REDUCING IMPACTS FROM SHIPPING IN MARINE PROTECTED AREAS: A TOOLKIT FOR CANADA

THE IMPACTS OF SHIPPING ON MARINE BIRDS

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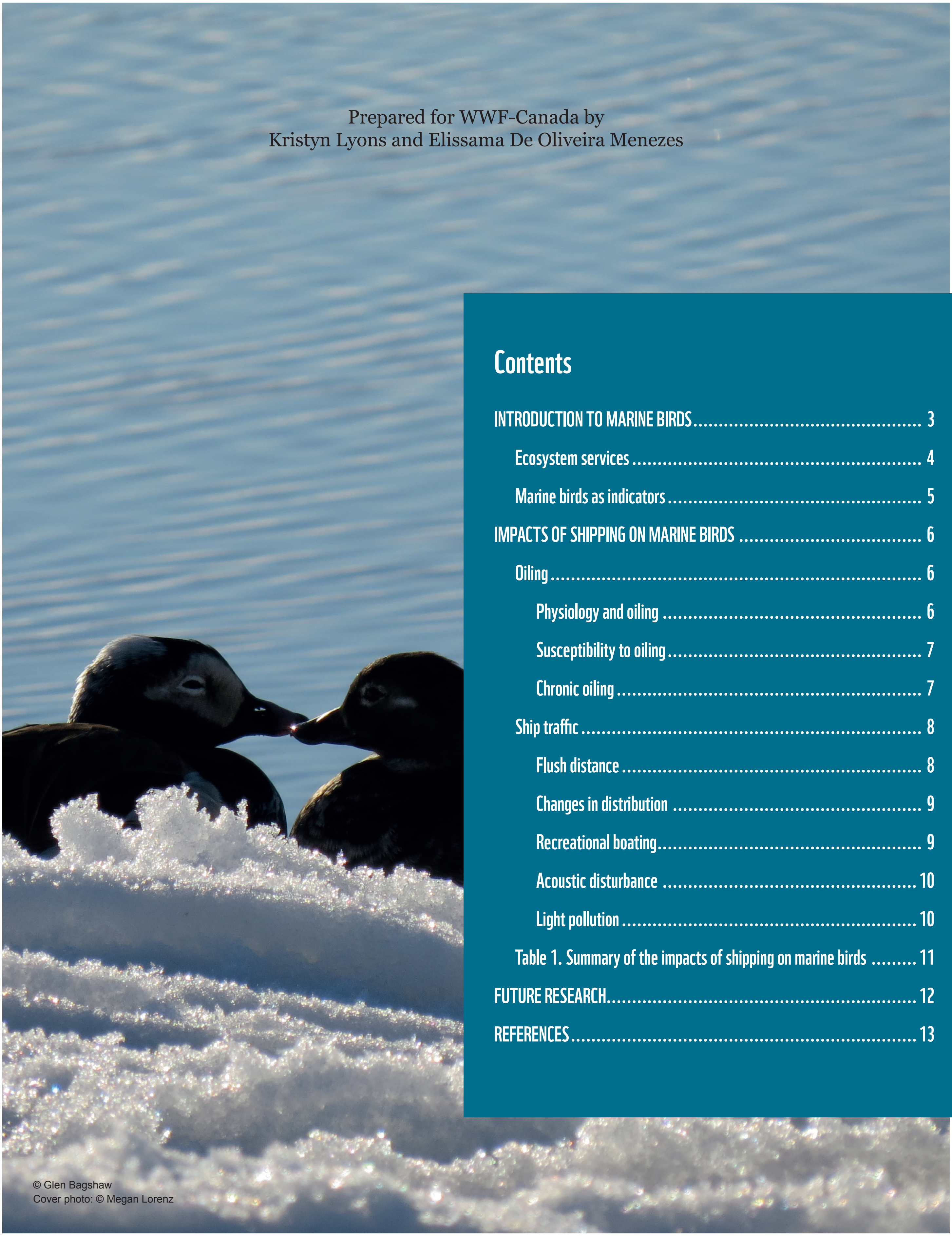

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INTRODUCTION TO MARINE BIRDS

