A STUDY OF THE RELATIONSHIPS BETWEEN THE BEHAVIOUR OF CETACEANS AND VESSEL TRAFFIC USING TWO CASE STUDIES: KILLER WHALE (*Orcinus orca*) AND HUMPBACK WHALE (*Megaptera novaeangliae*).

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ABSTRACT

Two studies were carried out to describe the relationship between vessel presence on the behaviour of both whales and dolphins. Each study conducted focal follows on members of two endangered sub-populations using a land-based theodolite station in order to track and mark positions of opportunistic vessel traffic in relation to animal surfacings.

Southern resident killer whales (*Orcinus orca*) were theodolite tracked during the months of May-August for three field seasons (1999-2001), off San Juan Island, Washington State, U.S.A, in an independent study. Migrating humpback whales (*Megaptera novaeangliae*) were theodolite tracked off Moreton Island, Queensland, Australia during 2005 from May-September in partial fulfilment for a Master of Science degree. For each study, four dependent whale variables were analysed in relation to two boat variables. Whale variables included mean time per dive (dive time), swimming speed, directness of path traveled (directness index) and the number of surface behaviours per hour such as breaches or tail-slaps (surface active behaviour). The two boat variables included a count of the number of boats within the study area during each tracking session (boat count) and the point of closest approach (PCA) by a vessel to the focal animal during the tracking session.

Southern resident killer whales were found to decrease path directness with the point of closest approach of vessels. As whales adopted a more circuitious path, distance travelled increased by 9.5% when boats were within 100 m. Humpback whales significantly decreased their rate of surface active behaviour by 50% when boats were present. This thesis presents data that show a snapshot of the levels to which both species are exposed to vessel traffic, as well as subtle short-term behavioural responses in relation to vessel presence.

I compare the impacts of vessel traffic identified for the two species, and suggest possible long-term population consequences due to potential interruptions of foraging and/or social behaviours. I discuss limitations of small data sets such as these and discuss ways in which further research can be better designed. Deliberate planning of vessel effect studies and their subsequent analyses can provide conservation managers useful information for determining recovery strategies of endangered whales and dolphins.

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Lastly I would like to thank the whales for being so cool and continuing to do their own thing underneath the glare of the paparazzi.

"You are the music, while the music lasts." —T.S. Eliot

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CHAPTER 1. INTRODUCTION

1.1. OVERVIEW

Cetaceans have an alluring attraction for human beings. We have hunted them, collected them for entertainment, protected, studied, and watched them the world over. Increases in human populations surrounding coastal areas have revolutionised the tourist industry and spurned the growth in whale watching markets with 10 million people a year participating in commercial whale watching operations (Hoyt 2001).

Though tourism impacts on cetacean populations continue to be debated, potential short-term consequences of human activity around cetaceans are becoming more defined for each species. Whale watching is one such behaviour that has reached high levels for accessible species such as the killer whale (*Orcinus orca*) and humpback whale (*Megaptera novaeangliae*). An increase in marine activity around marine mammals has led researchers and managers to investigate the measure of effects and/or significance of human disturbance on animals. Vessel traffic can have immediate direct impacts on cetaceans, such as collisions (Laist et al. 2001), while commercial whale watching can have detrimental effects due to targeting of key species (Ollervides 2001, Martinez 2003, Richter et al. 2006). Both non-migratory and migratory populations of cetaceans, such as killer and humpback whales, (refer to Appendix A for natural history of these species), present unique management challenges as tourism moves from seasonal bursts to year-round activity. To mitigate these impacts and provide essential data for conservation management, it is important to assess short-term responses to vessel presence and if possible identify their long-term consequences.

1.2. WHALE WATCHING

Killer whale

Generally speaking, human relationships with killer whales (*Orcinus orca*) have been tumultuous. Killer whales of Washington State, U.S.A. and British Columbia, Canada were the source of live captures for aquaria and marine parks in the 1960's and 70's. Most animals came from the southern resident community, with a total of 36 whales collected and at least 11 deaths (Hoyt 1990, Olesiuk et al. 1990). Selective removal of younger animals and males produced a skewed age and sex composition in the population, which may have slowed a later recovery (Olesiuk et al. 1990a). Though captures ceased in Washington State waters in 1976, these removals substantially reduced the size of the population, which did not recover to estimated pre-capture numbers until 1993 (Baird 2001).

Whale pods that frequent these regional waters have become an icon of the area as attitudes have shifted away from captive viewing. Much of this change in public views towards killer whales has been due to the rise of whale watching tourism (Baird et al. 1998). The whale watching industry for coastal communities such as those found in Washington State and British Columbia is one of the fastest growing tourism sectors worth more than $1 billion in revenue (Hoyt 2001). Whale watching has increased public awareness of marine mammals and environmental issues, thus providing an economic incentive for preserving populations (Duffus & Dearden 1993, Lien 2000). However, the growth of whale watching during the past two decades has meant that whales in the region are experiencing increased exposure to vessel traffic and the accompanying sound pollution.

