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Research Paper

Experts' opinions on threats to Leach's Storm-Petrels (*Hydrobates leucorhous*) across their global range

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ABSTRACT. Seabirds are declining globally, though the threats they face differ among and within species and populations. Following substantial population declines at several breeding colonies, Leach's Storm-Petrel (*Hydrobates leucorhous*) was uplisted from Least Concern to Vulnerable by the International Union for Conservation of Nature (IUCN) in 2016. Reasons for these declines are unclear, and it is important to identify threats the species faces across its global breeding range to guide research directions and inform conservation efforts. We solicited feedback from 37 Leach's Storm-Petrel scientific experts from eight countries on the importance of different threats facing the species on land and at sea. Perceived threats to extant colonies varied spatially, with a consensus within regions for main threats. Most researchers agreed that the main threats at or near colonies are avian and mammalian predators and onshore light attraction. At-sea threats have been less studied and were harder to identify and rank, but include offshore lights and structures, spatial shifts in prey, and contaminants. Climate change was not listed specifically because of its multifaceted repercussions, but several perceived threats are linked to climate change. Globally, introduction of mammalian predators is an overarching driver of seabird colony decline or extirpation; thus biosecurity must be considered an important measure for the conservation of storm-petrels. In addition, filling knowledge gaps and implementing a series of regionally relevant and targeted strategies that lead to small but cumulative conservation successes may be the best approach for this species.

Avis d'experts sur les menaces pesant sur les océanites cul-blanc (*Hydrobates leucorhous*) dans l'ensemble de leur aire de répartition

RÉSUMÉ. Les oiseaux de mer sont en déclin à l'échelle mondiale, bien que les menaces auxquelles ils sont confrontés diffèrent selon les espèces et les populations et au sein de celles-ci. Suite à une diminution significative de la population dans plusieurs colonies de reproduction, l'Océanite cul-blanc (*Hydrobates leucorhous*) est passée de "Préoccupation mineure" à "Vulnérable" par l'UICN en 2016. Les raisons de ces déclins ne sont pas claires et il est important d'identifier les menaces auxquelles l'espèce est confrontée dans son aire de reproduction mondiale pour guider les orientations de recherche et informer les efforts de conservation. Nous avons sollicité l'avis de 37 experts scientifiques de l'Océanite cul-blanc venant de huit pays sur l'importance des différentes menaces auxquelles l'espèce est confrontée sur terre et en mer. Les menaces perçues pour les colonies existantes varient spatialement, avec un consensus au sein des régions pour les principales menaces. La plupart des chercheurs s'accordent à dire que les principales menaces sur ou à proximité des colonies sont les prédateurs aviaires et mammifères ainsi que l'attraction de la lumière. Les menaces en mer ont été moins étudiées et étaient plus difficiles à identifier et à classer, mais comprennent les lumières en mer et les structures au large, les déplacements des proies et les contaminants. Le changement climatique n'a pas été spécifiquement répertorié en raison de ses multiples répercussions, mais plusieurs des menaces perçues sont liées au changement climatique. À l'échelle mondiale, l'introduction de mammifères prédateurs est un facteur déterminant

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du déclin ou de l'extinction des colonies d'oiseaux de mer. La biosécurité doit donc être considérée comme une mesure importante pour la conservation des pétrels-tempête. De plus, combler les lacunes dans les connaissances et mettre en œuvre une série de stratégies régionales pertinentes et ciblées conduisant à des succès de conservation modestes mais cumulatifs pourrait être la meilleure approche pour cette espèce.

Key Words: *expert opinion; Hydrobates leucorhous; Leach's Storm-Petrel; seabird conservation; threats*

INTRODUCTION

Human activities have grown at unprecedented rates in recent decades, affecting all ecosystems (Marques et al. 2019, Baud et al. 2021). Marine ecosystems, in particular, are deteriorating, with degradation driven mainly by coastal development, offshore energy production, fisheries, and pollution (Halpern et al. 2008, 2019). Perhaps it is not surprising, then, that declines in seabird numbers are more pronounced than in most other bird groups (Paleczny et al. 2015, Dias et al. 2019).

Rodríguez et al. (2019) reviewed threats (defined as human-induced or natural actions or events that negatively affect a species) for shearwaters and petrels (Procellariidae), highlighting that interspecific differences in threats are influenced by numerous behavioural, geographic, and life-history factors. Much attention has focused on population declines and threats to larger seabirds (Baker et al. 2002, Phillips et al. 2016), with fisheries bycatch being a major issue for divers (e.g., alcids and diving duck; Zydelis et al. 2013) and vessel-attracted scavenging species such as albatrosses (Anderson et al. 2011). For smaller species, such as storm-petrels, invasive mammals, especially rodents, are raising the most concern (Jones et al. 2008, Bolton et al. 2014, Dias et al. 2019), whereas fisheries bycatch is less of an issue (Bugoni et al. 2008, Jiménez et al. 2011; but see Pott and Wiedenfeld 2017). Approximately 44% of storm-petrel species are listed on the International Union for Conservation of Nature (IUCN) Red List as Near Threatened, Vulnerable, Endangered, or Critically Endangered, and data are insufficient to determine a threat category for an additional 7% of species (n = 27; BirdLife International 2021; Table A1.S1).