Marine birds, also known as seabirds, are a loosely defined group of birds that differ greatly from their terrestrial relatives. These birds spend a significant amount of time, often nearly their whole lives, at sea or in coastal marine environments.[1] Bird species from nine orders (Procellariiformes, Sphenisciformes, Gaviiformes, Podicipidiformes, Anseriformes, Phaethontiformes, Charadriiformes, Pelecaniformes and Suliformes) are considered marine birds. Shorebirds, those living in the coastal littoral zone, are typically not called marine birds.[2] Despite the fact that these birds account for such a small proportion of all bird species, approximately 3.5 per cent,[3] their role in marine ecosystems and environmental monitoring of those ecosystems is critically important.[4]

Marine birds have adapted several unique features for life in the marine environment that set them apart from passerines and other birds that make their homes on land. Their life histories, behaviour and physiology are different from their terrestrial relatives, although these factors also vary between families of marine birds.[5] Unlike passerines, marine birds are long-lived and reach sexual maturity at a later age. They also have lower reproductive rates, meaning they have small clutch sizes or lay few eggs.[6] Except for a few groups, such as cormorants, marine birds have also evolved "waterproof" plumage that allows them to forage and dive in the marine environment in ways other groups of birds cannot.[7] Species of marine birds can dive to different depths, depending on their weight and other physiological factors, which allows them to exploit different niches within the marine environment.[8] Marine birds also have salt glands that enable them to drink saltwater and excrete the salt later.[9] Behaviourally, marine birds differ from other groups because they nest in colonies with other birds. This colonial lifestyle allows birds to mitigate some of the risks of predation and to interact socially to mate and to pass on information regarding food availability.[10] Marine birds can fly long distances for migration and feeding. However, during breeding, marine birds are restricted because they are central place foragers and must return to the colony to feed their offspring.[11]

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1 Burger and Gochfeld, 2004.
2 Schreiber and Burger, 2001; Votier and Sherley, 2017.
3 Votier and Sherley, 2017.
4 Burger and Gochfeld, 2004; Montevecchi, 1993.
5 Burger and Gochfeld, 2004; Schreiber and Burger, 2001.
6 Schreiber and Burger, 2001.
7 Grémillet, et al., 2005.
8 Watanuki and Burger, 1999.
9 Votier and Sherley, 2017.
10 Ibid.
11 Burke and Montevecchi, 2009.

ECOSYSTEM SERVICES

Despite their diversity, the ecological services provided by marine birds are very similar. As top trophic level consumers,[12] marine birds facilitate energy and nutrient transfer from the lower trophic levels and among different environments.[13] Each year, marine birds eat approximately 70 to 100 million tonnes of food globally, most of which is zooplankton and fish.[14] Since marine birds feed at sea and spend time in colonies on land, these birds transfer nutrients from sea to land in the form of guano. This helps to enrich soils, eventually increasing biodiversity as well as primary and secondary production. These processes are particularly well studied and important in arctic and Antarctic ecosystems, where this transfer of nutrients is invaluable.[15]

© Kim Dunn / WWF-Canada

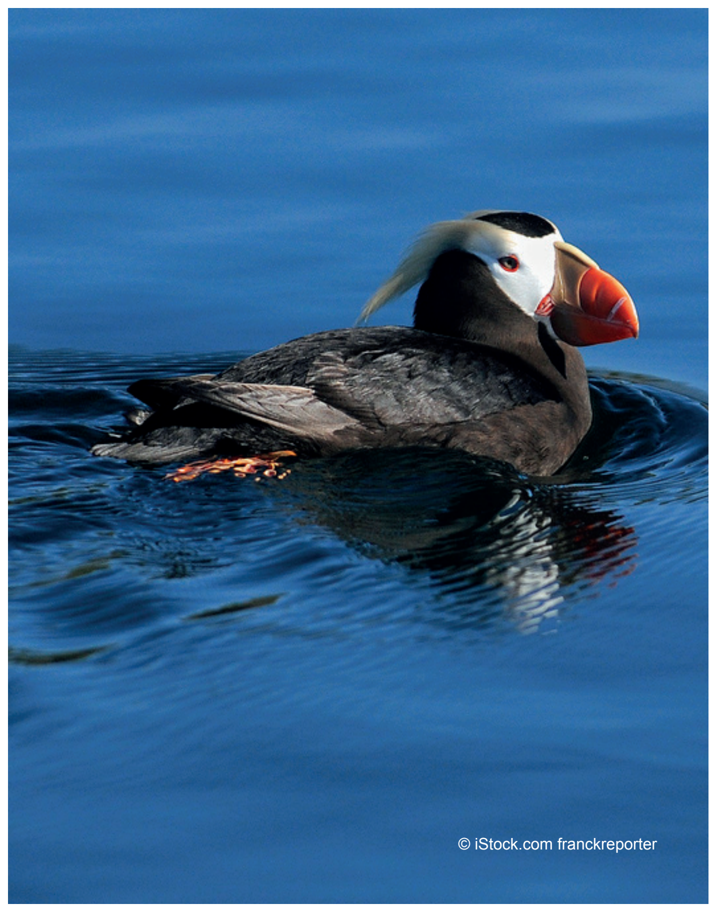
12 Montevecchi, 1993.
13 Votier and Sherley, 2017.
14 Ibid.
15 Zwolicki, et al., 2012.