Whale watching in Washington State is centred primarily on the southern resident population of killer whales (Figure 1-1). Viewing activity occurs predominantly in and around Haro Strait (Figure 1-2), the core summer area for the resident pods (Heimlich-Boran 1986, Bigg et al. 1987, Ford et al. 2000, Hauser 2006). Three killer whale pods, known as J, K and L, aggregate off San

Juan Island during this time, predominantly to mate and forage for salmon *Oncorhynchus* spp. (Ford et al. 2000). Each whale in the population is individually recognisable from identification photographs, and an annual photographic population census of resident pods has been conducted since 1973 (Ford et al. 2000), thereby leading researchers to document each individual whales sex, age and genealogy. Animals are individually recognised from the shape and coloration of both left and right saddle patches, dorsal fin shape, and any unique nicks, cuts or scaring (Figure 1-1).

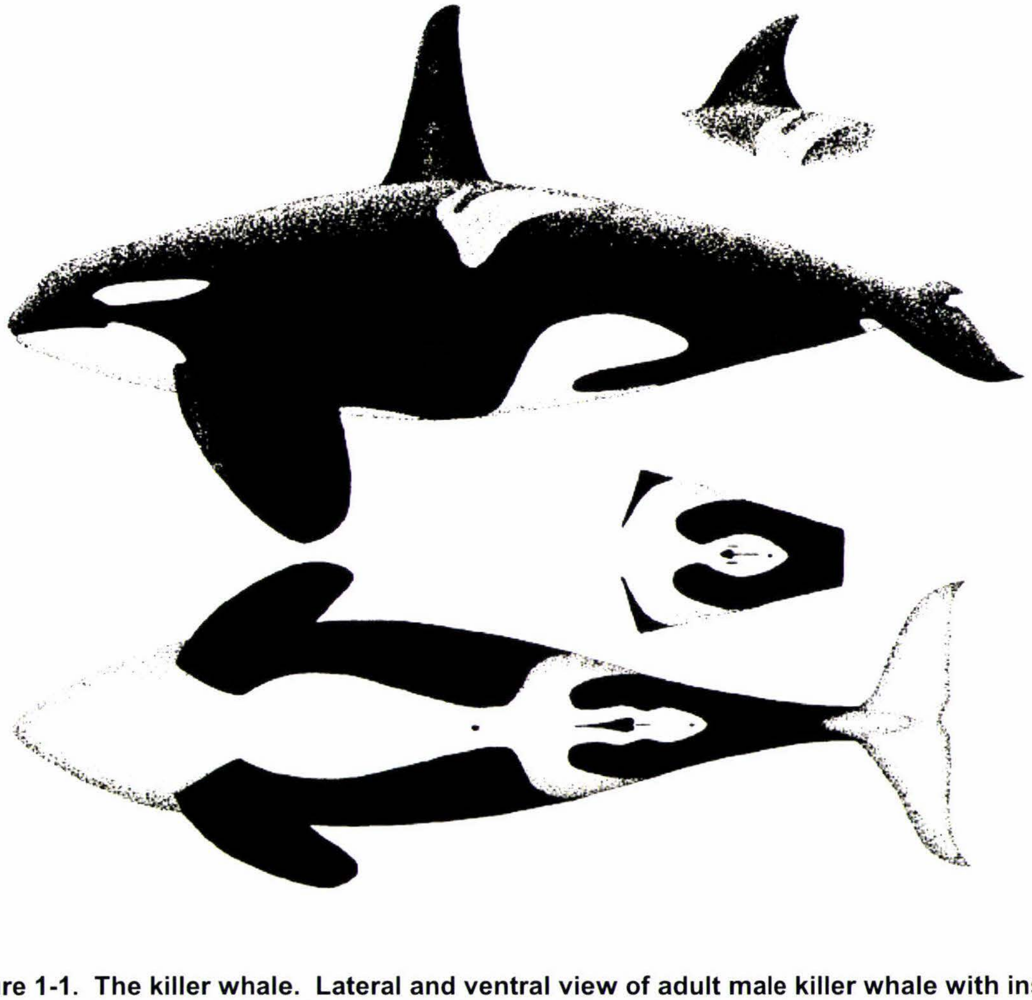

Figure 1-1. The killer whale. Lateral and ventral view of adult male killer whale with inset of female dorsal fin and genital pattern. Reprinted from Wiles (2004).

