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Techniques for hazing and deterring birds during an oil spill

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ABSTRACT

Preventing wildlife from becoming oiled is the priority in an oiled wildlife response. This is achieved through diverting spilled oil away from wildlife, or hazing, deterring, or excluding wildlife from oiled areas. This paper undertakes an international review of techniques deployed for hazing and deterring birds, the taxa most affected, during oil spills. Using these techniques as a baseline it then compares what techniques are used in New Zealand at airports, in agriculture, and at waste management facilities, to assess what could readily be deployed in New Zealand during oil spills, as currently there are few options planned for. As international literature suggests, the best technique is to use a variety of methods for targeted species to reduce habituation. This review highlights international practices that could be tested and implemented, to allow for planning for effective hazing and deterrence practices in New Zealand.

1. Introduction

Birds are the main taxa affected by oil spills, with some spills causing the deaths of hundreds and thousands of birds (Clark, 1978; Piatt and Lensink, 1989; Crawford et al., 2000; Wolfaardt et al., 2008; Wallace et al., 2017). In New Zealand, the 2011, Marine Vessel (MV) Rena oil spill resulted in over 2000 dead birds being collected from 49 species (Hunter et al., 2019).

For any oiled wildlife response, the prevention of wildlife getting oiled is always the priority, through containing the oil as close to the source as possible, diverting spilled oil away from wildlife-sensitive areas, or hazing, deterring, or excluding wildlife from oiled areas (IPIECA, 2014, 2017; Chilvers and McClelland, 2023). Hazing wildlife is the use of deliberate negative stimulus to move wildlife out of an area. Deterrence is the use of deliberately fearful or unpleasant stimuli (real or perceived) to elicit a defensive escape or avoidance response to prevent wildlife from entering an area where they are unwanted. Exclusion includes fencing or pre-emptive capture of wildlife, i.e. capturing wildlife and holding or translocating before wildlife is impacted by oil.

Humans have generally struggled to develop effective long-term means of deterring wildlife from agricultural fields, airports, human waste areas, and oil spills. Preventative methods have included pre-emptive capture (Crawford et al., 2000; Gartrell et al., 2013), physical barriers (Smith et al., 2022), habitat modification (Bishop et al., 2003), increased predator presence (Desoky, 2014), effigies (Andelt et al., 1997), chemical repellents (CAA Civil Aviation Authority of New Zealand, 2011), visual deterrence including lights, reflectors, balloons, and lasers (Read, 2001), pyrotechnics (Koski et al., 1993), and sound such as propane cannons and acoustic signals of both natural and manufactured sounds (reviewed by Bomford and O'Brien, 1990). Increasingly drones and other unmanned aircraft are also being used in the deterrence of birds at airports and in agriculture (Jarretta et al., 2020; Wilson et al., 2023). Birds often habituate to deterrence that doesn't kill them outright, within hours to days for many visual deterrents (Andelt et al., 1997) and days to weeks for many audio deterrents (Whisson and Takekawa, 2000). The best deterrence techniques for birds appear to be the use of varied (i.e. mixing the location, timing, and frequencies of sound and visual techniques) and targeted deterrence techniques in specific areas for known species or family taxa (Rivadeneira et al., 2018).

When considering hazing and deterrence methodology for wildlife during an oil spill there are key factors that need considering. First, gain an understanding of the target species and their normal behaviour, including information on the ways they feed (scavenger, granivore etc.), their breeding or migration patterns, and daily rhythms (roosting or flocking times). Second, identify the motivation for wildlife to be in the contaminated area. These motivations could be food, drinking water, migration path, breeding or resting areas, or predatory evasion. For each of these motivations, differing deterrence methods could be considered. For example, if the area is being used to forage, are there other uncontaminated areas that could be made available for them to feed, or would an increase in predator presence (real or perceived) in the area deter wildlife from entering the area? There is a need to recognize that time of day, weather, and season can have a significant impact on likely

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reactions to disturbances. Additionally, understand what makes the wildlife feel uncomfortable and therefore want to move away from a disturbance, but also how they may become acclimated to this stimulus. Lastly, but importantly, predict the likely response you are expecting from a specific disturbance, because there may be unintended consequences to the deterrence. Your action may lead to an even more negative consequence for the wildlife than getting oiled.

This paper undertakes a review of the knowledge and techniques already deployed around the world for hazing, deterring, or excluding birds during an oil spill. This review will not cover pre-emptive capture as there is a recent summary of this knowledge in Chilvers and McClelland (2023). Added to this, what techniques are already used or known in New Zealand, at airports, in agriculture, and at waste management facilities, are assessed to determine what techniques might already be available to be used in New Zealand for oil spill responses. This review aims to highlight practices that are already available in New Zealand that could be implemented and included in oiled wildlife response plans and suggest research that could be undertaken to trial techniques on New Zealand bird species to determine their efficacy. The overall aim is to identify effective hazing and deterrence practices so that response equipment and personnel can be appropriately located and trained throughout New Zealand and appropriate response options added to regional and national plans.