MARINE BIRDS AS INDICATORS

In addition to enriching soils, marine birds are also an important source of information for many scientists. As top predators, marine birds are often used as indicators of pollution, environmental change and other issues further down the food chain. Compared to other marine organisms, marine birds are relatively easy to observe because of their larger size and abundancy. These factors, along with the fact that they are long-lived, makes them an ideal study subject for some scientists.[16] The low reproductive rates and long lifespans of marine birds pose a challenge for scientists because these factors mean that their response to environmental change is slow.[17] In recent years, marine birds have been the messengers of bad news regarding climate change. Massive die-offs of species like the common murre (*Uria aalge*) have brought attention to the impacts that warming waters and the lack of ice cover in northern regions have on marine species.[18]

For a group that is known to be ecologically important, surprisingly little is known about the behaviour of marine birds and how it may be impacted by human activities.[19] Literature focus on the group is still sparse, with only a few studies focusing on anthropogenic impacts. This may be due to the logistical challenges associated with studying these impacts. Many marine bird species are migratory, making it difficult to track individuals and determine when and where exposure to harmful environmental impacts may have occurred.[20] Additionally, changes in populations of marine birds are difficult to quantify. In tropical islands, marine birds breed on land and feed in the surrounding waters. Despite the pleasant climates, it is challenging to track birds to their specific colonies and collect quantitative data on these islands' populations.[21] In Arctic regions, logistical issues caused by the remoteness and large area covered by marine birds has lead to patchy information regarding abundance and distribution.[22]

The issues scientists face while studying marine birds are especially concerning considering the many threats humans pose to the group. Fishing, poaching, habitat loss, guano collection, chemical pollution, marine debris, shipping, oil spills and introduced species are all anthropogenic impacts that threaten marine birds.[23] Because marine birds are some of the most threatened avian species, with monitored populations worldwide declining by approximately 70 per cent between 1950 and 2010,[24] examining how human disturbances impact this group is now more important than ever.



16 Burger and Gochfeld, 2004.
17 Montevecchi, 1993.
18 Mock, 2018.
19 Burger and Gochfeld, 2004.
20 Ibid.
21 Evans, et al., 2016.
22 Maftei, et al., 2015.
23 Burger and Gochfeld, 2004; Evans et al., 2016.
24 Votier and Sherley, 2017.

IMPACTS OF SHIPPING ON MARINE BIRDS

Impacts on behaviour are one of the many ways in which shipping can disturb marine birds.[25] Physiology, reproductive behaviour and success, and population trends may be impacted in the long term,[26] while foraging success, energy stores and chick-rearing could be impacted in the short term.[27] These impacts' existence is known to scientists, but they are generally not well understood. Basic information about the impacts that passing ships can have on bird species, such as flight reactions, distribution patterns and habitat loss, is seldom quantified, even for those bird species known to be sensitive to anthropogenic disturbances.[28] Those studies that do exist typically examine how these activities impact marine bird behaviour and physiology across temporal scales, but often focus on a single species.[29] The sections below discuss the various ways in which vessels impact marine birds, and Table 1 provides a summary of this information.