Leach's Storm-Petrel (*Hydrobates leucorhous*) was recently uplisted from Least Concern to Vulnerable globally (BirdLife International 2018), mainly as a consequence of population declines at northwest Atlantic colonies. The eastern (i.e., Atlantic) Canadian population was designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; COSEWIC 2020), the UK population was moved from Amber to Red by the UK Birds of Conservation Concern 5 (Stanbury et al. 2021), and the European population from Near Threatened to Vulnerable in the European Red List of Birds (Birdlife International 2021; Deakin et al. 2021). In general, storm-petrels are difficult to monitor and, therefore, colony abundance and population trends are either estimated infrequently or not available (Olivier and Wotherspoon 2006; Insley et al. 2014). However, Leach's Storm-Petrel is one of the most studied storm-petrel species, breeding from the Gulf of Maine to southern Labrador in the western North Atlantic, to Iceland, the British Isles, and coastal Norway in the eastern North Atlantic, and from Hokkaido to the Aleutians and Baja California in the Pacific (Pollet et al. 2021). In western North Atlantic colonies, apparent adult survival rates for Leach's Storm-Petrels range from 79%–86% at a number of colonies, which is lower than expected for population stability (Fife et al. 2015, COSEWIC 2020), whereas limited data using a short time series from two Pacific Ocean colonies suggest a higher (94%–99%) apparent survival rate (Rennie et al. 2020). Concomitant with low adult survival rate, population sizes have been decreasing at several large Atlantic colonies (Wilhelm et al. 2015, 2019, Pollet and Shutler 2018, 2019, d'Entremont et al. 2020, Deakin et al. 2021). Thus, reduced adult survival in western North Atlantic colonies could be a key driver of population decline.

Following the listing of Leach's Storm-Petrel as Vulnerable by the IUCN and Threatened by COSEWIC, a list of threats was compiled (BirdLife International 2018, COSEWIC 2020). Yet, understanding the impact of threats is complicated by the enormous spatial range of Leach's Storm-Petrels throughout their life cycle. Leach's Storm-Petrels forage hundreds of kilometers from their colony during the breeding season (Halpin et al. 2018, Hedd et al. 2018) and are trans-equatorial migrants during the non-breeding season (Halpin et al. 2018, Pollet et al. 2019). Given that this species is globally distributed across a seascape spanning a variety of threats and stressors, conservation planning must also consider spatial and temporal variation in risk. Current knowledge suggests that populations in the Pacific may be faring better than those in the Atlantic, potentially because of a different suite of threats in each ocean. Spatial variation is invaluable for assessing cumulative risk (but see Lieske et al. 2020), but it is often difficult to estimate given that multiple threats can influence ecosystems in a variety of ways. As such, solicitation of expert opinion is an effective approach to synthesize the current state of knowledge regarding sensitivity of marine birds to threats (Lieske et al. 2019). In this context, we created a survey with which Leach's Storm-Petrel researchers ranked threats for different colonies to assess spatial variation in risk, with the goal of supporting the selection of appropriate conservation strategies across the global range. We also identified knowledge gaps to be addressed to assist conservation of storm-petrels, and to inform conservation planning processes.

METHODS

The lead author contacted 48 Leach's Storm-Petrel researchers from nine countries or territories (Canada, Faroe Islands, Iceland, Japan, Mexico, Russia, St. Pierre et Miquelon, United Kingdom, and United States) covering the species' global breeding range to complete a survey (Appendix 1). The selected researchers have published articles on Leach's Storm-Petrels and were at different stages of their careers. The survey first asked researchers about their professional affiliations, how long they had been working with the species, and the location of the breeding colony(ies) where they conducted their research. Hence, threats that had caused extirpation of colonies were excluded from this survey. Participants were then asked to rank the importance of seven terrestrial and five at-sea threats (during both the breeding and non-breeding seasons; Table 1) at colony(ies) where they conduct

Table 1. Terrestrial and at-sea threats to Leach's Storm-Petrel (*Hydrobates leucorhous*) at existing study colonies given in the survey and added by participants. At-sea threats were presented separately for the breeding and non-breeding season.

	Already in the survey	Added by participants
Terrestrial threats	Mammalian predators	Researcher disturbance
	Mammalian herbivores	Avian competition for burrow
	Avian predators	Reduction in canopy
	Habitat loss	
	Onshore light attraction and collisions	
	Recreational disturbance	
	Coastal development	
At-sea threats	Mercury poisoning	Climate change
	Contaminant poisoning (other than mercury)	Weather events
	Offshore light attraction and collisions	Predation at offshore platforms
	Bycatch	Prey depletion
	Spatial shift in prey items	

research or have in-depth knowledge. The threats were chosen based on the COSEWIC assessment and status report (COSEWIC 2020). For each ranking question, survey participants could propose additional threats not provided in the survey, and researchers were not required to rank all threats. It was assumed that, although most research on Leach's Storm-Petrels is colony-based, researchers could also evaluate at-sea threats.