2. Material and methods

An online literature search was undertaken aligned with the PRISMA 2020 guidelines (Page et al., 2021) to create a list of publicly available articles or reports that specifically described hazing and deterrence methods that could be used during oil spill response from 1980 to 2023. Information was sourced from scientific journal articles, conference proceedings, and any other grey literature through searches on Google, Google Scholar, or the Web of Science database (search terms were in English and included singular words or combinations of scaring, hazing, deter, deterrence, birds, wildlife, oil, oil spill, oiled wildlife). Additionally, searches were specifically made through Oil Spill conference websites including Interspill and IOSC. Managers and practitioners at airports, in agriculture, and at waste management facilities in New Zealand were contacted for information and knowledge including grey literature, on what is currently available for use in scaring (hazing and deterring) birds in New Zealand and any testing of techniques previously undertaken.

3. Results

Wildlife management techniques to minimize crop damage in agriculture and reduce wildlife presence at waste sites have been undertaken around the world for centuries (Narayan and Rana, 2023). Deterrence techniques for keeping wildlife away from airports have occurred since commercial flights became commonplace (1920–30's, CAA Civil Aviation Authority of New Zealand, 2011, Metz et al., 2020), while hazing and deterrence of wildlife for oil spill response have only really been undertaken since the 1980's. More recently, with the extraction of oil from substrates such as oil sands, wildlife deterrence methods for longer-term standing oil or polluted ponds have also been documented. A summary of reports that were collated for oiled wildlife hazing and deterrence is listed below. Table 1 summarizes the techniques suggested from all reports, listing the species or taxa the techniques may work on, the potential advantages and disadvantages, the environments they could be deployed, their suggested area of effectiveness, and whether they have been used in New Zealand, in what industry, and on what species or taxa.

3.1. Oil spills and oil sands tailing ponds

In oiled wildlife literature, there are four core reports or manuals (summarised below in chronological order) on hazing and deterrence methods that outline techniques, how the devices are used, over what area the device may be effective, and what their advantages and disadvantages may be (Greer and O'Connor, 1994; Lehoux and Bordage, 2000; Bishop et al., 2003; Gorenzel and Salmon, 2008; Table 1).

Greer and O'Connor's (1994) technical report for Marine Oil Response Corporation, USA is the first report to review hazing and deterrence devices and strategies that have been used for deterring waterbirds, with emphasis on application to oil spills. The report describes devices, their recommended use, the area over which the device may be effective, and the potential advantages and disadvantages known for the device (Table 1). They also recommend strategies for hazing and deterrence of waterfowl such as:

1) Deterrence should be initiated as soon as possible to prevent birds from establishing or continuing regular use patterns within a contaminated area. Delays will decrease the program's effectiveness.
2) Habituation, or gradual decrease in response to the deterrence stimuli due to increased familiarity and acceptance of the device, may be minimized by using a combination of methods, and frequently changing the type, timing, and location of the equipment.
3) Deterrence effectiveness will vary with bird species, residency status, age, habitat, and season, and will be lower for birds already established at nesting colonies or important foraging areas. Migrating birds, such as shorebirds, may be difficult to haze from staging areas that are used annually.
4) Deterrence programs can be effective in small, well-defined areas or the immediate oil impact area. It is important to note that deterrence strategies will only be effective if there are equally attractive adjacent habitat areas into which species can be hazed.
5) A successful bird deterrence program is largely dependent on rapid implementation and diversification of technique application. Hazing operations should be mobile, aggressive, imaginative, motivated, and persistent.

Lehoux and Bordage (2000), "Deterrent techniques and bird dispersal approach for oil spills" written for Environment Canada, Canadian Wildlife Service, summarizes that the impacts of oil spills on birds in North America have mainly impacted seaducks (Order *Anseriformes*, Subfamily *Anatinae*) and alcids (Family *Alcidae*). The report reviews techniques and research on efficiency for their use of certain bird types. The report describes differing strategies that could be used when responding to oil spills either at sea, ashore, or for colonial birds (Table 1).