OILING

Oil spills of all magnitudes occur in the marine environment. Large scale oil spills have huge far-reaching impacts that often receive media attention and are well-documented.[30] Chronic oiling is less noticeable as it happens slowly over time with smaller amounts of oil being released; however, the impacts may be comparable to those of large-scale spills.[31] Oil enters the marine environment through several channels. Natural petroleum seeps, leaking shipwrecks and bilge cleaning (legal and illegal) contribute to chronic oiling,[32] while grounding, collisions and allisions, and equipment failures are typically responsible for larger oil-spill events.[33] Marine organisms are impacted by oiling, especially those in areas surrounding ports, refineries, vessel routes, oil terminals and oil rigs, where the spill risk is high.[34] Marine birds are the most prominent and abundant group killed or injured by oiling.[35]

Physiology and oiling

Marine birds spend much of their lives foraging at sea and sitting on the water surface. This makes them particularly vulnerable to oil spills, as do some aspects of their physiology.[36] Most marine birds have a special feather microstructure that traps air between their feathers and skin, keeping them dry and warm.[37] Marine birds have adapted this special feature specifically to keep water out. When they encounter polluted water, which has

25 Schwemmer, et al., 2011.
26 Bellefleur, et al., 2009.
27 Agness, et al., 2008.
28 Schwemmer, et al., 2011.
29 Bellefleur, et al., 2009.
30 Henkel, et al., 2014.
31 Fox, et al., 2016.
32 Henkel, et al., 2014.
33 Clear Seas, 2018.
34 Adzigbli and Yuewen, 2018.
35 Fox, et al., 2016.
36 Hinterland Who's Who, 2018.
37 Morandin and O'Hara, 2016; NOAA, 2015.

a different surface tension than nonpolluted water, the interlocking barbs, barbules and hooks that keep water away from the bird's skin collapse. This can lead to heat loss, impacting the bird's ability to thermoregulate and stay buoyant, potentially leading to hypothermia and death.[38] Birds may unintentionally dive into oil slicks while searching for food or inhale toxic fumes, which could lead to lung issues.[39] These physical impacts are often caused by heavy oils like crude oil. But lighter oils that are more soluble and have more volatile components can also be very harmful to birds. If these oils are inhaled, ingested via contaminated food or water or make contact with a bird's skin, they can be absorbed and cause many non-lethal effects, including liver damage and reduced viability of eggs.[40] These oils may also increase mortality rates and have long-term impacts on populations.[41] Finally, birds may attempt to fly to land to dry their feathers after becoming oiled. A combination of drying feathers and preening to remove oil may be successful for some birds; however, birds also risk becoming poisoned by ingesting oil during preening.[42] Flying to land to dry off also has consequences for marine birds. This time spent on land reduces the time available for breeding and feeding, and also increases the risks of predation.[43]

Susceptibility to oiling

While the impacts of oiling are a threat to all marine birds, the life histories and feeding habitats of some species make them more vulnerable. Diving auks such as thick-billed murres (*Uria lomvia*), common murres and dovekies (*Alle alle*) forage on the surface of the water, making them vulnerable to oiling.[44] Pelagic birds are also vulnerable to this type of disturbance because of their life history. These birds are slow to mature, meaning they experience a long juvenile stage followed by high survivorship during adulthood and low reproductive output. This combination of factors can result in a slower recovery from oil spills.[45]

In addition to certain marine bird biological factors, there are also behavioural factors that may make some species more sensitive to oiling.[46] For example, birds like the common murre float in large groups called rafts. These rafts may include up to 250,000 birds. If an oil spill occurs near a raft, the birds may unknowingly float into oil, which could impact many birds at once. This kind of occurrence is not unusual for common murres as their habitat often overlaps with busy shipping channels. Of the approximately 30,000 dead oiled birds collected in Alaska's Prince William Sound following the Exxon Valdez oil spill in 1989, around three-quarters (or more than 22,000) were common murres.[47] Although the sensitivity of some species, like the common murre, to oiling is well-documented, limited information exists on the sensitivity of many other marine birds to oiling. Therefore, more research is necessary to determine the risks that oiling events pose to bird species and marine ecosystems as a whole.[48]

Chronic oiling

Despite not knowing how sensitive many marine bird species are to oiling, the evidence that chronic oiling is occurring worldwide has been documented for decades. In the North Sea, nearly all of the bird carcasses that washed up on shore in the 1950s and 1960s were contaminated with mineral oil in some way.[49] Beached bird surveys were organized following this discovery to bring attention to the issue and push managers and policymakers to intervene. Despite the decrease in the number of oiled birds being detected, chronic oiling still occurs in the region.[50] More recently, scientists have estimated that approximately 300,000 seabirds are killed off

