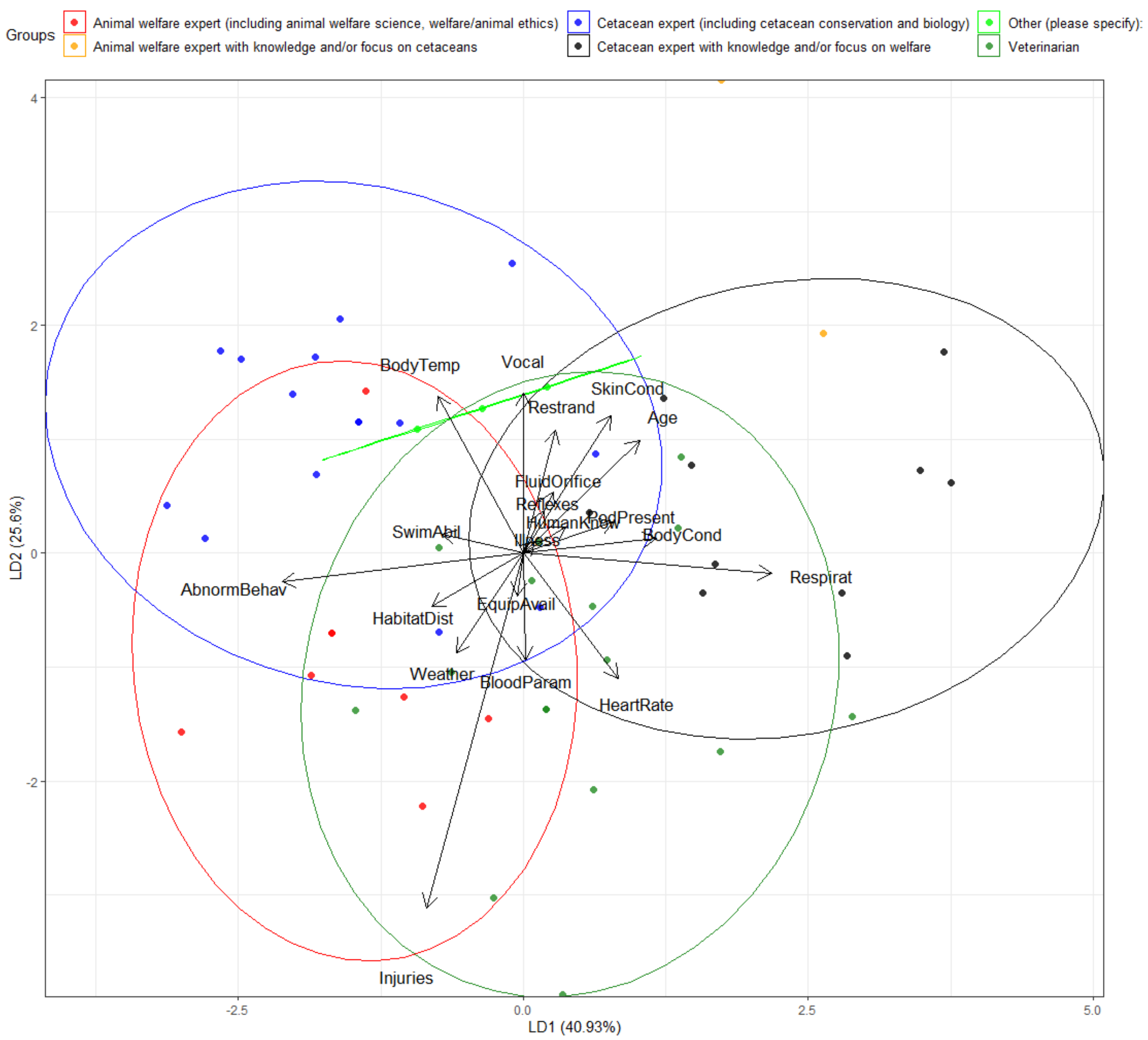

Figure A7.3. Biplot of the linear discriminant analysis of category scores for welfare indicator measurability, which attempts to find axes that discriminate among expertise groups. Category key: AbnormBehav: Abnormal movements and behaviours including arching, thrashing, straining, trying to move, agitated movements, slapping flukes, tremors/shivering; Respirat: Respiration rate and character/effort; Injuries: Signs of physical trauma, injuries and wounds; Reflexes: Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness; SkinCond: Animals skin condition such as sunburn, peeling, cracking or blistering; BodyCond: Body condition or nutritional status; Weather: Weather, ambient temperature, sea and tidal conditions; Age: Animal age based on length/weight, and reproductive status; Vocal: Vocalisation rate and type; SwimAbil: Swimming ability and orientation when returned to water; BodyTemp: Core/internal body temperature; Restrand: Length of time stranded and number of re-strandings; HeartRate: Heart rate and rhythm; PodPresent: Presence and behaviour of pod members; BloodParam: Measurement of blood parameters and serum/plasma chemistry; EquipAvail: Availability of resources including equipment; FluidOrifice: Bleeding/fluids/mucus from orifices; Illness: Signs of illness and disease; HumanKnow: Amount of human interaction and knowledge of responders; HabitatDist: Distance to animal's natural habitat type.

A total of 5% of the responses for survival indicator measurability were provided as "Don't know", and data imputation was applied. The first two linear discriminant axes accounted for 79% of the variation (Figure A7.4). The 'other' expertise group were highly differentiated, scoring on the positive side of both LD1 an LD2, however there were few ordination points (n = 3), but they appeared to be more highly correlated with 'signs of physical trauma, injuries and wounds' (Injury) scoring this as easily measurable. In contrast, 'cetacean expert with knowledge and/or focus on welfare' (n = 12) were more likely to score 'signs of physical trauma, injuries and wounds' (Injury) as less measurable. For the other expertise groups, the LDA suggested that 'cetacean expert (including cetacean conservation and biology)' (n = 16) were more likely to score 'respiration rate and character/effort' (Respirat) as easily measurable and 'measurement of blood parameters and serum/plasma chemistry' (BloodParam) as less measurable. This was in contrast to 'veterinarian' (n = 20) who tended to score the inverse.