DATA ANALYSIS

To determine which threat was the most important, weighted ordinal values were determined by the number of threat options in each question, with the top threat given the most weight. A top-ranked terrestrial threat was given a value of seven and a top-ranked at-sea threat was given a value of five. A lowest-rank terrestrial or at-sea threat was given a value of one. When a survey participant did not rank all proposed threats, we gave top values to the ranked threats and assumed the others were negligible (Table A1.S2). A score for each threat was calculated by summing all weighted values at three different geographic scales, as follows: global, ocean basin sector (western Atlantic, eastern Atlantic, western Pacific, and eastern Pacific), and jurisdiction (state, province, country). The number of participants was unequal among regions (jurisdiction and basin scales); therefore, score values varied greatly among regions. Hence, we determined for each threat what percent of the total weighted score it represented in each region.

RESULTS

Thirty-seven researchers (the authors) responded to the survey, representing eight of the nine countries where Leach's Storm-Petrels breed (we were unable to secure responses from Russia), with two, eight, twenty-four, and five responses for the western and eastern North Pacific, and the western and eastern North Atlantic, respectively. Most participants were government employees (n = 16), followed by university researchers (n = 15), but the group also included non-governmental organization employees (n = 5) and a museum employee (n = 1). More than two-thirds of participants (n = 26) had studied Leach's Storm-Petrels for more than 11 years and their combined experience represented a minimum of 433 years.

Terrestrial threats

Globally, survey participants ranked the three most important terrestrial threats that currently affect existing colonies as avian predators, mammalian predators, and onshore light attraction, with rankings differing among regions (Fig. 1; Table 2). Avian predators were the top threat in all four ocean basin sectors, tied with mammalian predation in the eastern Pacific. At the jurisdiction level, avian predators had the highest or second highest summed weighted scores in all but one case, the Faroe Islands, where they ranked fourth. Mammalian predators were ranked first, second, or third in the eastern Pacific, western Atlantic, and eastern Atlantic, respectively, but were not perceived as a threat in the western Pacific. At the jurisdiction level, mammalian predators ranked among the top three threats in nine of fourteen cases (64%). They were not ranked as a threat in four jurisdictions (Japan, Mexico, St. Pierre et Miquelon, and Iceland). Onshore light attraction received the third highest weight, ranking third in the western Atlantic and eastern Pacific, but only fifth in the western Pacific and eastern Atlantic. At the jurisdiction level, onshore light attraction was ranked second in Newfoundland and Labrador, New Brunswick, California (tied with avian predation), and St. Pierre et Miquelon (tied with avian predation and habitat loss), third in Alaska, British Columbia, and Mexico, and fourth to sixth elsewhere (Fig. 1). There was a high consistency in the responses from the survey participants at the jurisdiction level. This concordance of expert opinion was not present at the basin or global scales (Table A1.S3). The heterogeneity in perceived threats is potentially the result of the combined effect of the different specific issues faced at their colonies and the perceptions of the survey participants.

At-sea threats during breeding season

The top four at-sea threats during the breeding season were offshore light attraction, spatial shifts in prey, mercury, and pesticides and other contaminants (Fig. 2; Table 3). Offshore light attraction ranked first in the east Pacific, spatial shifts in prey ranked first in the east and west Atlantic, mercury ranked second in the west Atlantic and fourth in the eastern Pacific and the eastern Atlantic. Pesticides and other contaminants were either third (east Pacific, east Atlantic) or fourth (west Atlantic; Fig. 2). At the jurisdiction level, spatial shifts in prey items were ranked

Table 2. Weighted percent threat scores for each terrestrial threat for Leach's Storm-Petrel (*Hydrobates leucorhous*) at existing study colonies during the breeding season (number of survey participants who ranked each threat). Light: attraction to onshore lights. Threat with the highest score for each ocean basin is bolded.

	Avian predators		Mammalian predator		Light		Habitat loss		Mammalian herbivore		Disturbance		Coastal development		Unknown	
West Pacific	**33.3**	**(2)**	0.0	(0)	13.9	(1)	16.7	(1)	0.0	(0)	0.0	(0)	16.7	(1)	19.4	(1)
East Pacific	**28.3**	**(8)**	**28.3**	**(7)**	21.4	(6)	4.1	(1)	1.4	(1)	11.1	(4)	2.7	(1)	2.7	(1)
West Atlantic	**27.9**	**(23)**	17.0	(19)	16.8	(17)	14.6	(14)	9.3	(11)	6.9	(12)	7.5	(9)	0.0	(0)
East Atlantic	**30.5**	**(5)**	19.1	(4)	8.6	(3)	8.6	(2)	20.9	(4)	11.4	(3)	0.9	(1)	0.0	(0)
Overall	**28.5**		18.5		16.5		12.1		9.0		7.9		6.2		1.3	

first for seven jurisdictions, offshore light attraction was ranked first for three jurisdictions, and mercury and pesticides and other contaminants each ranked first for one jurisdiction (Fig. 2). Survey participants were in agreement with the most important threats within each jurisdiction but not at the basin or global scale (Table A1.S4).