Bishop et al. (2003), "Review of international research literature regarding the effectiveness of auditory bird scaring techniques and potential alternatives" written for the Department of Environment, Food and Rural Affairs, United Kingdom. The report reviewed the current state of knowledge through a literature search relating to bird deterrence, mainly in agriculture but included oil spills, to provide a basis for policy decisions and guidance material. Overall, it found auditory techniques to be relatively effective over short time periods as birds rapidly habituated. Visual techniques ranged from extremely effective (human disturbance) to ineffective (most scarecrows), based on how real a threat was perceived. Movement, changing locations, and the addition of sound increased efficacy. Exclusion techniques including pre-emptive capture, translocation, and fencing are effective, however, are usually restricted to small areas and numbers of wildlife. Habitat modification techniques are generally considered to be effective and environmentally friendly but are rarely investigated scientifically. Lethal techniques can be considered, however for oil spill response, designed to reduce deaths of wildlife, it usually goes against the response's aims. Combining and varying techniques are more effective than techniques applied singly but the report notes that combinations of techniques are rarely scientifically evaluated.

Gorenzel and Salmon (2008), "Bird hazing manual, techniques and

Table 1
Summary of hazing and deterrence techniques identified from literature review reports outlining species or taxa the techniques may work on, potential advantages and disadvantages, the environments they could be deployed, their suggested area of effectiveness, and whether they have been used in New Zealand, in what industry, and on what species or taxa.

Technique / references	Species	Advantages	Disadvantages	Deployment / distance effective	Use in NZ and species/ taxa
Pre-emptive capture / Translocations Chilvers and McClelland, 2023 Gartrell et al., 2013	Penguins, shorebirds, Pelicans	• Prevents oiling	• Often difficult and expensive to achieve • Can be dangerous to catch some species due to capture myopathy • Husbandry challenges of holding wildlife in captivity • Increased chances of injury and spread of disease back into wild population	Onshore (very difficult to capture birds at sea)	NZ Dotterels – Oiled wildlife response Magpies – NZ airports
Attractant – decoys	Waterfowl – ducks, geese and gulls	• Passive technique	• May attract birds to spill area	Onshore (would be difficult to undertake at sea)	Waterfowl – for hunting
- Alternative resting or foraging areas Gorenzel and Salmon, 2008					
Habitat modification Bishop et al., 2003 Gorenzel and Salmon, 2008	Waterfowl and roosting species	• Passive technique	• Can be destructive • Often used for long-term deterrence programs rather than oil spills	Onshore	Magpies, pigeons, gulls - NZ airports and waste management facilities
Exclusion Fence or net off areas Bishop et al., 2003 Gorenzel and Salmon, 2008	If done well enough most species	• Relatively inexpensive and readily available • Relatively quick to deploy	• Can only be used in defined area	Onshore	Passerines - NZ agriculture
Bird balls (bird-x.com/bird-products/bird-balls) Gorenzel and Salmon, 2008		• Only useful on smaller water bodies	• Bird balls would get covered with oil potentially spreading problem or increasing equipment cleanup	Onshore in small water bodies	
Visual & Audio					
Pyrotechnics Greer and O'Connor's, 1994 Lehoux and Bordage, 2000 Bishop et al., 2003 Gorenzel and Salmon, 2008	Effective on: Waterfowl and wading birds May or may not be effective on: Diving birds, gulls, terns, shorebirds, seabirds, shags and cormorants	• Quick to deploy on or offshore • Inexpensive and readily available • Can be directed at birds • Effective day and night	• Danger of igniting spilled oil and vegetation • Disturbing for non-target species including humans and domestic animals • Short duration of effectiveness • Requires continuous staffing • Dangerous – needs firearm training, license & PPE • May not be able to be used in urban areas	On and at sea (but would have to be based on a boat or other floating platform at sea)	Many species - NZ airports and waste management facilities
Aircraft Greer and O'Connor's, 1994 Lehoux and Bordage, 2000 Bishop et al., 2003 Gorenzel and Salmon, 2008	May or may not be effective on any species	• Readily available to remote areas • Effective over different habitats • Effective over large areas	• Increased potential of bird-aircraft collisions • Not feasible at night or in bad weather • Time-consuming and expensive	On and at sea 15–20 km	
Motorboats Greer and O'Connor's, 1994 Lehoux and Bordage, 2000 Bishop et al., 2003 Gorenzel and Salmon, 2008	May or may not be effective on or near water birds	• Available to remote areas • Can be rapidly effective • Can cover large areas	• Time-consuming and expensive • Not feasible at night or in bad weather • Doesn't work for diving birds • Can be hard to locate birds and direct them • Can cause injury from bird–vessel collision	Aquatic environments 5 km	
Vehicles / All Terrane Vehicles (ATV) Greer and O'Connor's, 1994 Lehoux and Bordage, 2000 Gorenzel and Salmon, 2008	May or may not be on: gulls and terns, shorebirds, sea birds, waterfowl, wading birds	• Can be rapidly effective • Can cover large areas on land	• Only available on land	Onshore only 1–2 km	Many species – NZ airports
Drones Bishop et al., 2003 Gorenzel and Salmon, 2008	May or may not be effective on any species	• Effective over different habitats • Effective over moderate areas • Could reach remote areas	• Time consuming unless automated • Not feasible at night or in bad weather • Not allowed to operate in many areas	On and at sea 2–5 km	Many species - NZ airports & agriculture