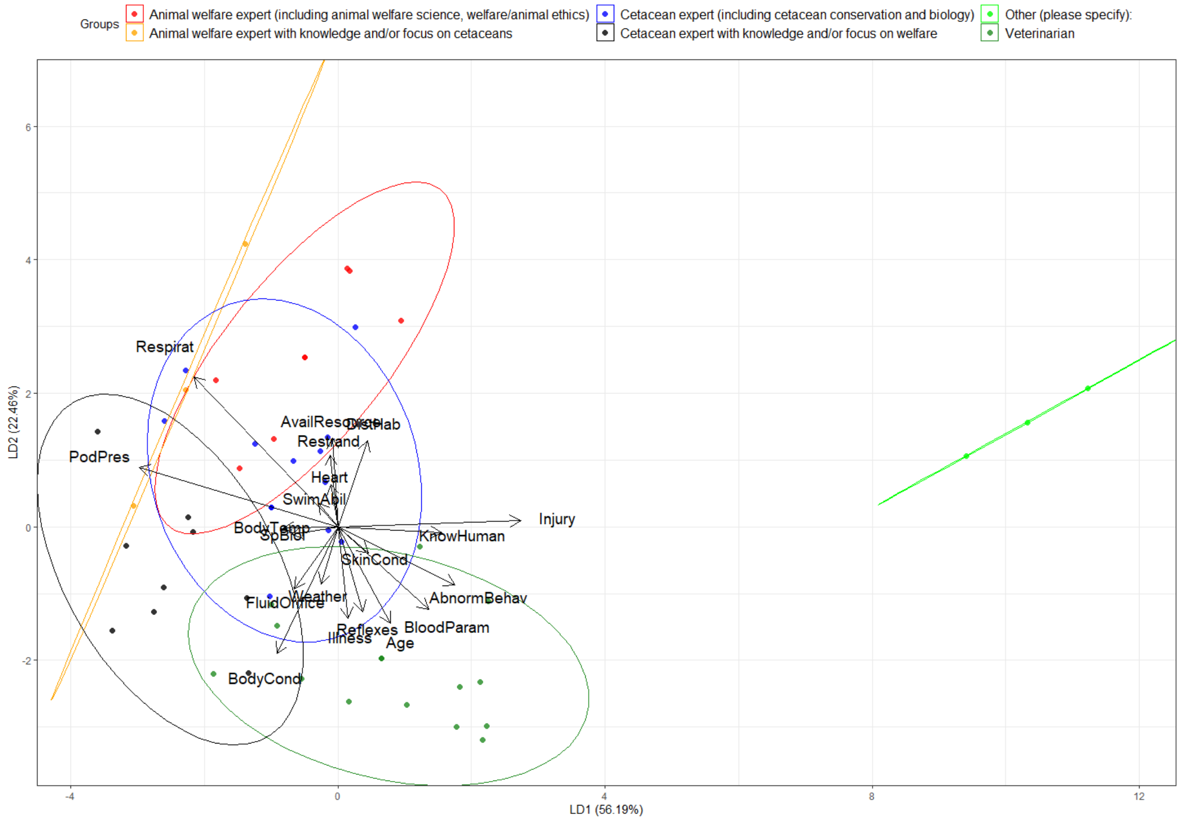

Figure A7.4. Biplot of the linear discriminant analysis of category scores for survival indicator measurability, which attempts to find axes that discriminate among expertise groups. Category key: Injury: Signs of physical trauma, injuries and wounds; BodyCond: Body condition and nutritional status; Respirat: Respiration rate and character/effort; Reflexes: Animal's level of response to stimuli/reflexes as a reflection of its level of awareness, alertness or consciousness; Age: Animal age based on length/weight and reproductive status; BloodParam: Measurement of blood parameters and serum/plasma chemistry; PodPres: Presence of pod members and social re-integration; SkinCond: Animal's skin condition such as sunburn, blistering/integrity or desiccation; SwimAbil: Swimming ability and orientation when returned to water; Restrand: Length of time stranded and number of re-strandings; AbnormBehav: Abnormal movements and behaviours including arching, thrashing, shivering, movements of pectoral and caudal fins; Illness: Signs of illness and disease; Weather: Weather, ambient temperature, sea and tidal conditions; AvailResource: Availability of resources including equipment; KnowHuman:

Number and experience/knowledge of responders; DistHab: Distance to animal's natural habitat type; BodyTemp: Core/internal body temperature; FluidOrifice: Bleeding/fluids/mucus from orifices; SpBiol: Species biology and response to stress; Heart: Heart rate and function

Appendix 8 Additional data related to the evaluation of welfare indicators from video footage: Chapter 4

Table A8.1 Stranding events (n = 14) and details of video footage collected of individual live cetaceans (n = 53) of four odontocete species between August 2010 and March 2022, New Zealand. Only pilot whale data were used in analyses, with data from other species providing ground-truthing to identified behavioural indicators. In the case of mass strandings, footage may have included multiple individuals, however the video length noted included only the focal animal. *Note three animals were filmed both cranio-laterally and laterally.

Year	**Location**	**Species**	**Stranding type**	**No. animals filmed**	**Video length (mins)**	**Source**	**Filming equipment**	**No. filmed cranio-laterally**	**No. filmed laterally**
2010	Northland	Long-finned pilot whale	Mass	1	0.5	Public	Video camera	1	0
2011	Golden Bay	Long-finned pilot whale	Mass	2	0.8	Public	Phone	0	2
2014	Golden Bay	Long-finned pilot whale	Mass	1	0.3	Public	Phone	1	0
2015	Golden Bay	Long-finned pilot whale	Mass	20	11.3	Public	GoPro	4	16
2017	Golden Bay	Long-finned pilot whale	Mass	5	1.2	Public	GoPro	4	1
2020	Waipu	Pygmy killer whale	Mass	2	294.4	Researcher	GoPro	2	0
2020	Whanganui	Long-finned pilot whale	Single	1	37.4	DOC	Phone	1*	1*

2020	Coromandel	Long-finned pilot whale	Mass	2	2.9	Public	Phone	0	2
2020	Raglan	Cuvier's beaked whale	Single	1	33.1	DOC	Phone	1	0
2021	Ruakaka	Grey's beaked whale	Mass	1	6.2	Public	Phone	0	1
2021	Golden Bay	Long-finned pilot whale	Mass	11	5.9	Public	GoPro	4	7
2021	Taranaki	Long-finned pilot whale	Mass	1	15.4	Public	Phone	1*	1*
2021	Christchurch	Long-finned pilot whale	Single	1	4.1	DOC	Phone	1*	1*
2022	Golden Bay	Long-finned pilot whale	Mass	4	13.8	Public	Phone	4	0
Total				**53**	**427.2**			**24***	**32***

Table A8.2 Ethogram of stranded odontocete behaviour derived from video observations of 53 focal individuals (4 species, 14 stranding events) on the New Zealand coast between August 2010 and March 2022. Two physiological parameters are included. Note: behaviours displayed only by pilot whales** vs those not displayed by pilot whales*.

Body location	**Type**	**Behaviour**	**Description**
Blowhole	Point	Blowhole twitch	Blowhole makes small muscular twitching movement
Blowhole	Point	Water from blowhole	Small amount of water expelled from blowhole without respiration

Blowhole	Point	Open-close blowhole**	Blowhole opens and closes but there is no movement of thorax indicating that respiration does not occur
Fin	State	Dorsal fin flutter	Dorsal fin makes small lateral shaking/tremor type movements
Fin	State	Pec fin flutter L	Pectoral fin left flutters in small shaking/tremor type movements dorso-ventrally
Fin	State	Pec fin flutter R	Pectoral fin right flutters in small shaking/tremor type movements dorso-ventrally
Fin	State	Tail flutter	Tail fluke flutters, small shaking/tremor type movements dorso-ventrally without lifting peduncle
Fin	State	Pec joint moves**	Joint of pectoral fin rotates anterior or posterior without lifting pectoral fin
Head	State	Head arch*	Head and thorax are lifted high off the ground into a curved arch
Head	State	Head lift	Head is lifted slightly off the ground without moving the thorax
Head	State	Head side-to-side	Head moves from side to side laterally
Head	State	Mouth open	Animal opens its mouth and closes it again
Head	Point	Movement in lower jaw	Small twitching type muscular movement in lower jaw/throat as if swallowing
Head	Point	Nuchal pad twitch**	Muscle twitch in nuchal fat pad behind the blowhole
Head	Point	Head-pec fin jerk/flinch**	Anterior part of body from pectoral fin to the head jerks/flinches suddenly to one side

Head	State	Eye open L**	Left eye is open continuously
Head	State	Eye open R**	Right eye is open continuously
Melon	State	Vocalisation**	Animal audibly vocalises
Posture	State	Dorsal recumbency**	Animal is lying on its dorsal (back) surface
Posture	State	Lateral recumbency	Animal is lying on its side (lateral)
Posture	State	Ventral recumbency	Animal is lying on its ventrum (underside)
Tail	State	Tail arch	Tail fluke and entire peduncle are lifted high off the ground into a curved arch
Tail	State	Tail hover	Tail is lifted slightly off ground and remains there hovering
Tail	State	Tail lift	Tail fluke and caudal peduncle lift slightly off the ground
Tail	State	Tail side-to-side	Tail moves from side to side (lateral)
Tail	State	Tail fluke slapping**	Animal slaps fluke up and down (dorso-ventral) on ground quickly and vigorously without lifting peduncle
Whole body	State	Body rocking	Entire body rocks laterally side to side
Whole body	State	Body tenses	Entire body girth appears to expand without respiration, possibly tensing all muscles
Whole body	State	Body tremble	Whole body trembles/shakes

Whole body	State	Whole body arching/ thrashing	Entire body thrashes/arches vigorously dorso-ventrally
Thorax	Point	Heartbeat**	Visible heartbeat close to left pectoral fin insertion on the ventrum
Thorax	Point	Respiration	Animal’s thorax expands, blowhole opens, and audible explosive exhalation and inhalation occurs

Table A8.3 Types of human intervention that occurred with individual focal stranded cetaceans (n = 53; 4 species across 14 stranding events) on the New Zealand coast between August 2010 and March 2022.

Intervention	**Description of intervention**
Present	Human within ~2m of individual focal stranded cetacean but not touching it
Watering	Human pours water onto cetacean
Touching	Human places hands on cetacean but is not trying to move it
Digging	Human digs out sand from around cetacean but has no direct contact
Rolling	Human rolls cetacean laterally (direct contact always occurs with rolling)
Noise	Noise caused by humans (other than normal talking) within ~2m of individual focal stranded cetacean
Holds dorsal fin	Human holds onto dorsal fin of cetacean using hands
Dog present	Canine is within ~2m of individual focal stranded cetacean but has no direct contact
Reflex test	Human performs reflex tests (palpebral, eyes or blowhole) on cetacean
Places block by sides	Human places wooden blocks or similar each lateral side of cetacean to prevent movement
Places sand by sides	Human builds sand wall at lateral sides of cetacean to prevent rolling
Holds peduncle	Human encircles peduncle of cetacean using arm
Rubbing	Human uses cloth to rub skin of focal stranded cetacean

Figure A8.1 Observation of dark green liquid (within black ovals) defecated from live-stranded long-finned pilot whale. Photo credits: Rob Leenheer.