Figure 1-2. Map of Haro Strait, Washington, USA. Reprinted from Google Maps – http://maps.google.com/maps (2009).

The waters of Haro Strait support a considerable tourism industry due to its proximity to urban and easily accessible whale watching ports. It is estimated that upwards of 500,000 people annually go whale watching with 81 commercial tour operators from the San Juan Islands and surrounding Canadian waters (NMFS 2008)

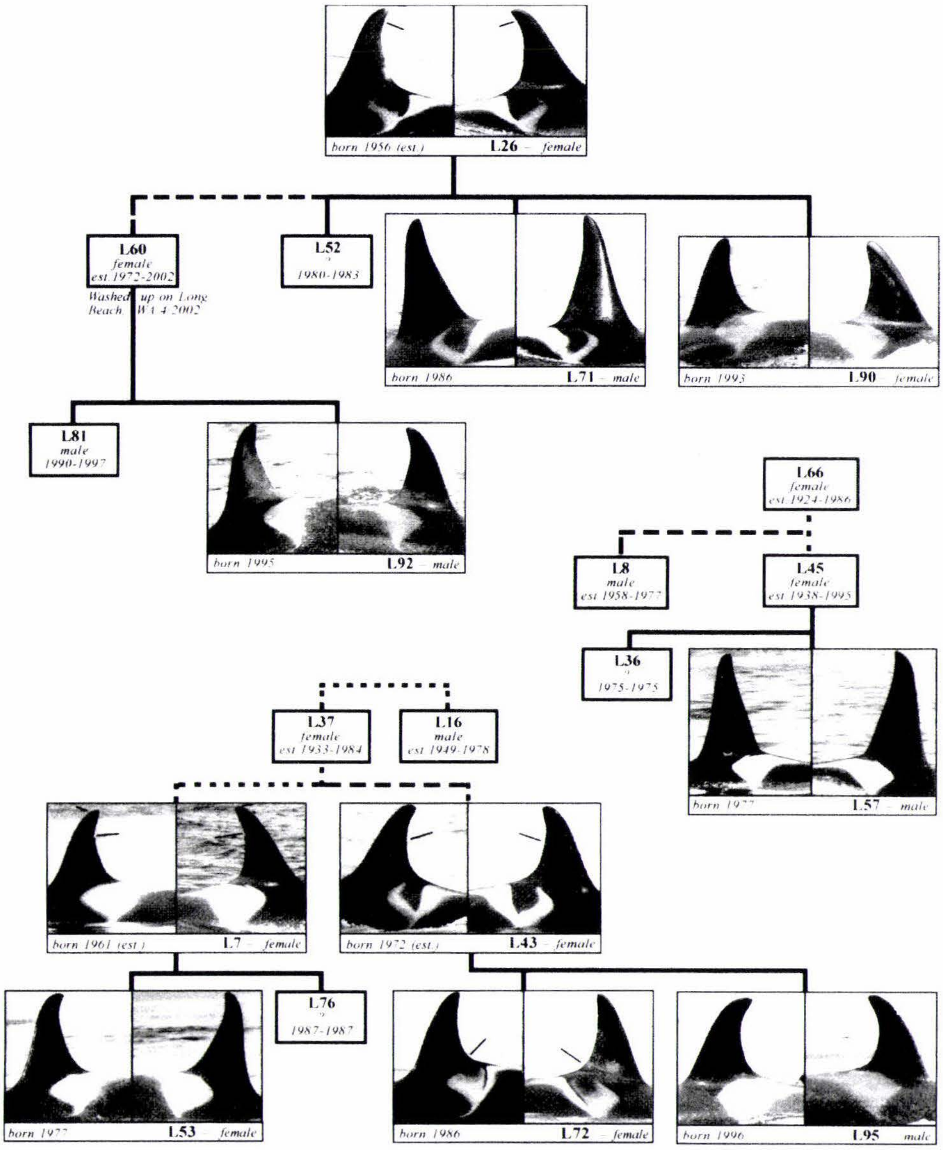

Figure 1-3. Killer whale photo-identification chart. Individual age, sex and genealogies are shown. Solid lines linking photos represent known relationships. Dashed lines represent possible relationships. Reprinted from The Center for Whale Research (2004).