(*continued on next page*)

Table 1 (*continued*)

Technique / references	Species	Advantages	Disadvantages	Deployment / distance effective	Use in NZ and species/ taxa
			• Doesn't work for diving birds • Can cause injury from collision with bird or birds attacking		
Visual					
Mylar tape / Flags / Reflective surfaces / Big-eye balloons / Kites / Metal cat faces with reflective eyes in trees Greer and O'Connor's, 1994 Bishop et al., 2003 Gorenzel and Salmon, 2008 Boag and Lewin, 1980	Passerines May or may not be on: gulls and terns, shorebirds, seabirds, waterfowl, wading birds, shags & cormorants	• Inexpensive and readily available • Quick to deploy	• Rapid habituation • Ineffective at night • Reflective surfaces may attract some species	Onshore	Passerines and plovers - NZ airports & agriculture
Overhead wires or lines Bishop et al., 2003 Gorenzel and Salmon, 2008	Effective on passerines, fish-eating birds, waterfowl	• Inexpensive and readily available • Relatively quick to deploy	• Mainly used over water • Can only be used in defined areas • Can cause entanglement and injury to wildlife	Onshore	Many species - NZ airports and waste management facilities
Lights / Strobe lights Greer and O'Connor's, 1994 Lehoux and Bordage, 2000 Bishop et al., 2003 Gorenzel and Salmon, 2008		• Quick & inexpensive • No auditory disturbance	• Can attract seabird species • Only effective at night • Human disturbance	Most likely onshore	
Lazers Bishop et al., 2003 Gorenzel and Salmon, 2008	Known; some diving birds (shags) gulls and terns, waterfowl May or may not shorebirds, sea birds, wading birds	• Quick & Inexpensive • No auditory disturbance • Can be operated automatically	• H&S and aircraft risk	Onshore	NZ airports
Human effigies Greer and O'Connor's, 1994 Lehoux and Bordage, 2000 Bishop et al., 2003 Gorenzel and Salmon, 2008 Boag and Lewin, 1980	May or may not be on: gulls and terns, shorebirds, sea birds, waterfowl, wading birds	• Quick & inexpensive • No auditory disturbance • Effective in poor weather	• Birds habituate within a few days • Effective only during daylight unless lights added • Limited range of effectiveness	Onshore	Passerines – NZ agriculture
Dead birds or effigies Greer and O'Connor's, 1994 Bishop et al., 2003 Gorenzel and Salmon, 2008 Boag and Lewin, 1980		• Quick & inexpensive • No auditory disturbance	• May attract birds and predators	Onshore 200 m	
Falconry, predator effigies, predators (dogs and humans – walking or kayaking) Greer and O'Connor's, 1994 Bishop et al., 2003 Gorenzel and Salmon, 2008	Shags/cormorants May or may not be on: Gulls, shorebirds, wading birds	• Limited species impacted	• Predator birds or dogs likely to get oiled	Onshore	Many species – NZ airports, agriculture, and waste facilities
Audio					
Gas Cannons Greer and O'Connor's, 1994 Bishop et al., 2003 Gorenzel and Salmon, 2008	Successfully used in Agriculture & Airports on passerines and pasture species May or may not be on: diving birds, gulls and terns, shorebirds, sea birds, waterfowl, wading birds, Shags/cormorants	• Quick to deploy on or offshore • Protective of large areas • Automatic and operates 2 weeks without refuelling • Effective day and night • Inexpensive and readily available • Complimentary with other devices	• Limited efficacy for shorebirds • Gas-operated exploders can be dangerous in oiled areas • Birds rapidly habituate. Varying number/location /pitch can help • High local human disturbance	On and at sea (but would have to be based on a boat or other floating platform at sea) 800 m	Passerines and shore birds - NZ Airports and agriculture
Electronic sound generators i.e. - Breco buoys - Marine Phoenix Wailers - Predator or distress calls Greer and O'Connor's, 1994 Lehoux and Bordage, 2000 Bishop et al., 2003 Gorenzel and Salmon, 2008 Reilly et al., 1997	Effective for geese, gulls, terns, and passerines Unknown for all others	• Good for open water • Rapidly deployed if available • Protects large areas • Effective day and night & during bad weather • Easy to handle and operate	• Less effective in noisy urban areas • Daily monitoring recommended • Requires boat to deploy device at sea • Disturbing to non-target species including humans • May attract some species	On and at sea (but would have to be based on a boat or other floating platform at sea) 500 m -2 km	Many species – NZ airports, agriculture and waste management facilities
Biosonics Greer and O'Connor's, 1994	Unknown	• Effective at lower sound intensities • Slower habituation	• Highly species-specific • May attract rather than deter birds	Onshore	