Figure A8.2 Observation of pectoral fin oriented laterally and superior to dorsal plane (within black ovals) in live stranded long-finned pilot whale. Photo credits: Kyle Mulinder.

Appendix 9 Additional data related to pygmy killer whale (Feresa attenuata) stranding: Chapter 5

Table A9.1. Pygmy killer whale (*Feresa attenuata*) behavioural responses during and post-ballistics euthanasia.

Type	Behaviour	Description
Point	Jaw open	Slack/open lower jaw
Point	Muscle relax	Relaxation of epaxial musculature, body becomes ‘limp’
State	Agonal convulsion	Unprovoked violent, rapid thrashing movements involving whole body (clonic convulsions)
State	Peduncle stiffens	Peduncle muscles stiffen (tonic convulsion) during euthanasia
State	Body tremble	Whole body trembles/shakes
State	Dorsal fin flutter	Dorsal fin makes minor lateral shaking/tremor type movements
State	Tail arch	Tail fluke and entire peduncle are elevated high off the ground into a curved arch
State	Tail flutter	Tail fluke flutters, minor shaking/tremor type movements dorso-ventrally without lifting peduncle
State	Tail hover	Tail is elevated off ground and remains hovering
State	Tail lift	Tail fluke and caudal peduncle elevated off the ground

Here further biological information is presented on the stranding of pygmy killer whales in New Zealand in 2020, where the species is recorded as vagrant (Baker et al. 2019). To date, this recent event totals only the third record of this species in New Zealand waters.

Morphology, sex, morphometrics and dental counts

The morphology, biometric measurements (Table A9.2), sex and dental counts on the left side (Table A9.3) of each animal were noted. The body colour of the animals was black, with a grey flank and underside, there was a pink-white colouring in an oval shape around the genital region and in a small patch on the ventrum between the pectoral fins. The tip of the snout was also pink-white in colour, and there were numerous scars, likely cause by *Isistius* species (Zerbini and de Oliveira Santos 1997; Baird 2018) on the ventral surface, particularly close to the mouth. Both animals were noted to have some parallel rake marks, mainly on the dorsal surface and flanks.

Table A9.2. External measurements (cm) of the stranded pygmy killer whales (*Feresa attenuata*) in New Zealand in 2020.

Measurement	Animal 1	Animal 2
Total length	237.0	247.0
Tip upper jaw to tip dorsal fin	157.0	142.0

Tip upper jaw to anus	157.0	162.0
Tip upper jaw to genital slit	135.0	140.0
Tip upper jaw to insertion flipper	49.0	52.0
Tip upper jaw to blowhole	28.0	26.0
Length flipper external	47.0	47.0
Length flipper internal	30.0	29.0
Width flipper	16.0	16.0
Width tail flukes	59.0	62.0
Length of gape	23.0	22.0
Height dorsal fin	24.5	26.5
Axillary half girth	74.0	75.0
Genital slit length	12.0	15.0

Table A9.3. Sex, individual length, and dental count of the stranded pygmy killer whales (*Feresa attenuata*) in New Zealand in 2020. TL = Total length, UL/LL = Upper left and lower left of jaw.

Animal	**Stranding date**	**Euthanasia date**	**TL (cm)**	**Sex**	**Dental Count UL/LL**
Animal 1	09-10/03/2020	10/03/2020	237	Male	11/13
Animal 2	09-10/03/2020	10/03/2020	247	Male	11/13

Reproduction

Gonads (testes and associated epididymides) were sampled from each animal following standard post-mortem procedures (Geraci and Lounsbury 2005), to enable an examination of maturity status. Both testes from each animal were photographed, measured, and weighed (with and without associated epididymides). Testes and epididymides were then sub-sampled (1 cm^3 blocks) and fixed in 10% neutral buffered formalin, within 10 hours post-mortem. Maturity status was assessed through standard histological examination of the testes following Betty et al. (2019).

The size and weight of the testes from both individuals were found to be similar (Table A9.4). The testes of both animals were noted to be hypertrophied (Figure A9.1), being enlarged and congested with apparent, numerous blood vessels. In both individuals, the seminiferous tubules were found to contain all cell types involved in spermatogenesis, and the lumina contained mature spermatozoa, confirming that the individuals were mature males (Figure A9.2).

Table A9.4. Measurements (mm) and weight (g) of the testes from the stranded pygmy killer whales (*Feresa attenuata*) in New Zealand in 2020

Measurement	**Animal 1**	**Animal 2**
Testes right length	428	448
Testes right width	116	122
Testes right diameter	67	69
Testes right weight	2212	2281

Testes right weight without epi	2083	2171
Testes left length	420	419
Testes left width	111	108
Testes left diameter	69	68
Testes left weight	2280	2140
Testes left weight without epi	2137	2007

Figure A9.1. Example of hypertrophied testes with developed vascular system found at dissection of both animals.

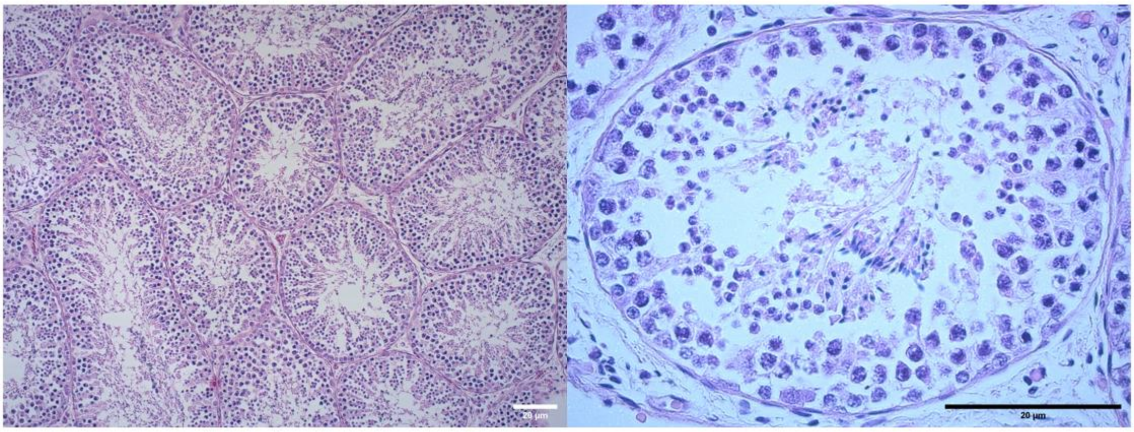

Figure 9.2. Histological example of the mature and active male testes (Animal 1), showing little interstitial tissue and multi-layered seminiferous epithelium with all stages of spermatogenesis (including the production of spermatozoa) visible within a well-developed lumen.

Appendix 10 Information provided in Standard Operating Procedures (SOPs) for technically enacting euthanasia: Chapter 6

Table A10.1. Information provided in SOPs for employing chemical euthanasia on stranded cetaceans in Victoria (VIC), Southern Australia (SA), Tasmania (TAS), Queensland (QDL) and New South Wales (NSW).