At-sea threats during non-breeding season

The top four offshore threats during the non-breeding season were the same as during the breeding season, namely offshore light attraction, spatial shifts in prey, mercury contamination, and pesticide contamination (Fig. 3; Table 3). However, the order at the ocean-basin scale was somewhat different. Offshore light attraction ranked first as a threat in the east Pacific and west Atlantic but only seventh in the east Atlantic, where spatial shifts in prey items ranked first (Fig. 3; Table 3). At the jurisdiction level, responses from survey participants were fairly consistent, with spatial shifts in prey items ranked first in five jurisdictions, offshore light attraction ranked first for four jurisdictions, mercury ranked first for one jurisdiction, and pesticides and other contaminants and prey depletion each ranked first for one jurisdiction. The agreement among survey participants was slightly more pronounced at the jurisdiction scale than at the basin scale (Table A1.S5).

GENERAL PERSPECTIVES ON THREATS

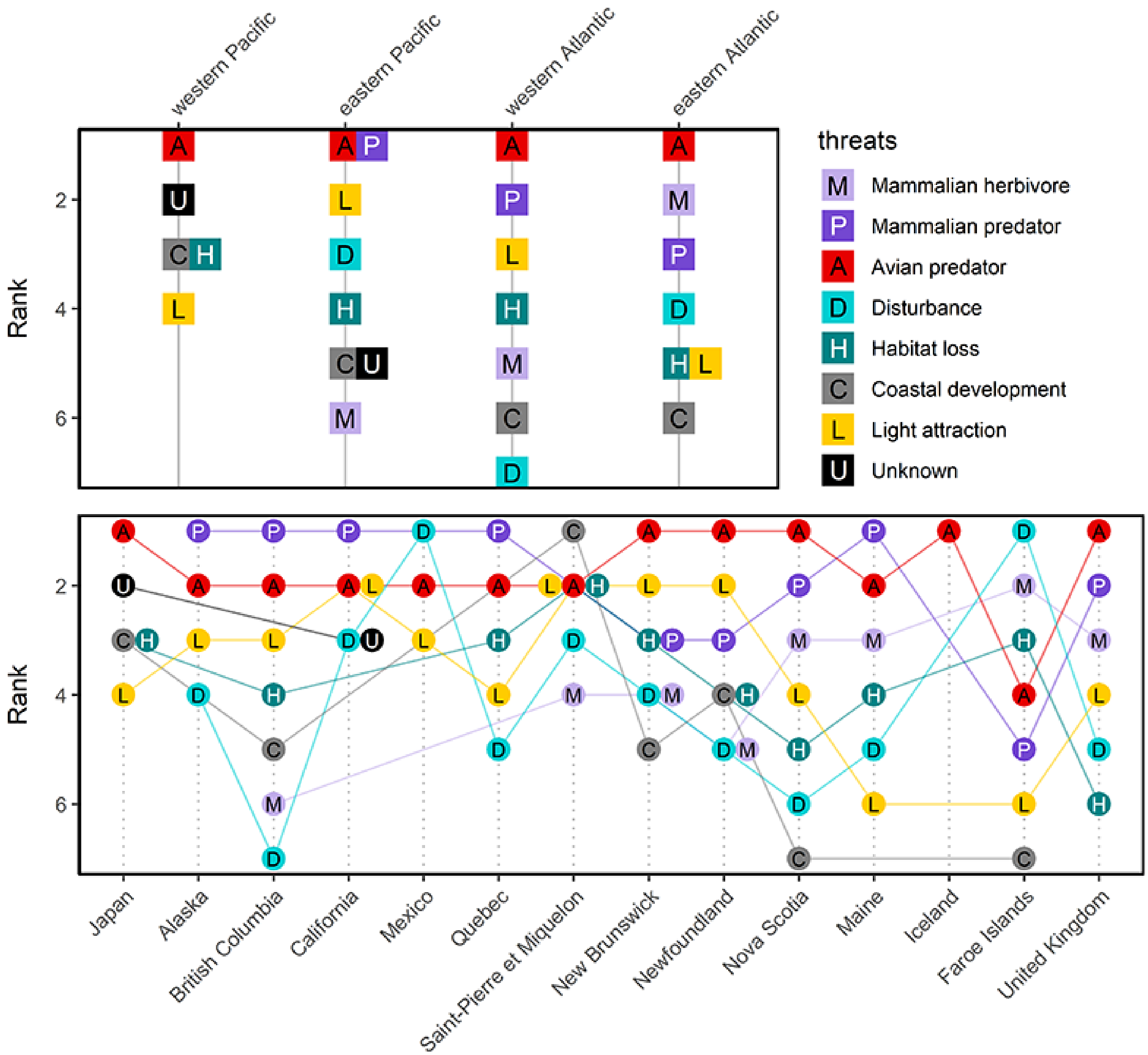
Avian predators

Avian predators of Leach's Storm-Petrels include Herring Gulls (*Larus argentatus* and *L. smithsonianus*), Great Black-backed Gulls (*L. marinus*), Lesser Black-backed Gulls (*L. fuscus*), Slaty-backed Gulls (*L. schistisagus*), Great-horned Owls (*Bubo virginianus*), Great Skuas (*Stercorarius skua*), and corvids (Corvidae; Stenhouse et al. 2000, Votier et al. 2006, Veitch et al. 2016, Hey et al. 2019, Pollet and Shutler 2019, Pollet et al. 2021). Corvids tend to destroy nest-burrows and presumably prey on adults, eggs, and nestlings, whereas gulls, skuas, and owls mostly prey on adults, although it is unclear if this includes breeding or non-breeding birds or both (Hoeg et al. 2021). However, the high proportion of the local Leach's Storm-Petrel population estimated consumed annually at some colonies (e.g., 9% on Great Island, Newfoundland, 16% on St. Kilda, Scotland [Stenhouse et al. 2000, Votier et al. 2006]) is not sustainable if all predation was on breeding adults, suggesting that breeding and non-breeding birds are being preyed on (Bicknell et al. 2013). In Newfoundland, capelin (*Mallotus villosus*) can be a major part of Herring Gull diets, and delayed capelin spawning caused gulls to use alternate food sources, including seabirds (Massaro et al. 2000), such as storm-petrels (Stenhouse and Montevecchi 1999). However, at Atlantic colonies, gulls breed earlier than Leach's Storm-Petrels. When juvenile storm-petrels leave their burrows, gulls are not attending colonies, which presumably reduces this direct predation pressure on fledging individuals (Hoeg et al. 2021). However, there is considerable predation of fledglings by gulls during onshore wrecks and at illuminated coastal facilities (Burt 2022).