38 Morandin and O'Hara, 2016.
39 NOAA, 2015.
40 Romero, et al., 2018.
41 Morandin and O'Hara, 2016; Romero, et al., 2018.
42 Hinterland Who's Who, 2018; Morandin and O'Hara, 2016.
43 Morandin and O'Hara, 2016.
44 Burke, et al., 2012.
45 Morandin and O'Hara, 2016.
46 Romero, et al., 2018.
47 NOAA, 2015.
48 Romero, et al., 2018.
49 Camphuysen, 2010.
50 Ibid.

the coast of Newfoundland each year due to chronic oiling.[51] Additionally, there is still evidence of ships deliberately discharging oil and bilge waters in the North Sea, despite regulatory restrictions.[52] While there are a few exceptions, for example, off the coast of California where natural seeps occur because of the geology of the area, discharge of oiled water from ships at sea is thought to be the main source of chronic oiling globally.[53] Although beached bird surveys have triggered policy responses and monitoring programs in many regions,[54] the literature suggests that ship operators often still fail to comply with these regulations and simply discharge oil in remote areas or at times when enforcement is lacking.[55] This is concerning given the lethality of small spills and chronic oiling,[56] and the populations' susceptibility to the impacts of large-scale stressors such as climate change.[57]

SHIP TRAFFIC

Flush distance measures how close a source of anthropogenic disturbance can get to a bird before they flush, or flee.[58] It is often measured by scientists to determine how sensitive a species is to ship traffic, and the gathered information may be used to inform management and policy decisions that aim to protect especially sensitive species and areas.[59] Several factors seem to impact flush distance;[60] however, the subject is not highly studied, and existing studies have often focused on only one species and only at a certain time of the year[61] or flush distance in freshwater environments.[62] Nonetheless, flush distance is still likely the most studied impact that shipping has on the behaviour of marine birds.

Flush distance

In their 2011 study, Schwemmer and colleagues explored the impacts that ship traffic has on the distribution of marine birds, the flush distances of sensitive marine bird species, the long- and short-term impacts of flushing on habitat use and the habituation of marine birds in response to shipping traffic. To examine these impacts, the researchers studied species known to be sensitive to ship traffic. The study species included red-throated loons (*Gavia stellate*), black-throated loons (*G. arctica*), common eiders (*Somateria mollissima*), long-tailed ducks (*Clangula hyemalis*), common scoters (*Melanitta nigra*) and white-winged scoters (*M. deglandi*), all found in regions of the German North Sea and Baltic Sea with highly concentrated shipping activity. By measuring flushing distance of these bird species, Schwemmer and colleagues found that the reaction of birds varied within and between species. Species found to have high levels of intraspecific variability in flush distance detected in the study were likely influenced by environmental factors and flock size. Individuals situated within larger flocks are likely to flush sooner than those in smaller flocks, as flocks tend to flee in response to the flight of their most sensitive individuals. The larger the flock size, the more likely it is that highly sensitive individuals are present.

Additionally, flock location, inside or outside of shipping lanes, significantly affected flush distance. Flocks observed in the shipping lanes had shorter flush distances, suggesting habituation to shipping traffic. Sea state also impacted flush distance, with distances decreasing as wave action increased for some of the observed common scoters and long-tailed ducks observed. This may be because higher sea states make it more difficult for birds to see oncoming ship traffic or because it is often easier for marine birds to take off due to the stronger winds

51 Henkel et al., 2014.
52 Camphuysen, 2010.
53 Henkel, et al., 2014.
54 Žydelis, et al., 2006.
55 Fox, et al., 2016.
56 Burke, et al., 2012.
57 Morandin and O'Hara, 2016; NOAA, 2015.
58 Blumstein, 2003.
59 Schwemmer, et al., 2011.
60 Ronconi and Clair, 2002.
61 Burthe, et al., 2014.
62 Schwemmer, et al., 2011.

that often accompany a higher sea state. Other factors, like molting, may also impact flush distance. Temporary habitat loss occurred following flushing, which is likely to have energetic implications because of the energy necessary to flee from ship traffic and foraging time lost. The researchers concluded that more studies should be undertaken to examine the flush distances for other species, differences between seasons and the impacts that speed and noise may have on marine birds.[63]