SOP	Cetacean size	Example animals	Sedation agent	Sedation dose	Sedation route	Needle gauge	Euthanasia agent	Euthanasia dose	Euthanasia route	Needle gauge	Additional information
VIC Used in: SA	<2 m	Juvenile pygmy sperm whale: length 2 m, est. 200–250 kg Common dolphin: length 2 m, est. 110 kg	Midazolam	0.02–0.1 mg/kg	IV	NA	Pentobarbitone sodium	325 mg/ml at 25 ml/m	IV	NA	20 mins after sedative
VIC	<2 m	Juvenile pygmy sperm whale: length 2 m,	Acepromazine	1 mg/kg, ca. 35 mg/m	IM	1.5 inch (14–18 g)	Pentobarbitone sodium	325 mg/ml at 25 ml/m	IV	NA	45 mins after sedative

Used in: SA		est. 200–250 kg Common dolphin: length 2 m, est. 110 kg									
VIC Used in: SA	2–4 m	Pygmy sperm whale: maximum length 3.66 m, maximum body mass 480 kg (female), 374 kg (male) Bottlenose dolphin: length 3 m, est. 650kg	Acepromazine	1 mg/kg, ca. 35 mg/m	IM	2–3.5 inch (14–18 g)	Pentobarbitone sodium	325 mg/ml at 25 ml/m	IV, IC	IC 6–12 inch	45 mins after sedative

VIC Used in: SA	2–4 m	Pygmy sperm whale: maximum length 3.66 m, maximum body mass 480 kg (female), 374 kg (male) Bottlenose dolphin: length 3 m, est. 650 kg	Medetomidine	0.04–0.08 mg/kg	IM	2-3.5 inch (14–18g)	Pentobarbitone sodium	325 mg/ml at 25 ml/m	IV, IC	IC: 6–12 inch	45 mins after sedative
VIC Used in: SA	4–7 m	False killer whale: length 5–6 m, est. 1,000–1,400 kg Long-finned pilot whale:	Acepromazine	1 mg/kg, ca. 35 mg/m	IM	3.5 inch (14–18g)	Pentobarbitone sodium	325 mg/ml at 25 ml/m	IV, IC	IC: >12 inch	45 mins after sedative

		length 4.5–6 m, est. 1,200–1,800 kg									
VIC Used in: SA	4–7 m	False killer whale: length 5–6 m, est. 1,000–1,400 kg Long-finned pilot whale: length 4.5–6 m, est. 1,200–1,800 kg	Medetomidine	0.04–0.08 mg/kg	IM	3.5 inch (14–18 g)	Pentobarbitone sodium	325 mg/ml at 25 ml/m	IV, IC	IC: >12 inch	45 mins after sedative
VIC Used in: SA	>7 m	Killer whale female length 7–8 m, est. 4,000 kg Killer	Acepromazine	1 mg/kg, ca. 35 mg/m	IM	10 inch (14–16 g)	Pentobarbitone sodium	325 mg/ml at 25 ml/m	IC, blowhole	IC: >12 inch, blowhole: 75 cm flexibl	45 mins after sedative

		whale, male: length 8–9.5 m, est. 6,000–8,000 kg								e catheter after expiration	
VIC Used in: SA	>7 m	Killer whale female length 7–8 m, est. 4,000 kg Killer whale, male: length 8–9.5 m, est. 6,000–8,000 kg	Medetomidine	0.04–0.08 mg/kg	IM	10 inch (14–16 g)	Pentobarbitone sodium	325 mg/ml at 25 ml/m	IC, blowhole	IC: >12 inch, blowhole: 75 cm flexible catheter after expiration	45 mins after sedative
VIC	Large cetacean	Humpback whale, Southern right whale	Midazolam, Acepromazine, Xylazine	0.05 mg/kg, 0.15 mg/kg, 3.5 mg/kg	IM	11 inch (16–18 g)	Pentobarbitone sodium	10 mg/kg			

Used in: SA											
NSW	<8 m		Benzodiazepine, Midazolam	15 mg/m	IM		Potassium chloride (KCl)	60 mg/kg	IV		
NSW	<8 m		Diazepam	0.1 mg/kg	IM		Potassium chloride (KCl)	60 mg/kg	IV		
NSW	<8 m		Acepromazine	100 mg/m	IM		Potassium chloride (KCl)	60 mg/kg	IV		
NSW	<8 m		Pentobarbitone	200–300 ml	IV		Potassium chloride (KCl)	60 mg/kg	IV		
NSW	<8 m						Pentobarbitone	50–100 mg/kg (25–35 ml/m) at 325 mg/ml	IC, IV		
TAS	>7 m		Midazolam	0.05–0.1 mg/kg	IM	16–18 g 300–500 mm	Potassium chloride (KCl)	75–200 mg/kg (300 mg/ml; 4 mmol/ml)	IC	11 g, 1000 mm	Pentobarbital sodium can be used where eco-toxicity is not an issue

TAS	>7 m		Acepromazine	0.2–1 mg/kg	IM	16–18 g 300–500 mm	Potassium chloride (KCl)	75–200 mg/kg (300 mg/ml; 4 mmol/ml)	IC	11 g, 1000 mm	Pentobarbital sodium can be used where eco-toxicity is not an issue
TAS	>7 m		Xylazine	3–4 mg/kg	IM, IV	16–18 g 300–500 mm	Potassium chloride (KCl)	75–200 mg/kg (300 mg/ml; 4 mmol/ml)	IC	11 g, 1000 mm	Pentobarbital sodium can be used where eco-toxicity is not an issue
TAS	>7 m		Tiletamine/Zolazepam	1–5 mg/kg	IM	16–18 g 300–500 mm	Potassium chloride (KCl)	75–200 mg/kg (300 mg/ml; 4 mmol/ml)	IC	11 g, 1000 mm	Pentobarbital sodium can be used where eco-toxicity is not an issue
TAS	>7 m		Medetomidine	0.01–0.03 mg/kg	IM	16–18 g 300–500 mm	Potassium chloride (KCl)	75–200 mg/kg (300 mg/ml; 4 mmol/ml)	IC	11 g, 1000 mm	Pentobarbital sodium can be used where eco-

											toxicity is not an issue
TAS	>7 m		Ketamine	2.5 mg/kg	IM	16–18g 300–500 mm	Potassium chloride (KCl)	75-200 mg/kg (300 mg/ml; 4 mmol/ml)	IC	11 g, 1000 mm	Pentobarbital sodium can be used where eco-toxicity is not an issue
QDL	Upto pilot whale size	Pilot whale					Pentobarbitone		IV, IC		

Table A10.2. Information provided in SOPs for employing ballistics euthanasia on stranded cetaceans in Western Australia (WA), Victoria (VIC), Tasmania (TAS), Queensland (QDL), Southern Australia (SA), New South Wales (NSW) and New Zealand (NZ).

SOP	Cetacean size	Firearm type	Firearm calibre	Projectile shape	Projectile characteristics	Projectile grain	No. of shots required	Aim	Angle of aim	Distance from cetacean at discharge
WA Used in: VIC, TAS, QDL, SA	<7 m	Bolt action rifle	.308 Winchester or .300 Winchester Magnum	Blunt	Solid, hydrostatically stabilised	180 gr	3	Hindbrain	Slightly posterior to the blowhole, angled backwards at 45˚ along the animal's midline. Midway between the eye and the pectoral fin when the animal is viewed laterally	0.5–1.0 m
NZ	<2 m	High power rifle	.260, .270, .303, .308	Not provided	Standard sporting round	Not provided	Not provided	Rear of brain	Hand span behind blowhole or one/third of way between eye and origin pectoral fin	Not provided
NZ	2–6 m	High power	.303, .30-06	Not provided	Soft nose	Not provided	Not provided	Rear of brain	Hand span behind blowhole or	Not provided

		hunting rifle							one/third of way between eye and origin pectoral fin	
NSW	Small cetacean: dolphins	Rifle	.223, .243	Not provided	Solid	Not provided	Not provided	Brain	Through the blowhole, angled backwards to an imaginary mid-point on a line between the pectoral flippers. Alternatively, a lateral aim can be directed midway between the eye and the ear aperture	Not provided
NSW	Medium cetaceans: pilot whales	Rifle	.308, .375, .458	Not provided	Solid	Not provided	Not provided	Brain	Through the blowhole, angled backwards to an imaginary mid-point on a line between the pectoral flippers. Alternatively, a lateral aim can be	Not provided

									directed midway between the eye and the ear aperture	
NSW	<5 m	Shotgun			Slug or buckshot (nine lead pellets)	28 gm	Not provided	Brain	Through the blowhole, angled backwards to an imaginary mid-point on a line between the pectoral flippers. Alternatively, a lateral aim can be directed midway between the eye and the ear aperture	Not provided
QDL	<9 m	Rifle	7.62x39, .308 Win	Not provided	Not provided	125 gr, 150 gr	Not provided	Brain	Through the blowhole angled slightly backwards or a temporal shot	Not provided

Table A10.3. Information on euthanasia via explosives following (Coughran et al. 2012) that is recommended in SOPs for Western (WA), Victoria (VIC) and Queensland (QDL) Australia, and the related equipment required for such peri-cranial implosion techniques (Coughran et al. 2012) and *pers. comm.* Peter Mawson.