In eastern Canada, Herring Gull and Great Black-backed Gull populations decreased following the collapse of the northern cod fishery that provided gulls with a large food source from offal (Regular et al. 2013, Wilhelm et al. 2016, Weseloh et al. 2020). We might therefore expect avian predation on storm-petrels to decrease, although some individual gulls specialize in feeding on storm-petrels (Pierotti and Annett 1991, Hey et al. 2019). In skuas, specializing on seabirds and/or prey-switching from discards to seabirds (including storm-petrels) results in high levels of storm-petrel predation (Votier et al. 2006). Changes in regional fisheries policy could also affect those behaviors in the future (Votier et al. 2004, Bicknell et al. 2013).

Avian predation pressure may also be influenced by small mammal population dynamics on islands, where avian predators are initially attracted by the mammals but switch to seabirds once the nesting season begins. In cases where conservation strategies include removal of problematic mammals (e.g., mice, voles, and hares), there is potential for unintended consequences of predator diet-switching that inadvertently increases predation pressure on storm-petrels (Rayner et al. 2007, Hervías et al. 2013). Dynamics among avian predators and predation on storm-petrels and other prey may be complex and differ among regions and colonies (Stenhouse and Montevecchi 1999, Steenweg et al. 2011, Thomsen et al. 2018). In some cases, removal of just a few specialist avian predators has some positive effect on prey species (Sanz-Aguilar et al. 2009, Scopel and Diamond 2018). Where human activities have exacerbated avian predation, management strategies should be carefully considered. These strategies must also have clear objectives for both predator and prey, with an evaluation plan to assess if targets are met and the implementation of adaptive management when objectives are not reached (Libois et al. 2012, Fuentes et al. 2014, Bourgeois et al. 2015). In other cases of avian predation from a native predator, management might not be advisable. Avian species may also be competitors, with examples of Atlantic Puffins (*Fratercula arctica*) outcompeting Leach's Storm-Petrel for nesting sites (Lormee et al. 2012, Wilhelm et al. 2015, 2019).