(*continued on next page*)

Table 1 (*continued*)

Technique / references	Species	Advantages	Disadvantages	Deployment / distance effective	Use in NZ and species/taxa
Bishop et al., 2003 Gorenzel and Salmon, 2008			• May attract predators and scavengers		

strategies for dispersing birds from spill sites" is a guide produced by the University of California, Davis with funding from the Office of Spill Prevention and Response and the Department of Fish and Game. This manual starts by outlining the initial consideration for hazing and deterrence during an oil response including the assessment of habitat, bird populations, and spill factors. There are then six sections describing the operation and deployment, advantages and disadvantages of the most common hazing and deterrence techniques used in North America including most auditory and visual techniques (Table 1). The later sections suggest hazing techniques for differing bird groups and habitat types (including differences for day and night), gives a brief description of birds likely to occur in California waterways, and outlines suggestions on how to keep records when deploying hazing techniques during an oil spill.

There are many overall guides and plans on oiled wildlife response like Berg (2003) "Best practices for migratory bird care during oil spill response" written for the US Fish and Wildlife Service outlines plans for all aspects of an oil spill response from health and safety, deterrence, capture and transport, rehabilitation, and release. The deterrence section gives an outline of the need to ground truth data, develop deterrence programs, and determine pre-emptive capture considerations, however, does not suggest specific equipment or techniques to be used for environments or species/taxa. Similarly, the International Petroleum Industry Environmental Conservation Association guides (IPIECA, 2014, 2017), outline how hazing and deterrence should fit into an oiled wildlife response, including what the aims and objectives should be, some operational suggestions, and suggested techniques. These documents, however, give little detail on efficacy, or when, or where techniques could be used. Because of these limitations, or generalization of the information, the majority of such reports or plans are not further summarised in this review.

One of the earliest papers testing bird deterrence in the field for oiled or contaminated areas is Boag and Lewin (1980) on the effectiveness of waterfowl deterrents on natural and polluted ponds. This paper detailed their trials of three types of waterfowl deterrent (a model falcon, a moving series of reflectors suspended from a frame, and a human effigy) mounted on floats, to deter waterfowl from entering a series of small natural ponds in boreal forests in Alberta, Canada. Only the human effigy appeared to be effective. Based on this result, the human effigy was tested on an artificial tailings pond that received aqueous and bituminous effluent from an oil sands extraction plant. Twenty-seven effigies were deployed over the 150-ha pond. Their effectiveness was judged by comparing the number of waterfowl dying in or associated with this pond in 1975 (without deterrents) with the number dying in or associated with it in 1976 (with deterrents). The number of dead birds in 1976 was significantly lower than expected based on the relative abundance of birds in the two years.

Other field trial papers included Reilly et al. (1997) who tested the Marine Phoenix Wailer in Miramichi Bay, New Brunswick, Canada. They trailed Phoenix Wailers for effectiveness in keeping Surf scoters (*Melanilla perspicillala*) away from juvenile mussel collector lines, with the assumption that if birds could be repelled from a strong attractant like food, it would work for an oil spill. Results indicated that the Wailer was effective in a circular open-water area within a 500-meter radius. Whisson and Takekawa (2000) undertook effectiveness tests using a Breco Bird Scarer, on Scaups (*Aythya* spp.) and Surf Scoters in the San Francisco Bay estuary. Although this device is known to have the potential to reduce bird mortality in oil spills, this research showed the deterrent not to be effective on waterfowl in the estuary at the time they were testing. Read (2001) tested deterrence techniques to prevent deaths of waterfowl on toxic waterbodies. Using four behavioural traits nocturnal movements, their attraction to reflective surfaces, their fear of diurnal predators, and their naivety to local conditions and deterrents, a rotating intermittent beacon directed at a shallow angle across the water surface was tested which appeared to effectively discourage most waterfowl. Additionally, a series of deterrents with gas-powered sonic guns and the provision of clean alternative water bodies nearby significantly lessened the likelihood of waterfowl injury or mortality in toxic waterbodies during daylight hours.

Reports on trials of hazing and deterrence techniques linked to radar activation started with Koski et al. (1993), suggesting that any stimulus, or combination of stimuli, could be linked to manual monitoring or radar activation, only operating when wildlife is identified either by observation or on radar, therefore activating only when birds were in the area and lowering habituation likelihood.