Cetacean size	Cetacean species	Explosive	No. sticks	Size of sticks	Additional boosters	Shape for detonation	Placement of explosives	Machinery required	Reference
10.5 m	Humpback whale	Powergel Magnum	5	125 g	None	Triangular pyramid	Cranium dorsally	D9 or D65EX bulldozers	(Coughran et al. 2012)
9.8 m	Humpback whale	Powergel Magnum	14	125 g	None	Triangular pyramid	Cranium dorsally	D9 or D65EX bulldozers	(Coughran et al. 2012)
12.7 m	Humpback whale	Powergel Magnum	22	125 g	2x 50 g	Triangular pyramid	Cranium dorsally	D9 or D65EX bulldozers	(Coughran et al. 2012)
9.5 m	Humpback whale	Powergel Magnum	15	125 g	None	Triangular pyramid	Cranium laterally	D9 or D65EX bulldozers	(Coughran et al. 2012)

Equipment List

- 30 x 20 kg sandbags for tamping explosive and stabilizing the whale
- Shovels for filling sandbags
- 50 x medium cable ties for sealing and securing the sandbags to rope (see Figure 5 in Coughran et al. 2012)
- 4 used car tyres with loops to act as anchors for securing ropes
- waterproof camera
- wet suits and booties for personnel entering water
- modified dolphin cradle to manoeuvre the whale
- 100 m of 10–12 mm diameter nylon rope for securing explosives
- 200 m of 40 mm nylon rope to stabilize whale and to tow it up the beach (after euthanasia)
- 50 m of 2–3 mm nylon string.
- 2 x sharp rope cutting knives (Green River® or Spyderco® serrated edge knife)
- D-9 dozer
- 5/8th inch Chain sling to be shackled to Dozer blade to attach 40 mm towing rope.
- 18 x sticks of 125 g Power Gel® (ICI Australia Ltd)
- 6 x electric detonators
- 10 m of detonating cord.
- 2 x 75 m lengths of 2-core low resistance electrical cable. Check cable continuity and resistance with multi-meter. Short out cable ends when finished
- 2 x 12 V heavy-duty truck batteries or 2 x exploders
- 2 x rolls of self-amalgamating electrical tape (for waterproof detonator electrical joins)
- 4 x rolls of plastic electrical insulation tape (to tape electrical cable to rope)
- 2 x pairs pliers
- 1 x wooden or brass skewer for making holes in explosive for detonating cord
- .300 Winchester Magnum or .308 Winchester bolt-action, 3x solid, hydrostatically stabilised 180 grain bullets (updated based on Hampton et al. 2014b)
- Radio contact from blast site with both ends of beach, hinterland and offshore. Ensure radios and mobile telephones are switched off prior to detonators being removed from shielded metal box and inserted into explosives.
- Guard boat to control offshore traffic
- Air horn

Appendix 11 Methods, reported TTD and taxa involved in euthanasia events: Chapter 7

Table A11.1. Marine mammal euthanasia via chemical methods (injection and inhalation), including details of methods and time-to-death or insensibility (TTD) as reported in the peer-reviewed literature between 1980 and 2020.

Taxon	Species	Method	Length of animal (m)	Mass of animal (kg)	Chemical agent	Parenteral injection route	Injection location	Dose	TTD (mins)	Ref.
Cetacean	Cetacean	Chemical			Barbiturate					[14]
Delphinid	Bottlenose dolphin	Chemical			Barbiturates	IV				[3]
Delphinid	Common dolphin	Chemical	1.91		Pentobarbitone Euthatol	IP	Peritoneal cavity	60 mL	20	[15]
Delphinid	Common dolphin	Chemical			Barbiturates	IV				[3]
Delphinid	White-beaked dolphin	Chemical	2.66	273.7	Midazolam	IM		0.08 mg/kg	20	[59]
					Acepromazine	IM		0.8 mg/kg		
					Xylazine	IM		1.6 mg/kg		
Delphinid (Blackfish)	False Killer whale	Ballistics, Chemical			Pentobarbitone					[16]

Delphinid (Blackfish)	Long-finned pilot whale	Chemical			T61	IV	Dorsal fin	0.14 cc per pound of body weight		[38]
Delphinid (Blackfish)	Long-finned pilot whale	Chemical			Pentobarbital					[39]
Delphinid (Blackfish)	Long-finned pilot whale	Chemical	5.54, 5.55		Etorphine			2.45 mg/mL		[40]
					Acepromazine			10 mg/mL		
Delphinid (Blackfish)	Melon-headed whale	Chemical	2.12, 2.40, 2.48	125, 200, 125	Xylazine	IM	Epaxial muscles	0.5 mg/kg	8	[41]
					Ketamine	IM	Epaxial muscles	2.5 mg/kg		
Delphinid (Blackfish)	Pilot whale	Chemical	2.1		Diazepam	IM		20 mg		[43]
					Sodium pentobarbital	IH		23,400 mg		
					Phenytoin	IH		300 mg		

Delphinid (Blackfish)	Pilot whale	Chemical	2.97	Meperidine	IM	100 mg	[43]
				Sodium pentobarbital	IC	19,500 mg	
				Phenytoin	IC	2500 mg	
Delphinid (Blackfish)	Pilot whale	Chemical	3.58	Xylazine	IM	6000 mg	[43]
				Acepromazine	IM	100 mg	
Delphinid (Blackfish)	Pilot whale	Chemical	3.52	Sodium pentobarbital		46,800 mg	[43]
				Phenytoin		6000 mg	
Delphinid (Blackfish)	Pilot whale	Chemical	3.59	Xylazine	IM	1000 mg	[43]
				Acepromazine	IM	100 mg	
				Sodium pentobarbital		46,800 mg	
				Phenytoin		6000 mg	
Delphinid (Blackfish)	Pilot whale	Chemical	3.5	Sodium pentobarbital		46,800 mg	[43]

					Phenytoin			6000 mg		
Delphinid (Blackfish)	Pilot whale	Chemical	3.49		Xylazine	IM		6000 mg		[43]
					Acepromazine	IM		100 mg		
Delphinid (Blackfish)	Pygmy killer whale	Chemical	2.46		T61	IV				[53]
Kogiid	Pygmy sperm whale	Chemical	3.1		Midazolam	IM		50 mg (5 mg/mL)		[54]
					Pentobarbital (Euthasol)	IV				
Mustelid	Southern sea otter	Chemical	0.45	1.45	Fentanyl citrate, Diazepam	IM				[56]
					Pentobarbital sodium	IV				
Mustelid	Southern sea otter	Chemical			Pentobarbital	IV		2340 mg		[57]
					Pentobarbital	IV		5850 mg		
Mysticete	Fin whale	Chemical	10.5		Xylazine	IV	Major vein close to heart/thorax	5000 mg	60	[17]

				T61	IV	Major vein close to heart/thorax	100 mL		
				KCl	IV	Major vein close to heart/thorax	1200 mmol/600 mL sterile water		
Mysticete	Fin whale	Chemical, Inhalation	13.5	Pentobarbital, T61	Inhalation	Blowhole	60 mL (390 mg/mL)	40	[18]
				T61	IV	Fluke	2 x 60 mL		
Mysticete	Gray whale	Chemical	8.22	Pentobarbital	IV	Ventral margin of peduncle	500 cc		[19]
Mysticete	Gray whale	Chemical	8–12	Midazolam	IM		0.02 mg/kg		[20]
				Pentothal sodium	IV	Superficial caudal peduncle veins			

Mysticete	Humpback whale	Ballistics, Chemical			Detomidine, Midazolam, Butorphanol	IM	12-inch dart			[36]
					Barbiturate	IV, IP				
Mysticete	Humpback whale	Chemical	8.78	9500	Midazolam	IM	Left epaxial muscle cranial to scapula	400 mg (0.04 mg/kg)	99	[37]
					Acepromazine	IT	Caudal to right pectoral fin	1950 mg (0.2 mg/kg)		
					Xylazine	IV	Right pectoral fin between ulna and radius	31,000 mg (3.4 mg/kg)		
					KCl	IC, IV	Near heart	100 mg/kg (1.3 mmol/kg)		
Mysticete	Humpback whale	Chemical	8.3	8000	Midazolam	IM		415 mg (0.05 mg/kg)	138	[37]

					Acepromazine	IM		2100 mg (0.25 mg/kg)		
					Xylazine	IM, Retrobulbar, IV		30,000 mg (3.5 mg/kg)		
					KCl	IT, IV		220 mg/kg (3 mmol/kg)		
Mysticete	Humpback whale	Chemical	9.76	13,000	Midazolam	IM		325 mg (0.025 mg/kg)	109	[37]
					Acepromazine	IM		2000 mg (0.15 mg/kg)		
					Xylazine	IV	Right pectoral fin vessel	33,500 mg (2.6 mg/kg)		
					KCl		Near heart	150 mg/kg (2 mmol/kg)		