Another 3000-8000 people watch whales annually from private recreational vessels, which make up over 30% of all vessels travelling with whales (Koski 2006). Occasionally vessel counts have reached maximums of 120 vessels (Baird 2002). During summer months commercial whale watch operations run tours from 0900h to 2100h and until sunset in spring and early autumn (Koski 2004, 2006). Commercial vessels represent nearly 50% of all vessels travelling with the whales (Koski 2006). Commercial whale watching boats range in size and configuration from small open vessels capable of holding 6-16 people to large passenger crafts that can carry up to 280 customers. Many of the smaller vessels routinely make two to three trips per day to view the whales. Commercial kayaking operations include up to 18 companies that occasionally go whale watching as well (Koski 2006). Whales may also encounter a variety of other types of vessel traffic such as scientific research vessels, Homeland Security enforcement vessels or Coast Guard, sport fishing vessels, ocean liners, commercial freight traffic (*e.g.* oil tankers), and commercial fishing rigs (*e.g.* seiners and gillnetters). Additionally, private floatplanes, helicopters and small aircraft take advantage of viewing opportunities when available (Marine Mammal Monitoring 2002).

High numbers of regional vessel traffic observing this small number of killer whales has led to whale watching disturbance to be implicated as a factor in the population's endangered status. Killer whales continuing to use areas of high underwater noise has led some researchers to suggest that they have become habituated to the presence of boat noise (Jelinski et al. 2002). Older data sets, such as this case study may verify whether or not animals have habituated and also add to the small body of existing data on southern resident killer whales.

Humpback whale

The humpback whale (*Megaptera novaeangliae*) (Figure 1-4) undertakes one of the world's longest annual mammalian migrations (Rasmussen et al. 2007), between high-latitude summer feeding areas and low-latitude winter breeding areas (Chittleborough 1965, Dawbin 1966). Humpbacks passing along the eastern Australian coastline also likely inhabit the Antarctic feeding grounds known as Area V (Figure 1-5) (Dawbin 1966). The Area, (or Group V) stock (as they are labelled), of southern hemisphere humpbacks was severely depleted with the advent of mechanised commercial whaling operations in 1912 (Clapham 2008). By the time the International Whaling Commission (IWC) initiated a ban on humpback whaling in 1962, the population was considered to have little more than 5 percent of it's original stock remaining (Chittleborough 1965).

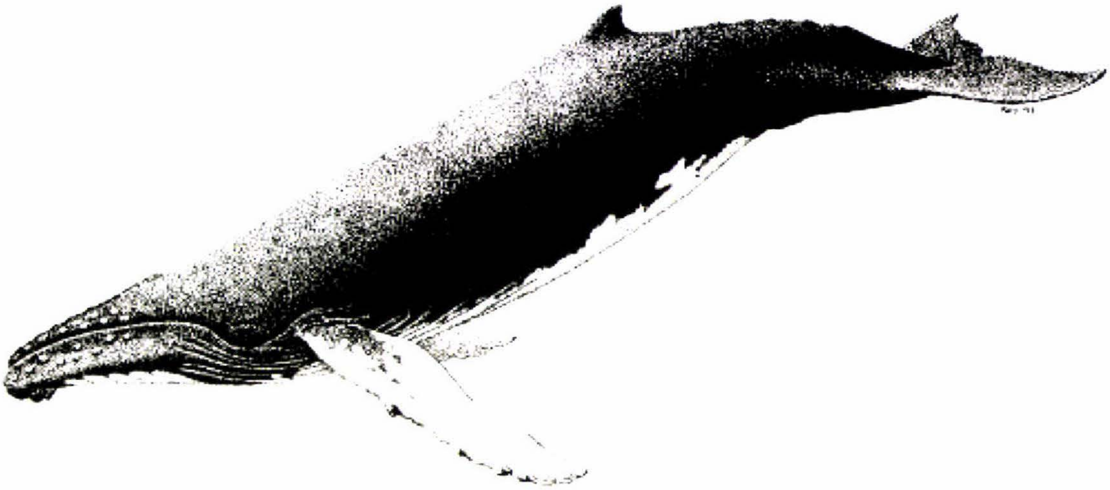

Figure 1-4. The humpback whale. Reprinted from Clapham (1999).