Ronconi and co-authors followed this work with use of radar-linked bird deterrence use on oil sand tailing ponds in NE Alberta, Canada (Ronconi et al., 2004; Ronconi and St Clair, 2006). Ronconi et al. (2004) developed an activation system based on scaring only flying birds to link their behaviour with a stimulus (i.e. effigies and/or sound), that may create conditions for learned avoidance. Manual on-demand activation of deterrents over the course of an oil spill would likely be costly and labour-intensive and could only occur during the day. Therefore, they tested a radar-activated deterrence system for deterring birds from contaminated ponds from oil sands and found these systems to be very effective, however only for flying birds.

Ronconi and St Clair, 2006 continued their research by trialling the radar trigged deterrence on oil sands tailing ponds with results showing that the use of on-demand deterrence systems, particularly with gas cannons deterred waterfowl from tailings ponds. They suggest the best time of year (early-spring), and family classes of birds (waterfowl and shorebirds) these devices could be used on, noting that because it was radar, the devices were effective both day and night.

3.2. Hazing and deterrence in a New Zealand context

From the summary of the oiled wildlife hazing and deterrence literature above it was noted that most of the literature is over 15 years old and none is from New Zealand or even the Southern Hemisphere. Hence, none of the trials are on species that were identified as heavily impacted by the MV Rena oil spill in New Zealand predominantly little blue penguins (*Eudyptula minor*), shearwaters (*Ardenna* spp.), and petrels (*Pelecanoides* spp.; Hunter et al., 2019). Therefore, a further investigation into what hazing, and deterrence mechanisms are currently being used in New Zealand was undertaken to determine if there is any knowledge of their efficacy on species within this area. A summary of knowledge collated is listed below and any additional information gleaned was added to the summary in Table 1.

3.2.1. Airports

There is extensive information, use, and testing of deterrence methods for birds at airports throughout the world as it can be such a costly and human–wildlife life-threatening interaction. There are many reviews of techniques for use at airports around the world, predominantly issued by regional authorities (Cleary and Dolbeer, 2005; Belant and Martin, 2011; Desoky, 2014). Many of the techniques are long-term habitat modification (grass epiphytes that deter birds from feeding, land-use, and water control at and around airports) or lethal control (poisoning, shooting, destruction of eggs or nests) which are not relevant to oiled wildlife response because of the time they take to establish or less likely to be used (lethal control). However, many other techniques could be used, modified for use, or are already identified and used within oiled wildlife literature such as the use of lights, Myer tape, Bigeyes, netting, audio deterrence (cannon guns, pyrotechnics, bioacoustics, ultra-sound, infra-sound, radar) and visual deterrence (lasers, dead birds, falconry, model aircraft, drones, people, dogs, and vehicles).

In New Zealand, the government authority responsible for aerodromes is the Civil Aviation Authority of New Zealand (CAA). In 2011, the CAA issued an Advisory Circular (AC139–16, CAA Civil Aviation Authority of New Zealand, 2011) which describes standards, practices, and procedures that are an acceptable means of compliance with Civil Aviation Rule Part 139.71 for wildlife hazard management, concerning the control of bird hazards at aerodromes. The advisory gives an overview of a bird hazard management plan, bird incident statistics, and describes deterrence methods including land use management, lethal control, exclusion techniques, and active deterrence/hazing techniques. The report finishes with a description of the main species involved in airport interactions and suggests methods for their control. Out of the species listed in the CAA document, 13 were also species recorded as found dead during the MV Rena oil spill (Hunter et al., 2019; red-billed gull (*Chroicocephalus scopulinus*), black-billed gull (*C. bulleri*), black-backed gull (*Larus dominicanus*), Oystercatcher (*Haematopus* spp.), spur-winged plover (*Vanellus miles*), Canada geese (*Branta canadensis*), mallard ducks (*Anas platyrhynchos*), paradise shelducks (*Tadorna variegate*), rock pigeon (*Columba livia*), Australian magpie (*Gymnorhina tibicen*), and passerines (Blackbirds, *Turdus merula*, Starlings, *Sturnus vulgaris,* and House Sparrows, *Passer domesticus*). This indicates that some of the techniques already used in New Zealand at airports could potentially be used on species during an oil spill responses.

3.2.2. Agriculture

Multiple techniques are known and used worldwide to protect or reduce the impacts of birds on agricultural crops (particularly fruit such as grapes, stone- and pip- fruit; Tracey et al., 2007; Smith et al., 2022), and to prevent the spread of disease from wild birds around poultry farms (Atzeni et al., 2016). Techniques similar to those already mentioned for oil response and at airports are reported, as well as increasingly, drones or unmanned aerial vehicles (UAV), being tested and used in agriculture (Bhusal et al., 2022; Wilson et al., 2023).