Mysticete	Minke whale	Chemical	3.04	276	Midazolam	IM	0.14 mg/kg	48	[37]
					Acepromazine	IM, IV	1.6 mg/kg		
					Xylazine	IM, IV, IC	15.3 mg/kg		
					KCl	IC	168 mg/kg (2.2 mmol/kg)		
Mysticete	Minke whale	Chemical	5.8		Barbiturates	IV			[42]
Mysticete	Minke whale	Chemical	2.84		Diazepam	IM	20 mg		[43]
					Sodium pentobarbital	IH	70,200 mg		
					Phenytoin	IH	9000 mg		
Mysticete	Minke whale	Chemical	2.93	214.8	Meperidine (Meperidine HCl)	IM	100 mg (0.46 mg/kg), (25 mg/mL)	31	[44]

					Pentobarbital sodium	IC	13.65 g (63 mg/kg)		
					Phenytoin sodium	IC	1.75 g (8.1 mg/kg)		
Mysticete	Right whale	Chemical, Inhalation, Exsanguination	9.75	10,000	Midazolam	Retrobulbar	90 mg (0.009 mg/kg)	123	[37]
					Diazepam	Retrobulbar	150 mg (0.015 mg/kg)		
					Acepromazine	Retrobulbar	450 mg (0.045 mg/kg)		
					Xylazine	Retrobulbar	13,000 mg (1.3 mg/kg)		
					Medetomidine	Retrobulbar	22 mg (2.2 µg/kg)		

					Isoflurane	Inhalation		200 mL		
Mysticete	Southern Right whale	Chemical	14	40,000	Xylazine	IM	Tongue	8000 mg (0.2 mg/kg), 19,800 mg (0.5 mg/kg)	2981	[55]
					Midazolam	IM	Tongue	840 mg (0.021 mg/kg)		
					Thiopental sodium in saline	Inhalation	Blowhole	113 g in 2000 mL		
					Chloral hydrate	Inhalation	Blowhole	500 g		
					Ketamine	IM	Tongue	99,000 mg (2.47 mg/kg)		
					T61	IV	Near heart	750 mL		
					KCl	IV	Near heart	10,000 mL of 1 mmol		

Odontocete	Sperm whale	Chemical	6.1		Barbiturate Beuthanasia-D Special	IV	Left pectoral fin	20 cc	5	[58]
					Barbiturate Beuthanasia-D Special	IV	Vein on dorsal side of fluke	20 cc		
Pinniped	Antarctic fur seals	Chemical			Tiletamine hydrochloride, Zolazepam hydrochloride			1:1		[1]
Pinniped	Bearded seal	Chemical	1.8	92.8	Telazol	IV	Epidural vein			[2]
Pinniped	California sea lion	Chemical			Xylazine hydrochloride	IM		2.5 mL of 100 mg/mL		[10]
					Sodium pentobarbital	IC		40 mL of 389 mg/mL		
Pinniped	California sea lion	Chemical			Tiletamine Zolazepam (Telazol)	IM		175 mg 1:1, 100 mg		[11]

					Pentobarbital	IV, IC		2730 mg	
Pinniped	California sea lion	Chemical			Pentobarbital	IV			[12]
Pinniped	California sea lion	Chemical		37	Tiletamine-zolazepam	IM		200 mg	[4]
					Pentobarbital, Phenytoin sodium	IV	Subclavian vein	10 mL of 39% and 5%	
Pinniped	California sea lion	Chemical, Inhalation			Telazol	IM		1.0 mg/kg	[5]
					Metatomadine	IM		0.04 mg/kg	
					Isoflurane	Inhalation			
Pinniped	California sea lion	Chemical			Barbiturate				[50]
Pinniped	California sea lion	Chemical			Pentobarbital sodium, Phenytoin sodium	IV	Subclavian vein	1 mL/5 kg of 39% and 5%	[6]
Pinniped	California sea lion	Chemical, Inhalation							[60]

Pinniped	California sea lion	Chemical		13–168	Pentobarbital	IV	Subclavian vein	80 mg/kg	[7]
Pinniped	California sea lion	Chemical			Pentobarbital sodium, Phenytoin sodium	IV	Subclavian vein	1 mL/5 kg of 39% and 5%	[8]
Pinniped	California sea lion	Chemical			Barbiturate				[9]
Pinniped	Cape fur seal	Chemical	1.93	182	Sernylan	IM		500 mg	[13]
					Rompun	IM		60 mg	
					Scoline	IM		100 mg	
Pinniped	Grey seal	Chemical		58.5	Euthanyl				[21]
Pinniped	Grey seal	Chemical		155	Pentobarbital sodium (Euthasol)	IV		70 mL	[22]
Pinniped	Grey seal	Chemical		19	Pentobarbitone (Euthatal)	IV	Extradural intravertebra l vein	150 mg/kg	[23]
Pinniped	Grey seal	Chemical			Pentobarbital	IV			[24]
Pinniped	Grey seals	Chemical			T61			0.3 mL/kg	[31]

Pinniped	Harbor seal	Chemical		Pentobarbitone	IV	1900 mg	[25]
Pinniped	Harbor seal	Chemical	90				[26]
Pinniped	Harbor seal	Chemical		Pentobarbital sodium, Phenytoin sodium	IV	5 mL of 39% and 5%	[27]
Pinniped	Harbor seal	Chemical, Inhalation					[60]
Pinniped	Harbor seals	Chemical		Sodium pentobarbital	IV	0.5 mL/kg	[28]
Pinniped	Harbor seals	Chemical		T61		0.3 mL/kg	[29]
Pinniped	Harbor seals	Chemical	120	Pentobarbital sodium, Phenytoin sodium	IV	10,140 mg	[30]
			70	Pentobarbital sodium, Phenytoin sodium	IV	2340 mg	

			57	Pentobarbital sodium, Phenytoin sodium	IV		8800 mg	
			90.3	Pentobarbital sodium, Phenytoin sodium	IV		5460 mg	
Pinniped	Harbor seals	Chemical		T61			0.3 mL/kg	[31]
Pinniped	Harp seal	Chemical		Pentobarbital	IV	Extradural intravertebral vein	15 mL (240 mg/mL)	[32]
Pinniped	Harp seal	Ballistics, Chemical, Exsanguination		Barbiturate	IV		30 mg/kg	[33]
Pinniped	Harp seal	Chemical, Exsanguination		Barbiturate	IV		30 mg/kg	[34]
Pinniped	Hooded seal	Ballistics, Chemical, Exsanguination		Barbiturate	IV		30 mg/kg	[33]

Pinniped	Hooded seal	Chemical, Exsanguination			Barbiturate	IV		30 mg/kg	[34]
Pinniped	Hooded seal	Chemical, Exsanguination			Pentobarbital	IV	Extradural intravertebral vein	20 mg/kg	[35]
Pinniped	New Zealand fur seal	Chemical	1.56	47.5	Barbiturates	IC			[45]
Pinniped	Northern elephant seal	Chemical		42.5	Pentobarbital, Phenytoin sodium	IV	Epidural venous sinus	10 mL of 39% and 5%	[4]
Pinniped	Northern elephant seal	Chemical		60	Pentobarbitone	IV	Extradural intravertebral sinus	20 mL	[46]
Pinniped	Northern elephant seal	Chemical			Pentobarbitone	IV	Extradural intravertebral sinus	20 mL	[47]
Pinniped	Northern elephant seal	Chemical		37.5	Pentobarbital	IV		3.9 g	[48]
Pinniped	Northern elephant seal	Chemical		196	Pentobarbital Beuthanasia	IV	Epidural sinus		[49]

Pinniped	Northern elephant seal	Chemical	Barbiturate			[50]
Pinniped	Northern elephant seal	Chemical	Pentobarbital	IV	389 mg/mL	[51]
Pinniped	Northern elephant seal	Chemical, Inhalation				[60]
Pinniped	Pacific Harbor seal	Chemical	Pentobarbital	IV	389 mg/mL	[51]
Pinniped	Pinnipeds	Chemical	Barbiturate			[14]
Ursid	Polar bear	Chemical	Pentobarbital			[52]

Table A11.2. Marine mammal euthanasia via physical methods (ballistics and explosives), including details of methods and time-to-death or insensibility (TTD) as reported in the peer-reviewed literature between 1980 and 2020.