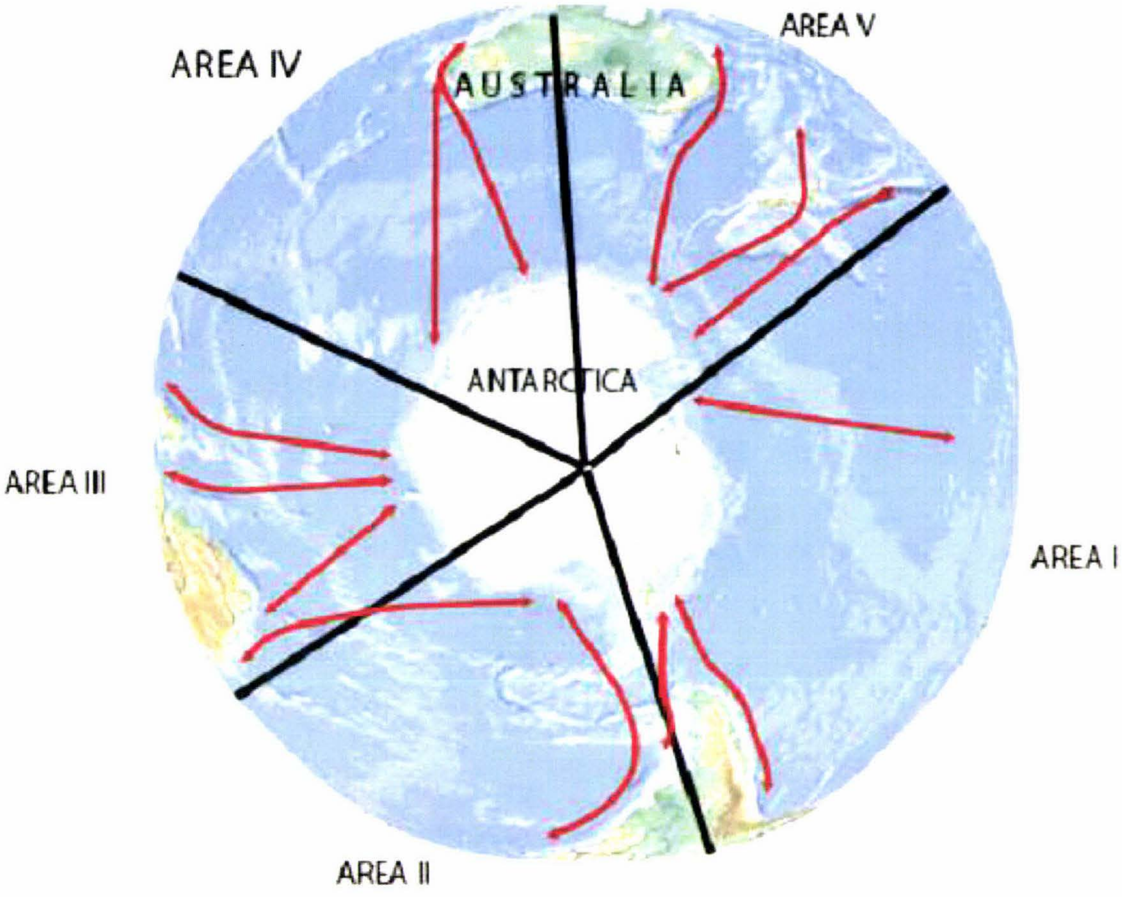

Figure 1-5. Boundaries of six southern hemisphere whaling areas adopted in the 1930's. Note Area V near eastern Australia. Reprinted from Jenner (2001).

The tendency of humpback whales to linger close to populated shorelines and shallow bays while migrating between feeding and breeding grounds was a fact fully utilised by early whalers. East Australian shore stations at Tangalooma and Byron Bay are said to have processed 7,423 humpback whales of the 19,687 reported captures between 1912 and 1963 (Paterson et al. 2001). The Tangalooma Whaling Station was located on Moreton Island (Figure 1-6) and operated from 1952 until 1962, processing 6,277 humpback whales (Orams & Forestell 1994). Despite severe stock depletion, the Group V humpbacks continue to maintain their pattern of annual migrations along the east coast of Australia (Rock et al. 2006).