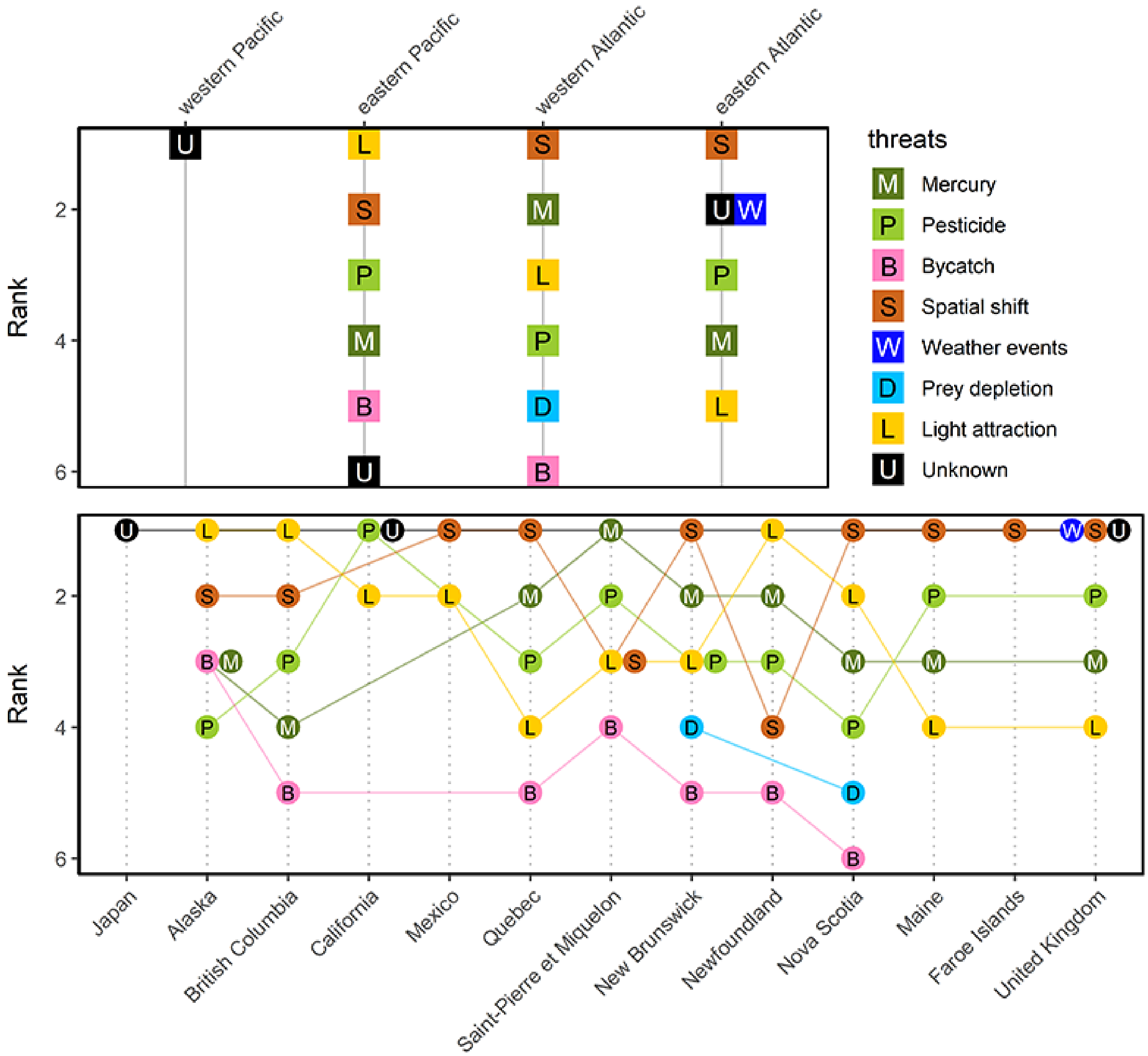
Fig. 1. Ranks of onshore threats for Leach's Storm-Petrel (*Hydrobates leucorhous*) evaluated for extant colonies studied by the authors. Threats are presented for each ocean basin sector (top) and state/province/country (bottom). Note that threats that may have led to the extirpation of colonies are not factored into the ranking.



Mammalian predators

Seabirds tend to breed on islands free of mammalian predators and, as a result, may lack anti-predator defense mechanisms (e.g., Buxton et al. 2016). Therefore, seabirds are highly vulnerable if mammalian predators are introduced to a colony (Borrelle et al. 2018), and they rarely coexist with introduced mammalian predators (De León et al. 2006). Historical presence of introduced mammalian predators (mostly rats) has decimated storm-petrel colonies (McClelland et al. 2008), making mammalian predators the top threat for storm-petrels (Dias et al. 2019). Mammalian predators can also naturally occur on seabird islands, and measures to deal with naturally occurring mammals will be different than for introduced species. Co-occurrences of mammalian predators with storm-petrels will have different outcomes depending on the density of other species, and it is not necessarily a sustainable situation (Towns et al. 2006; but see Montevecchi and Tuck 1987, Hammer and Bond 2022). The St. Kilda field mouse (*Apodemus sylvaticus*), meadow vole (*Microtus pennsylvanicus*), American mink (*Neovison vison*), North American river otter (*Lontra canadensis*), and red fox (*Vulpes vulpes*) have been detected at Leach's Storm-Petrel colonies for

Fig. 2. Ranks of at-sea threats during the breeding season for Leach's Storm-Petrel (*Hydrobates leucorhous*) evaluated for extant colonies studied by the authors. Threats are presented for each ocean basin sector (top) and state/province/country (bottom).