Changes in distribution

In addition to measuring flush distance to determine the impacts of anthropogenic disturbances on marine birds, changes in distribution may also be used as an indicator of disturbance. For example, Agness and colleagues examined the impacts of shipping on Kittlitz's murrelet (*Brachyramphus brevirostris*) in 2008 by examining how density, group size and behaviours are impacted by vessel disturbance. The authors suggest that this species may be particularly sensitive to disturbances due to their high wing loading, making the flight more energetically costly for many species of the Auk family. Researchers observed birds raising chicks and those that were not to determine whether the energetically demanding task of chick-rearing impacted the birds' response to vessel activity. Although vessel traffic did impact the density of Kittlitz's murrelets near shore, researchers found that environmental and biological factors overall had more influence on density, group size and behaviours. Researchers also found that group size was not influenced by vessel activity, so group dynamics were not impacted. Their behaviour was impacted on days when ship traffic was higher. When vessel activity was greater, researchers observed Kittlitz's murrelets diving three times more than usual. However, this behavioural response that may have been intended to help the birds with energy recovery (lost during increased flight) would only be beneficial if the diving resulted in their catching prey. In addition, researchers observed that flight response also went up more than 30-fold with increased vessel activity, which could prove very harmful for a species whose flight is so energetically costly. Birds carrying fish to feed to their young were found to continue to rest on the sea surface as vessels approached, with only 1 per cent of fish-holders fleeing from approaching vessels. Individuals not carrying fish had the greatest flight response from large vessels. Vessel speed and size also had impacts on these behavioural responses of Kittlitz's murrelets. In particular, vessels approaching at fast and moderate speeds caused 95 per cent of fish-holding birds to dive, fleeing from vessels, a behaviour not observed in fish-holders when vessels were not present.[64]

Recreational boating

Similar to Agness and colleagues' study in 2008, in 2009, Bellefleur and colleagues examined the impacts of recreational boat traffic on marbled murrelets (*B. marmoratus*) in the waters surrounding the Pacific Rim National Park Reserve in British Columbia. Although recreational vessel traffic is different from commercial shipping, some parallels can be drawn between them. The researchers sought to determine the flush distance of marbled murrelets at different times of day, during different seasons, at various ages and when boats approached at different speeds. They found that when approached by recreational boats, most of the murrelets dove to avoid the watercraft and resurfaced nearby. If the murrelets decided to fly away instead, they typically left the feeding area entirely.[65] As was found in the study conducted by Agness and colleagues in 2008, the type of boat and its speed and approach impacted the behavioural response of the birds, with faster boats resulting in an increase in flushing behaviour.[66] The marbled murrelets demonstrated some degree of habituation to vessels in areas where boat traffic was concentrated as flush distance decreased by approximately five metres, but overall flushing behaviour increased in these areas by around 17 per cent.[67]

63 Ibid.
64 Agness, et al., 2008.
65 Bellefleur, et al., 2009.
66 Ibid.
67 Ibid.

ACOUSTIC DISTURBANCE

Marine mammals are negatively impacted by the underwater noise associated with shipping, but the impacts of noise on marine birds are virtually unknown.[68] The majority of marine birds use sight to find prey while diving;[69] however, some birds dive to depths where little light is available or frequently dive at night, which suggests that they are likely to rely on senses other than vision. Additionally, hearing is important for many birds in the air and while in their colonies. Emperor penguins (*Aptenodytes forsteri*) and king penguins (*A. patagonicus*) find their partners in large, noisy colonies by using distinctive sounds, a process that may be negatively impacted by nearby noise.[70] Research in the high Arctic also shows that fish populations, such as arctic cod, are disturbed and displaced by vessel noise, which is problematic for the marine birds, such as black guillemots (*Cepphus grylle*) and northern fulmars (*Fulmarus glacialis*), that prey upon them.[71] Finally, the noise generated by offshore windfarms may cause marine birds to avoid the turbines and area surrounding them, though little is known about this behaviour or its possible repercussions.[72]