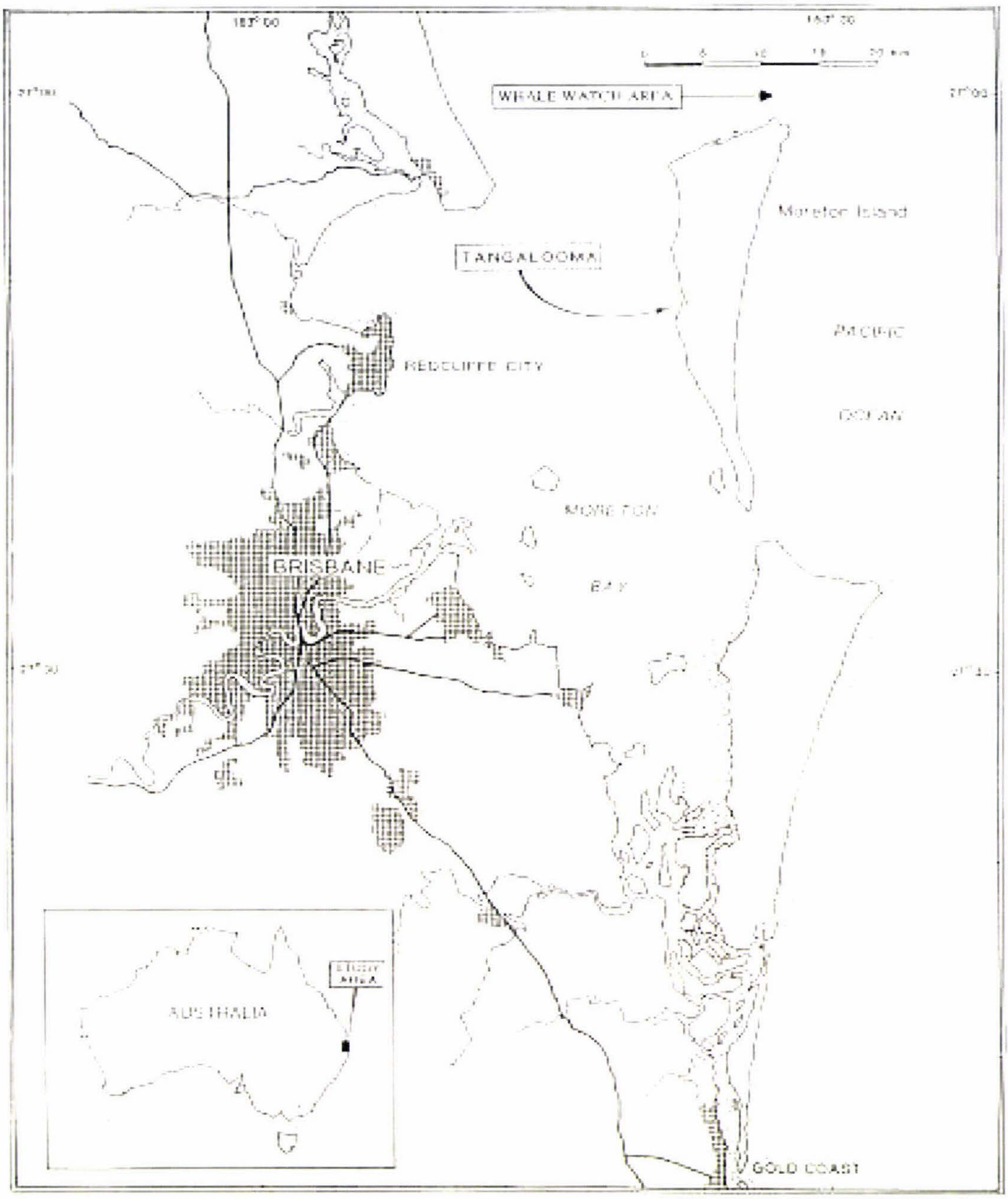

Figure 1-6. Tangalooma whaling station located on Moreton Island. Reprinted from Orams (2000).

Current population estimates show humpback whales numbering 7,090 individuals (Noad et al. 2005). As their numbers have increased, the Australian government has discovered the economic and conservation benefits of tourism (Hoyt 2001). The same features that made Tangalooma an attractive location for a whaling station also make it a suitable location for whale watching. In just a few decades, the whaling factory at Tangalooma has transformed into a popular tourist resort, which has been conducting whale watch cruises since 1992. Regional commercial whale watching is only permitted within established marine park boundary waters. Moreton Bay Marine Park waters surround Moreton Island (refer to Appendix B for map of marine park area) and allows for permitted tourism that focuses on the various marine life such as sea turtles, dugongs, bottlenose dolphins and humpback whales. The industry operation around Moreton Bay Marine Park is relatively small and tightly regulated, with just 2 operators currently permitted to run from 0900-1800 h each day. However, Moreton Bay borders Queensland, the fastest-growing region in Australia of over 1.6 million people (Chilvers et al. 2005), therefore potential exists for increased demand for humpback whale watching.

1.3. SOUND POLLUTION

Killer whale

Killer whales like other dolphins, rely on their acoustic system for navigation, location of prey, and communicating with other pod members (Ford 1989). Increased anthropogenic sound can have the potential to mask echolocation and temporarily or permanently damage hearing sensitivity. Masking echolocation may impair foraging or other behaviours and be detrimental to survival (Bain & Dahlheim 1994, Erbe 2002, Williams et al. 2006).

Another auditory effect of sound exposure is hearing loss. Temporary hearing loss or temporary threshold shift (TTS) involves recovery of baseline hearing over a period of time (Holt 2008). The magnitude of the shift depends on the energy content of the sound. The hearing threshold is the amplitude necessary for detection, and the threshold varies depending on frequency across the hearing range of an individual (Nowacek et al. 2007). Permanent hearing loss or permanent threshold shift (PTS) does not show recovery over time and is the manifestation of auditory injury (Holt 2008).

Studies on killer whales have shown short-term responses to sound exposure such as changing swimming direction, dive duration, vocal behaviour (Williams et al. 2002, Foote et al. 2004), or long-term changes such as leaving once preferred habitat (Morton & Symonds 2002).