Taxon	Species	Method	Length of animal (m)	Mass of animal (kg)	Firearm	Projectile characteristics	Orientation	Explosives	TTD (mins)	Ref
Delphinid	Bottlenose dolphin	Ballistics	1.3–2.7		0.300	180 g blunt non-deforming solid	Dorso-ventral			[66]
Delphinid	Common dolphin	Ballistics	2.5–5		12 gauge shotgun	28 g slug, buckshot	Lateral, Dorso-ventral			[61]
Delphinid	Common dolphin	Ballistics								[62]
Delphinid	Common dolphin	Ballistics	1.8		0.308	180 g blunt non-deforming solid	Dorso-ventral			[66]
Delphinid (Blackfish)	False Killer whale	Ballistics, Chemical								[16]
Delphinid (Blackfish)	Long-finned pilot whale	Ballistics	2.5–5		12 gauge shotgun	28 g slug, buckshot	Lateral, Dorso-ventral			[61]
Delphinid (Blackfish)	Long-finned pilot whale	Ballistics								[64]

Delphinid (Blackfish)	Long-finned pilot whale	Ballistics			.30-06		Lateral, Dorso-ventral			[65]
Delphinid (Blackfish)	Risso's dolphin	Ballistics	2.7		0.308	180 g blunt non-deforming solid	Dorso-ventral			[66]
Kogiid	Pygmy sperm whale	Ballistics	1.8–2.5		.300, .308	180 g blunt non-deforming solid	Dorso-ventral			[66]
Mysticete	Humpback whale	Ballistics, Chemical			0.577	3 rounds	Peri-cranial			[36]
Mysticete	Humpback whale	Explosives	9.11	10000			Dorso-ventral	6 x AN60	0	[63]
			10.5	15000	0.300	5 rounds	Dorso-ventral	5 X 125 g Powergel magnum		
			9.8	15000				14 X 125 g Powergel magnum	0	
			12.7					22X 125 g Powergel magnum and 2X 50 g Boosters	0	

			9.5	15000				15X 125 g Powergel magnum	0	
Mysticete	Humpback whale	Ballistics	4.2–4.3		0.300	180 g blunt non-deforming solid	Dorso-ventral			[66]
Pinniped	Harp seal	Ballistics, Chemical, Exsanguination								[33]
Pinniped	Hooded seal	Ballistics, Chemical, Exsanguination								[33]
Ziphiid	Cuvier's beaked whale	Ballistics	4.2		0.300	180 g blunt non-deforming solid	Dorso-ventral			[66]

Table A11.3. Cetacean species reported as euthanised using chemical methods and respective chemical information and time-to-death or insensibility (TTD) as reported by the United Kingdom (UK) to the International Whaling Commission (IWC) between 2014 and 2018.

Taxon group	**Species**	**Number euthanised**	**Chemical agent**	**Injection route**	**Dose reported**	**TTD (mins)**
Delphinid	Atlantic white-sided dolphin	1	Pentobarbitone	Intravenous	100 mL	
Delphinid	Bottlenose dolphin	1	Somulose	Intravenous	50 mL	
Delphinid	Bottlenose dolphin	1	Pentoject	Intravenous	3 x 50 mL	<2

Delphinid	Common dolphin	1	Pentobarbital	Intravenous	40 mL at 200 mg/mL	
Delphinid	Common dolphin	1	Pentobarbitone	Intravenous	30 mL	
Delphinid	Common dolphin	1	Pentobarbitone 20%	Intravenous	30 mL	2
Delphinid	Common dolphin	1	Euthatal	Intravenous	50 mL	<1
Delphinid	Common dolphin	1	Pentobarbital	Intravenous	50 mL	<2
Delphinid	Common dolphin	1	Euthatal	Intravenous	50 mL	
Delphinid	Common dolphin	1	Pentobarbitone	Intravenous	50 mL	
Delphinid	Striped dolphin	1	Pentobarbitone	Intravenous	50 mL	2
Delphinid	Striped dolphin	1	Barbiturate	Not provided	Not provided	
Delphinid	Striped dolphin	1	Pentobarbiturate	Intrathoracic	30 mL	
Delphinid	White-beaked dolphin	1	Pentobarbitone	Intravenous	100 mL	
Delphinid	White-beaked dolphin	1	Pentobarbital sodium	Intravenous	100 mL	<3
Delphinid (Blackfish)	Risso’s dolphin	1	Pentobarbitone	Intramuscular	100 mL	
Phocoenid	Harbour porpoise	1	Euthatal	Intravenous	20 mL	
Phocoenid	Harbour porpoise	1	Pentobarbital	Intravenous	25 mL	
Phocoenid	Harbour porpoise	1	Barbiturate	Intravenous	20 mL	
Phocoenid	Harbour porpoise	1	Dolethal	Intracardiac	40 mL	
Phocoenid	Harbour porpoise	1	Euthatal	Intraperitoneal	20 mL	
Phocoenid	Harbour porpoise	1	Dolethal	Intravenous	15 mL	<2
Phocoenid	Harbour porpoise	1	Pentobarbiturate, Sedation: medetomidine, ketamine	Intracardiac	20 mL	
Phocoenid	Harbour porpoise	1	Pentoject	Intravenous	25 mL	2

Table A11.4. Cetacean species reported as euthanised using ballistics methods and respective ballistics information and time-to-death or insensibility (TTD) as reported by the United Kingdom (UK) to the International Whaling Commission (IWC) between 2014 and 2018.

Taxon group	Species	Number euthanised	Firearm	Number shots	Projectile characteristic	Orientation discharge	TTD (mins)
Delphinid	White-beaked dolphin	1	Unknown				
Delphinid (Blackfish)	Long-finned pilot whale	Multiple	.243	1	100 gr	Lateral	
Delphinid (Blackfish)	Long-finned pilot whale	1	Unknown				Presumed instant
Delphinid (Blackfish)	Long-finned pilot whale	1	Unknown				Presumed instant
Delphinid (Blackfish)	Long-finned pilot whale	1	Unknown				Presumed instant
Delphinid (Blackfish)	Long-finned pilot whale	1	.308	3		Lateral	Presumed instant
Delphinid (Blackfish)	Long-finned pilot whale	1	Shotgun				
Delphinid (Blackfish)	Long-finned pilot whale	1	.270		Soft-point		
Delphinid (Blackfish)	Risso's dolphin	1	.243	2			Presumed instant
Mysticete	Minke whale	1	Unknown	3			Presumed instant
Phocoenid	Harbour porpoise	1	.22	1			Presumed instant
Ziphiid	Cuvier's beaked whale	1	Unknown	2			Presumed instant

Table A11.5. Cetacean species reported as euthanised using ballistics methods and respective ballistics information and time-to-death or insensibility (TTD) as reported by New Zealand (NZ) to the International Whaling Commission (IWC) between 2007 and 2020.

Taxon group	Species	Number euthanised	Firearm	Number shots	Projectile design	Projectile grain	Number reported as TTD instant	Number presumed instant	TTD (mins)
Delphinid	Bottlenose dolphin	1	.357	1			1		

Delphinid	Bottlenose dolphin	1	Shotgun	2			1		
Delphinid	Bottlenose dolphin	1	Shotgun	1			1		
Delphinid	Bottlenose dolphin	1	.243	1			1		
Delphinid	Common dolphin	1	.22				1		
Delphinid	Common dolphin	1	.223	2					1
Delphinid	Common dolphin	1	.308	1					0.3
Delphinid	Common dolphin	1	.308	1			1		
Delphinid	Common dolphin	1	.308	1			1		
Delphinid	Common dolphin	1	.303	1			1		
Delphinid	Dusky dolphin	1	.223	3			1		
Delphinid	Dusky dolphin	1	.22	2			1		
Delphinid	Dusky dolphin	1	Unknown						
Delphinid	Hector's dolphin	1	Boltgun				1		
Delphinid	Southern Right whale dolphin	1	.30-06						
Delphinid	Striped dolphin	1	.243	1			1		
Delphinid (Blackfish)	Long-finned pilot whale	48	.30-06	1			48		
Delphinid (Blackfish)	Long-finned pilot whale	48	.303	1			48		
Delphinid (Blackfish)	Long-finned pilot whale	1	.30-06	2	Soft-point	150 gm	1		
Delphinid (Blackfish)	Long-finned pilot whale	32	.30-06	1	Soft-point	150 gm	32		