In New Zealand, a variety of protection measures are used for agricultural crops, however, exclusion in the form of temporary or fixed netting and the use of cannon guns or other sound deterrence appear to be the most often used and effective (Watkin et al., 2000). There have been trials of simple deterrence techniques such as big-eye balloons in vineyards in New Zealand, however their effectiveness was not shown to be high (McLennan et al., 1995; Fukuda et al., 2008). One of the most interesting long-term deterrence tested involved the rearing and establishment of the native endangered New Zealand Falcon – Kārearea (*Falco novaeseelandiae*), New Zealand's only endemic bird of prey which is an avivore (a specialised predator of birds) at vineyards in Marlborough, New Zealand. The introduction of falcons to the vineyards was associated with a significant decrease in the abundance of introduced passerines and a 95 % reduction in the number of grapes removed relative to vineyards without falcons (Kross et al., 2011).

3.2.3. Waste management

In New Zealand, gull species are the bird species most attracted to landfill sites. Land management practices are the most promoted deterrent tool i.e. good litter control, minimising the uncovered working face (denying the food source), covering waste at the end of each day, and minimising and manage pools and puddles of water. However, if these measures are not enough more active and passive techniques can be used such as the use of mobile high wires, predatory bird kites, sonic bird scaring devices, shooting of species not protected by law, and anti-roosting strips on surrounding buildings (WasteMINZ, 2022). There do not appear to have been any trials or research of any techniques undertaken in New Zealand testing the efficacy of hazing and deterrence devices at New Zealand waste management sites.

4. Discussion

This review aimed to understand what oiled wildlife hazing and deterrence techniques are available, being used, or have been tested internationally, and based on the information collected, understand which of these techniques are being used or have been tested in New Zealand (although not for oiled wildlife response). Although many of the techniques are already being used in New Zealand, none of them have been used or tested on the species that were collected dead in the highest numbers from oiling during the MV Rena response (i.e. little blue penguins, shearwaters, and petrels; Hunter et al., 2019). However, techniques have been used at airports and waste management sites on other species that are likely to be involved in oil spills, especially in an oil spill that was closer to shore than the MV Rena which grounded 12 nm offshore and/or in more coastal/estuarine environments.

Chilvers and Battley (2019) identified New Zealand bird species for which hazing and deterrence, including pre-emptive capture, are likely to be the most beneficial or only response options beneficial for the species during an oil spill in New Zealand. For family groups, the species identified were petrels, shearwaters, and terns (predominantly *Sterna* spp.*),* two out of the three groups that were found dead in the highest numbers during the MV Rena response (Hunter et al., 2019). For individual species that were identified on New Zealand's main islands, where hazing and deterrence are most likely able to be undertaken, the main bird groups were diving birds (shags, *Phalacrocorax* spp., *Trictocarbo* spp., and *Luecocarbo* spp.), shorebirds (Australian bittern, *Ixobrychus novaezelandiae;* New Zealand shore plover, *Thinornis novaeseelandiae*, Southern and Northern New Zealand dotterel, *Charadrius obscurus obscurus* and *C. obscurus aquilonius* respectively; Wrybill, *Anarhynchus frontalis;* Eastern bar-tailed godwit, *Limosa lapponica baueri,* oystercatchers, *Haematopus* spp. and stilts, *Himantopus* spp.), and penguins (yellow-eyed penguin, *Megadyptes antipodes*, and *Eudyptes* spp). Although it can be important to identify species that are most vulnerable and therefore most likely to benefit from hazing and deterrence, response operations decisions are usually based on communities, habitats, or specific areas. Therefore, considering the families and species above, hazing and deterrence operations are most likely going to be needed at sea and on shorelines for a New Zealand response.

Taking the identified species and environments above that would most benefit from hazing and deterrence operations in New Zealand and comparing them with the techniques, species/taxa, and environments they are used in that are listed in Table 1, helps identify the techniques and practices that could be researched, implemented, and planned for in New Zealand. Predominantly the two habitats that would most benefit from hazing and deterrence in New Zealand are at sea and shoreline/estuary environments.