Humpback whale

The large size of baleen whales makes them unsuitable for many acoustic measurements on hearing thresholds. However, both vocalisations and anatomical studies suggest a low frequency hearing range (Richardson et al. 1995, Parks et al. 2007, Lusseau 2008). Although low pitch calls produced by humpbacks are said not to overlap with the high frequency of fast outboard engines (Au & Green 2000), vessel activities can still elicit behavioural responses from animals. Both horizontal (increased speed, alteration in swimming paths) and vertical (increased dive times) avoidance strategies have been documented for humpbacks in response to vessel approaches (Baker & Herman 1989, Scheidat et al. 2004). Animals have also shown increased surface active behaviours (breaching, pectoral or tail fluke slaps) (Baker & Herman 1989, Corkeron 1995, Peterson 2001), and abrupt course changes (Au & Green 2000).

Sound pollution can also be generated by a variety of other human related activities such as dredging, drilling, seismic testing and sonar practices (Holt 2008). McCauley et al. (2000) recorded course and speed changes to avoid close encounters with operating seismic arrays near Western Australia. Several of these observations showed whales approaching a seismic array to within 100 m and then swimming quickly away by changing direction. This may have been due to the array's directionality of sound energy downwards. Likewise, studies near Hawaii examined behavioural responses of humpback whales exposed to full-scale Acoustic Thermometry of the Ocean Climate (ATOC) signals and saw whales diving longer and covering more distance between surfacings during exposure (Frankel & Clark 2002). Social and mating behaviour such as singing can also be impacted. During playbacks of the U.S. Navy's Low Frequency Active sonar (LFA), humpback whale songs were significantly longer, but returned to pre-exposure levels after playbacks (Miller et al. 2000). High vessel noise was also associated with an increase in rate and repetitiveness of humpback feeding calls in southeast, Alaska, indicating a modification of call patterns (Doyle et al. 2008).

1.4. POPULATION STATUS

All species of cetaceans are listed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) under Appendix I or II (Hilton-Taylor 2000). Appendix I includes species threatened with extinction while Appendix II includes species that may become threatened with extinction unless trade is regulated (Klinowska 1991). The World Conservation Union (IUCN) Red List of Threatened Species identifies 62 species of cetaceans at various levels of risk of extinction (Hilton-Taylor 2000).

Killer whale

Killer whales worldwide are listed under Appendix II of CITES, which prohibits the international trade of killer whales (or killer whale parts) without appropriate permits.

Annual population censuses indicated that southern resident killer whale numbers experienced a population decline of 21% (van Ginneken et al. 2000) after 1990s and was petitioned for listing under the United States Endangered Species Act (ESA) of 1973. The National Marine Fisheries Service (NMFS) determined the stock to be below its optimum sustainable population and they were therefore designated as Depleted under the Marine Mammal Protection Act in 2003 (Federal Register 2003). In 2005, this distinct population segment of killer whales was listed as Endangered (Federal Register 2005) under the ESA. For Washington State, local killer whale pods are designated as the official marine mammal. The state Fish and Wildlife Commission protects all forms of killer whales and also listed the species as Endangered in 2004 (Wiles 2004). In September 2007, San Juan County, Washington State enacted a local ordinance designed to prevent boat harassment by making it unlawful to feed or knowingly approach southern resident killer whales within 100 metres in county waters (WAC 2007).

Humpback whale

Globally, humpback whales are listed as Least Concern, meaning it's at low risk of extinction, with the Arabian Sea and Oceania sub-populations still listed as Endangered (IUCN 2008). Most monitored stocks have shown evidence of recovery from whaling (*i.e.* some increasing to more than 50% of their levels three generations ago) (Reeves et al. 2003). The Oceania sub-population (including Group V humpback whales) have not yet attained 80% of those levels (Reeves et al. 2003). Importantly, the large illegal kills by Soviet factory ships in the southern hemisphere from the 1950s to the early 1970s may have delayed recovery of southern stocks (Clapham & Baker 2002). Due to the large numbers of animals taken and the subsequent population declines, humpback whales continue to be listed in Appendix I of CITES which does not allow trade for commercial purposes in products from protected species (Cetacean Specialist Group 1996). Thus all trade is banned between countries that are parties to CITES, and therefore limited room exists for a global whaling market.

While there has been an observed increase in abundance in recent decades, the Queensland Nature Conservation (Wildlife) Regulation 1994, classify southern humpback whales as Vulnerable as a migratory and threatened species (Hilton-Taylor 2000, Chilvers et al. 2005). Under Queensland legislation, the humpback is protected out to three nautical miles offshore and under Australian legislation within the Australian Exclusive Economic Zone, offshore to 200 nautical miles (Vang 2002).