Delphinid (Blackfish)	Long-finned pilot whale	2	.30-06	2	Soft-point	150 gm			2
Delphinid (Blackfish)	Long-finned pilot whale	27	.30-06	1	Soft-point	150 gm	27		
Delphinid (Blackfish)	Long-finned pilot whale	1	.30-06	2	Soft-point	150 gm	1		
Delphinid (Blackfish)	Long-finned pilot whale	1	.243				1		
Delphinid (Blackfish)	Long-finned pilot whale	29	.30-06				28		0.5
Delphinid (Blackfish)	Long-finned pilot whale	6	Bushmaster Semiauto 7.62x39SP	3			6		0.5
Delphinid (Blackfish)	Long-finned pilot whale	1	Bolt-action rifle 7mm-08	5			1		0.5
Delphinid (Blackfish)	Long-finned pilot whale	4	.303						4
Delphinid (Blackfish)	Long-finned pilot whale	43	.308	3			35		4
Delphinid (Blackfish)	Long-finned pilot whale	11	.30-06	2			10		3
Delphinid (Blackfish)	Long-finned pilot whale	8	.303				8		
Delphinid (Blackfish)	Long-finned pilot whale	19	.270	1–3			2		<2

Delphinid (Blackfish)	Long-finned pilot whale	7	Rifle 6.5x55	3					2
Delphinid (Blackfish)	Long-finned pilot whale	25	.30-06				23		
Delphinid (Blackfish)	Long-finned pilot whale	1	.303						
Delphinid (Blackfish)	Long-finned pilot whale	1	Shotgun	2					3
Delphinid (Blackfish)	Long-finned pilot whale	10	.30-06					10	
Delphinid (Blackfish)	Long-finned pilot whale	71	.303	3			70	1	
Delphinid (Blackfish)	Pilot whale (unknown sp.)	8	.308	3			5		3
Delphinid (Blackfish)	Pilot whale (unknown sp.)	30	.30-06	3			27		0.3
Delphinid (Blackfish)	Pilot whale (unknown sp.)	19	.303	1			19		
Delphinid (Blackfish)	Pygmy killer whale	7	.308	2				7	
Delphinid (Blackfish)	Pygmy killer whale	3	Unknown	3					
Delphinid (Blackfish)	Short-finned pilot whale	3	.30-06	1			3		
Kogiid	Pygmy sperm whale	1	.303	1					

Kogiid	Pygmy sperm whale	2	.30-06	3			1		
Kogiid	Pygmy sperm whale	1	.308	3			1		
Kogiid	Pygmy sperm whale	7	.308	3			7		
Kogiid	Pygmy sperm whale	1	.303	1	Soft-point	150 gm	1		
Kogiid	Pygmy sperm whale	2	.30-06	1	Soft-point	150 gm	2		
Kogiid	Pygmy sperm whale	6	.30-06		Soft-point	140 gm	6		
Kogiid	Pygmy sperm whale	1	.303		Soft-point	150 gm	1		
Kogiid	Pygmy sperm whale	3	.303				3		
Kogiid	Pygmy sperm whale	2	.308	1			2		
Kogiid	Pygmy sperm whale	1	.30-06				1		
Kogiid	Pygmy sperm whale	1	.308	1			1		
Kogiid	Pygmy sperm whale	2	.303	1			2		
Kogiid	Pygmy sperm whale	8	.30-06				8		
Kogiid	Pygmy sperm whale	2	.303				2		
Kogiid	Pygmy sperm whale	1	.270	2			1		
Kogiid	Pygmy sperm whale	1	.30-06				1		
Kogiid	Pygmy sperm whale	2	.303	1			2		
Kogiid	Pygmy sperm whale	4	.30-06	1			3		
Kogiid	Pygmy sperm whale	2	.303	1			2		
Kogiid	Pygmy sperm whale	2	.30-06				1	2	
Kogiid	Pygmy sperm whale	3	.303				2	1	
Kogiid	Pygmy sperm whale	1	.300	2				1	
Kogiid	Pygmy sperm whale	2	.303	1					
Mysticete	Bryde's whale	1	.270	1			1		

Mysticete	Dwarf minke whale	1	.30-06	3			1		
Mysticete	Humpback	1	.303						720
Mysticete	Humpback	1	.416	4					
Mysticete	Minke whale	1	.308	1			1		
Mysticete	Minke whale	1	.308	1			1		
Mysticete	Minke whale	1	.270	3					0.3
Mysticete	Minke whale	1	.30-06	3					1
Mysticete	Sei whale	1	.30-06	1			1		
Ziphiid	Arnoux's beaked whale	2	.303	1			2		
Ziphiid	Cuvier's beaked whale	1	Unknown						
Ziphiid	Cuvier's beaked whale	1	.30-06	1			1		
Ziphiid	Cuvier's beaked whale	1	.30-06	6					35
Ziphiid	Gray's beaked whale	1	.308	1			1		
Ziphiid	Gray's beaked whale	1	.44 magnum	1			1		
Ziphiid	Gray's beaked whale	1	.44 magnum	1			1		
Ziphiid	Gray's beaked whale	1	.303	2			1		
Ziphiid	Gray's beaked whale	1	.303	1			1		
Ziphiid	Strap-toothed whale	1	.308	2			1		
Ziphiid	Strap-toothed whale	1	.308	2	Soft-point	180 gm	1		

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Name and title of main supervisor:	Professor Karen A Stockin
In which chapter is the manuscript/published work?	2
What percentage of the manuscript/published work was contributed by the student?	70%

Describe the contribution that the student has made to the manuscript/published work:

Designed and implemented the Delphi method questionnaires. Undertook data analyses, including statistical analyses and validation. Wrote the first draft and edited subsequent drafts of the manuscript and responded to reviewers.

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Designed and implemented the Delphi method questionnaires. Undertook data analyses, including statistical analyses and validation. Wrote the first draft and edited subsequent drafts of the manuscript and responded to reviewers.

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What percentage of the manuscript/published work was contributed by the student?	75%

Describe the contribution that the student has made to the manuscript/published work:

Designed the study, collected data at strandings and undertook all video analyses. Conducted data analysis, including statistical analyses. Wrote the first draft and edited subsequent drafts of the manuscript and responded to reviewers.

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STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Rebecca Mary Boys
Name and title of main supervisor:	Professor Karen A Stockin
In which chapter is the manuscript/published work?	5
What percentage of the manuscript/published work was contributed by the student?	70%

Describe the contribution that the student has made to the manuscript/published work:

Designed the study, collected data at the live stranding event and subsequent collection of biological samples. Undertook all video analyses and conducted data analysis. Wrote the first draft and edited subsequent drafts of the manuscript and will respond to reviewers.

Please select one of the following three options:

- ○ **The manuscript/published work is published or in press**
  Please provide the full reference of the research output:
- ◉ **The manuscript is currently under review for publication**
  Please provide the name of the journal:
  Marine Mammal Science
- ○ **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	Rebecca Boys Digitally signed by Rebecca Boys Date: 2022.07.22 20:35:33 +12'00'	Main supervisor's signature:	Prof Karen A Stockin Digitally signed by Prof Karen A Stockin Date: 2022.07.22 09:34:00 +12'00'

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Name and title of main supervisor:	Professor Karen A Stockin
In which chapter is the manuscript/published work?	6
What percentage of the manuscript/published work was contributed by the student?	75%

Describe the contribution that the student has made to the manuscript/published work:

Designed the study, liaised with all government agencies and reviewed SOPs to collect data. Conducted data analysis, wrote the first draft and edited subsequent drafts of the manuscript and responded to reviewers.

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(●) **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

Boys, R.M.; Beausoleil, N.J.; Betty, E.L.; Stockin, K.A. When and how to say goodbye: An analysis of Standard Operating Procedures that guide end-of-life decision-making for stranded cetaceans in Australasia. Marine Policy 2022, 138, 104949, https://doi.org/10.1016/j.marpol.2021.104949.

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Name and title of main supervisor:	Professor Karen A Stockin
In which chapter is the manuscript/published work?	7
What percentage of the manuscript/published work was contributed by the student?	75%

Describe the contribution that the student has made to the manuscript/published work:

Designed the study, undertook literature searches and data mining of database to collect data. Conducted data analysis, wrote the first draft and edited subsequent drafts of the manuscript and responded to reviewers.

Please select one of the following three options:

- (selected) **The manuscript/published work is published or in press**

  Please provide the full reference of the research output:

  Boys, R.M.; Beausoleil, N.J.; Betty, E.L.; Stockin, K.A. Deathly silent: Exploring the global lack of data relating to stranded cetacean euthanasia. Animals 2021, 11, 1460. https://doi.org/10.3390/ani11051460.

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