Despite the lack of research about the effects of acoustic disturbance caused by shipping on marine birds, Dooling and Therrien postulate in their 2012 study that the impacts are likely similar to how land birds and other marine vertebrates experience acoustic disturbance. The researchers note that birds in the air are known to be sensitive to continuous noise exposure and blast noise, both of which can cause physical damage to the auditory system. Noise above certain levels can also mask communication between birds. Levels that are too low to mask communication could still result in harmful behavioural and physiological impacts. The importance of further research specific to diving birds to determine whether they use sound to communicate, forage and avoid predators underwater, and how these activities may be impacted by anthropogenic noise, cannot be overemphasized.[73]

LIGHT POLLUTION

Artificial light from offshore oil and gas rigs and offshore wind farms are known to have negative impacts on marine birds.[74] Shipping also causes light pollution in the marine environment, but its impacts are not as well documented in the literature. The studies that discuss the impacts of light from ships emphasize the dangers of collisions with ships or structures. Marine birds may become disoriented by marine light pollution or be attracted to artificial light when visibility is low, leading to collisions.[75] These collisions are especially common during migration and in the winter.[76] Comparisons may be made with land birds, which are negatively impacted by artificial light. In addition to an increased risk of predation, land birds are also known to reach sexual maturity faster, forage more intensely and extend their dawn song as a result of artificial light.[77]

68 Dooling and Therrien, 2012.
69 Wanless, et al., 1999.
70 Dooling and Therrien, 2012.
71 Ivanova, 2016.
72 Wilson, et al., 2010.
73 Dooling and Therrien, 2012.
74 Wilson, et al., 2010.
75 AMAP, 2018; Davies et al., 2014.
76 AMAP, 2018.
77 Davies, et al., 2014.

Table 1. Summary of the impacts of shipping on marine birds

Stressor	Direct impacts	Physiological or behavioural impacts
Chronic oiling (natural petroleum seeps, fuel leak due to shipwrecks, bilge cleaning)[78]	Waterproofing[79]	• Hypothermia, loss of foraging time, increased risk of predation[80] • Reduced breeding time[81]
	Inhalation of fumes[82]	• Lung issues[83]
	Contact with skin[84]	• Liver damage, reduced viability of eggs[85]
	Ingestion of oil[86]	• Negatively impacts reproduction, disrupts hepatic function, impacts osmoregulation, increases metabolic rate, and may cause anemia and oxidative damage to red blood cells[87]
Ship traffic	Flushing[88]	• Temporary or long-term habitat loss, energetic costs of flight response to disturbance[89] • May impact the ability to provide for young[90] • Changes in distribution and diving behaviour[91]
Acoustic disturbance	Masking of communication[92]	• May render seabirds unable to locate mates or share foraging information[93]
	Disturbance of fish populations[94]	• May lead to changes in prey distribution, which could impact species that rely on affected fish[95]
Light pollution	Disorient birds[96]	• May lead to collisions with the light source or nearby structures[97]
	Increased visibility	• Increased risk of predation[98]

78 Henkel, et al., 2014.
79 Morandin and O'Hara, 2016
80 Hinterland Who's Who, 2018; Morandin and O'Hara, 2016
81 Morandin and O'Hara, 2016.
82 NOAA, 2015.
83 Ibid.
84 Romero, et al., 2018.
85 Ibid.
86 Morandin and O'Hara, 2016.
87 Ibid.
88 Agness, et al., 2008; Bellefleur et al., 2009; Schwemmer, et al., 2011.
89 Schwemmer, et al., 2011.
90 Agness, et al., 2008; Bellefleur, et al., 2009.
91 Agness, et al., 2008.
92 Dooling and Therrien, 2012.
93 Ibid.
94 Ivanova, 2016.
95 Ibid.
96 AMAP, 2018; Davies, et al., 2014.
97 Ibid.
98 Davies, et al., 2014.

FUTURE RESEARCH

The studies mentioned above contribute to our knowledge of the impacts of shipping on marine birds. But they are not truly representative of the many natural and human-caused pressures faced by marine birds, because they only focus on the impacts of a single stressor on a single species. Most of these studies do not consider the cumulative effects of anthropogenic stressors on marine bird populations.[99] Due to the lack of knowledge about the impacts of ship traffic on marine birds and other marine organisms, it is thought that managers cannot create effective spatial plans and conservation measures.[100] However, because many marine birds are of conservation concern, future studies need to address the cumulative effects of anthropogenic impacts on marine birds to aid in better marine planning.[101]

99 Burthe, et al., 2014.
100 Schwemmer, et al., 2011.
101 Ibid.

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