1.5. STUDY RATIONALE AND OBJECTIVES

All cetacean species are most likely affected to some degree by vessel traffic (Richardson et al. 1995). Vessel disturbance has the potential to interrupt cetacean social affiliations, weaken hunting efficiency, and cause physical harm (*e.g.* collisions, deafness). Repeated disturbance from boat traffic could also bring about long-term effects such as a drop in the rate of reproduction, higher mortality, habitat avoidance, and can threaten the survival of populations (David 2002). Any type of on the water vessel has the potential to affect whales through the physical presence and activity of the vessel, increased underwater sound levels or a combination of these factors. Marine mammal tourism in particular has the potential to contribute to noise pollution to which animals are exposed, because this is not a transient disturbance that happens by a whale; rather it is a source of disturbance that targets individuals and follows them. If animals are repeatedly disturbed during important behaviours (*e.g.* nursing, mating, feeding, resting), then temporary behavioural responses may become biologically significant (Lusseau 2005, Bejder et al. 2006, Williams et al. 2006). For example, continual disruption of feeding could cause individuals to incur a reduced energy intake or to abandon habitat (Lusseau 2005, Williams et al. 2006).

Transient cetaceans may be less likely to encounter regular tourist traffic, while resident species, may be exposed to heavier traffic associated with port and marina areas. They are also more within reach of recreational and commercial whale watch traffic. Highly exposed animals could habituate to traffic or disperse, while animals that are not much disturbed can suffer greatly (Richter et al. 2006, Nowacek et al. 2007). In some cases the advantages of the availability of resources such as food or opportunities to mate may outweigh the perceived disturbance (Gill et al. 2001). It is important for researchers to attempt to define these thresholds that are exclusive to each species, population, habitat, and situation to better mitigate potential effects.

This thesis utilises two independent case studies to examine the effects of vessel traffic on the behaviour of two contrasting cetaceans, namely an odontocete, (the killer whale), and a mysticete, (the humpback whale). Killer whale data were collected as an independent project of my own from San Juan Island. This three-year data set went for the most part unanalysed for nearly a decade after collection. Then, in 2005, I was invited by Dr. Mark Orams to conduct similar research on humpbacks after his Masters student dropped out leaving the position open. Shortly after I enrolled, Dr. Orams vacated his position as my supervisor and funding for this research was stunted to a single data collection season. In order to have the quantity of data for analyses Massey University was kind enough to allow the use of my previously collected data set in conjunction with this thesis research. Due to logistical constraints, explicit investigations such as Before-After-Control-Impact (BACI) experiments (Stewart-Oaten & Bence 2001) were not conducted. Both studies used theodolite surveyor instruments to measure behaviour of focal animals and vessel traffic. With each study we chose to use non-invasive land-based data collection platforms. This allowed researchers to be removed from any measurable vessel effects found. Each case recorded the same measurable whale variables in relation to vessel traffic conditions (no-boat and opportunistic traffic). The method of recording data differed due to the types of theodolites available. Only the killer whale study had access to a theodolite with a serial data port available for laptop connection. Local whale watching guidelines were used to specify boat categories for each species. In each case, whale behaviour could be tested in relation to whether boaters were violating or following local guidelines. The objective of this thesis is to accurately define and describe the relationships between two marine mammals (an odontocete-toothed whale and mysticete-baleen whale) and vessels.

1.6. THESIS STRUCTURE

Chapter 1 represents an overview of the whale watching literature relevant to this study, particularly in relation to sound pollution threats faced by both humpback and killer whales. This chapter concludes with the rationale, objectives, and structure for this thesis.

Chapter 2 presents a case study carried out on southern resident killer whales from San Juan Island, Washington State, U.S.A. Killer whale behaviour was measured using a theodolite to assess whether behavioural responses to boats could be detected. Results are given from three field seasons conducted for the years 1999 to 2001 inclusive. Discussion and conclusions relating this and similar impact studies on resident killer whales are also presented.

Chapter 3 details a case study conducted on Group V humpback whales during their northern and southern migrations off Moreton Island, Queensland, Australia. Humpback whale behaviour was measured using a theodolite to assess whether behavioural responses to boats could be detected. Results from this study are presented and discussed from a single field season conducted in 2005. This chapter concludes discussing humpback whale management considerations for Cape Moreton.

Chapter 4 concludes this thesis with a synthesis of the results between both case studies. Impacts identified for both species are compared and contrasted, and overall conclusions drawn considering long-term population consequences due to potential (energetic) consequences of short-term behavioural responses. Limitations of impact studies such as this, as well as further research suggestions, are additionally presented in this chapter.

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