various periods of time and are potential predators of eggs, nestlings, and/or adults (Skelpkovych and Montevecchi 1996, Bicknell et al. 2009, 2020, Hoeg et al. 2021). For example, over 900 Leach's Storm-Petrels were found in larders of red foxes over six years on Baccalieu Island, Newfoundland and Labrador, Canada, the species' largest colony, which is now free of these predators (Sklepkovych and Montevecchi 1996). Red foxes have recently been detected in some colonies in Quebec (J.-F. Rail, *personal observation*). In British Columbia, North American river otters (*Lontra canadensis*) have been implicated in declines of Leach's Storm-Petrels (Carter et al. 2012). In one breeding season, an American mink and North American river otter killed at least 700 adult Leach's Storm-Petrels at Country Island Nova Scotia, Canada (J. Rock, *personal communication*). Nova Scotia has the largest mink farming industry in Canada (Bowman et al. 2017). Mink are powerful swimmers, and a single mink, wild or escaped, arriving in a seabird colony can have devastating impacts because they engage in surplus killing (Roesler et al. 2012). In contrast, introduced predators usually occur because of some accidental or deliberate anthropogenic intervention and may have greater impacts on seabird colonies. Introduced mammalian predators are a major global problem at seabird colonies (Dias et al. 2019), and both prevention and early detection of introduced predators should be of high priority because costs associated with

Table 3. Weighted percent threat scores for each at-sea threat for Leach's Storm-Petrel (*Hydrobates leucorhous*) during the breeding and non-breeding season (number of survey participants who ranked each threat). Light: attraction to offshore lights. Threat with the highest score for each ocean basin is bolded.

	Light		Spatial shift in prey		Mercury		Pesticides and contaminants		Bycatch		Prey depletion[†]		Weather events[†]		Unknown	
At-sea threats during the breeding season																
West Pacific	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	**100.0**	**(2)**
East Pacific	**37.8**	**(8)**	20.7	(4)	9.8	(3)	17.1	(5)	8.5	(3)	0.0	(0)	0.0	(0)	6.1	(2)
West Atlantic	23.6	(19)	26.8	(18)	**24.6**	**(18)**	17.6	(17)	2.8	(8)	4.6	(3)	0.0	(0)	0.0	(0)
East Atlantic	6.9	(1)	**34.5**	**(2)**	10.3	(1)	13.8	(1)	0.0	(0)	0.0	(0)	17.2	(1)	17.2	(1)
Overall	**24.7**	**(28)**	25.4	(24)	20.0	(22)	16.8	(23)	3.7	(11)	3.2	(3)	1.2	(1)	5.0	(4)
At-sea threats during the non-breeding season																
West Pacific	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	**100.0**	**(2)**
East Pacific	**35.6**	**(7)**	23.7	(4)	10.5	(3)	10.5	(3)	9.2	(3)	0.0	(0)	0.0	(0)	10.5	(2)
West Atlantic	**27.4**	**(19)**	24.9	(18)	21.0	(17)	15.0	(16)	4.6	(8)	5.0	(4)	2.1	(2)	0.0	(0)
East Atlantic	5.9	(1)	**29.4**	**(2)**	8.8	(1)	11.8	(1)	0.0	(0)	14.7	(1)	14.7	(1)	14.7	(1)
Overall	**26.4**	**(27)**	24.4	(25)	17.5	(21)	13.5	(20)	5.0	(11)	4.7	(5)	2.8	(3)	5.7	(5)

[†]Threat added by survey participants

mammalian eradication are high (Samaniego-Herrera et al. 2013), and recovery of seabird colony ecosystems and seabird populations after mammal eradication can take decades (Drummond and Leonard 2010, Jones 2010; but see Jones et al. 2016).

Mammalian herbivores

The presence of mammalian herbivores is often the result of deliberate introduction by humans. Mammalian herbivores are a threat to Leach's Storm-Petrels through soil erosion and compaction, burrow destruction, and changes in vegetation composition and structure (Peterson et al. 2005). For example, in the western North Atlantic, the most commonly introduced species are snowshoe hares (*Lepus americanus*), historically introduced as food for island caretakers or as sources of pelts (Wheelwright 2016), and sheep (*Ovis* spp.), introduced for seasonal or year-round pasturing. White-tailed deer (*Odocoileus virginianus*) are not introduced in Nova Scotia but often swim to breeding colonies (I. Pollet, *personal observation*). Although they are herbivores, sheep and deer regularly consume eggs of ground-nesting birds and have been documented occasionally biting off legs, wings, or heads of young seabirds (Furness 1988). However, the presence of mammalian herbivores is a far lower mortality risk to storm-petrels than is the presence of mammalian predators.