At sea appears to have the least number of techniques known to be able to be used internationally and none have been trialled either in New Zealand or internationally (for this paper we will define at sea to be territorial waters or out to 12 nm). Within this area, the predominant hazing techniques that could be used are sound (gas canons, electric sound like Phoenix Wailers), pyrotechnics, drones, motorboats, and aircraft. Sound and pyrotechnics would have to be based on a boat or other floating platform. Boats, aircraft, and drones are known to disturb wildlife at sea (Lyons and Menezes, 2020), and given during an oil spill many of these platforms are used during cleanup operations they may operate as deterrence techniques unintentionally, as they undertake their assigned tasks. Monitoring if these activities do act as deterrence during an oil spill would help determine their effectiveness and understand if there is a need to combine these activities with other techniques to be an effective deterrent. Gas cannons and pyrotechnics are used on land in New Zealand in agriculture and at airports. Floating electronic sound deterrence are currently not used in New Zealand so either sound-making instruments would need to be used or trialled on platforms, or floating instruments like Phoenix wailers would need to be bought and trialled. In all cases, observations and monitoring of all of these techniques use would be needed to determine the intended and unintended impacts on target and non-target species. At sea is a very important habitat New Zealand needs to understand how hazing and deterrence techniques could work because 1796 carcasses (15 species and 87 % of all carcasses found) during the MV Rena response were of species that are predominantly only found in the at sea region (Hunter et al., 2019). Therefore, having deterrence options that work in this habitat could save numerous individuals and species during an oil spill.

All of the techniques listed in Table 1 could be used for onshore deterrence and hazing in New Zealand. Onshore habitat are areas with high numbers and diversity of New Zealand species that will be involved in multiple behaviours (feeding, resting, nesting, roosting) depending on the factors such as time of day, season, habitat, and weather. Therefore, it is likely that multiple techniques will need to be used during an oil spill, to account for species' behaviour and the factors that are influencing them. Although many of the techniques listed in Table 1 have been used in New Zealand, few have been quantitatively trialled. Those that have been used are mainly in agriculture where hazing is needed for a set period, usually at the same time of year (harvest), and on known species. For airports, hazing is needed year-round, however is usually undertaken on a limited number of species with a much larger area of similar habitat the wildlife can be dispersed to (just as long as they are not in the airport or on take-off and landing flight paths). There are examples from duck hunting practices in New Zealand of attractants (potatoes in ponds as a food source) and decoy ducks being used to attract waterfowl to areas. These techniques could potentially be used to attract waterfowl away from oil spills. All currently used and available techniques within New Zealand could, at the very least, be used or trialled during an oil spill but preferably should be tested beforehand. One of the most important bird taxa likely to be impacted in any oil spill in New Zealand (Hunter et al., 2019), and one that no trial of any technique except pre-emptive capture, (Chilvers and McClelland, 2023) has been undertaken on are penguins. Penguins' behaviours and habitat use are different from other birds because of their inability to fly and their often cathemeral behaviours (active and or feeding both during day and night), which means many of the techniques known to work on flying birds are unlikely to work on penguins, therefore deterrence techniques will need to be modified to allow for penguin behaviours and habitat use.

5. Conclusion

From the international literature search, there are many lessons learned when considering what hazing and deterrence techniques there are, how, when, and where to use them, and on what species and habitats, and these will change for any area, region, or country depending on the environment and animals' behavioural factors. All hazing reports confirm that the most effective hazing plans include a combination of techniques that frequently change the type, timing, and location of the equipment to reduce habituation to deterrent. The presence of humans is also highly recommended, and this would also allow for the ground truthing and monitoring of impacts techniques are having on target and non-target species. Matching the hazing technique to the target species' biology and physiology is critical as there is no point, for example, in undertaking nighttime hazing techniques when the species only operates during the day, or visual deterrence when the species relies more on hearing. Additionally, hazing techniques need to ensure they do not become attractants, such as light at night which is an attractant for sea birds. There is also the consideration that many of the techniques listed in Table 1 cannot or should not be used in built-up human areas due to levels of light or noise pollution, and the use of all techniques should always be considered in the light of health and safety, local legislation, animal welfare, and impacts on non-target species.

This review compared what techniques are known internationally with what is currently being used in New Zealand. There is the potential to use many of the techniques that are currently already being used around the world, however, most techniques have not been tested on species most likely to be impacted in an oil spill in New Zealand, and some equipment is not available currently in New Zealand to try. Greer and O'Connor's (1994) suggested that hazing and deterrence actions should be initiated as soon as possible and be mobile, aggressive, imaginative, motivated, and persistent. However, to initiate hazing operations quickly you need to know what can be used in an area, region, or country, and on what species it is likely to be effective, and therefore have the equipment and trained personnel in the right places to deploy and undertake the tasks. There can be several steps to this process, including an oiled wildlife preparedness plan based on an analysis of areas at risk of oiling, vulnerable species to oiling, and potential response options for species (Chilvers and Battley, 2019). Following this, a comparison of hazing and deterrence techniques, species, habitat, and likely effects, like this review, can be undertaken for any region/country before a spill occurs and the findings incorporated into the regions oiled wildlife preparedness and response plan.

Ethical approval

No Ethics approval was required for this research.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

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