Onshore light attraction and collisions

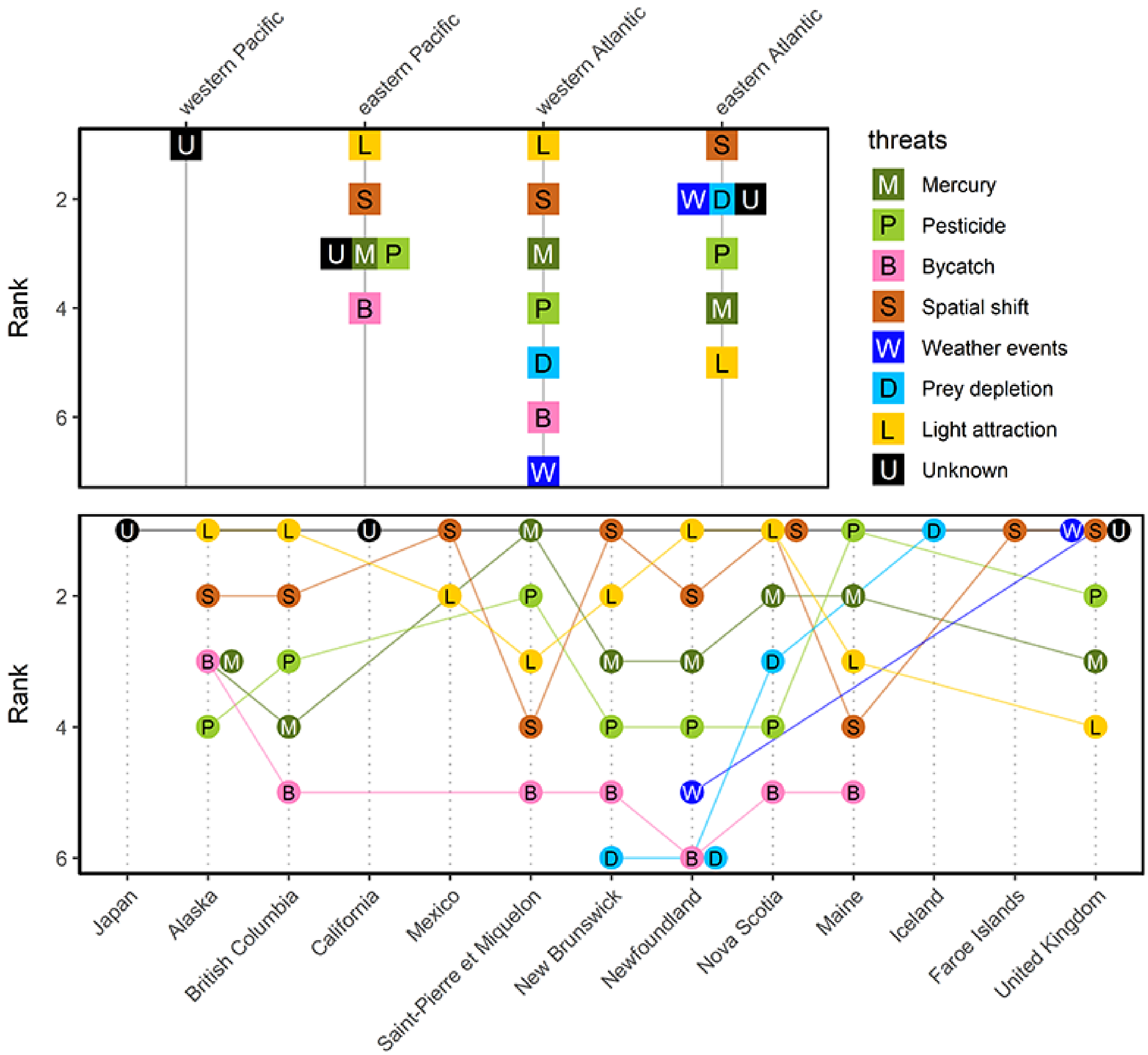
Leach's Storm-Petrels travel to and from their colonies at night, presumably to avoid diurnal predators, especially gulls (Watanuki 1986, Pollet et al. 2021). They likely use moonlight to visualize landscape cues, but it is not their only cue (Yoda et al. 2017, Wynn et al. 2020). Juveniles are especially attracted to light (Wilhelm et al. 2021, Burt 2022) and, when onshore, birds are susceptible to collisions with buildings and vehicles, more prone to predation, and can become disoriented and grounded (Troy et al. 2013, Rodríguez et al. 2015). Effects of this threat depend on the proximity of a colony to onshore light sources and the type, color, and direction of lights (Miles et al. 2010, Rodríguez et al. 2017, Syposz et al. 2021). More than 1900 stranded Leach's Storm-Petrels were found on the island of Newfoundland during autumn 2018 and 2019 (Wilhelm et al. 2021), but these onshore stranding events have not been monitored systematically (but see Burt 2022); therefore, the total impact of onshore strandings is not well known. From a conservation perspective, onshore light attraction is probably one of the easiest threats to mitigate and reduce. For example, people living on island communities are invited to turn off their lights during peak fledgling seasons of endemic seabirds (https://web.archive.org/web/20221019115210/https://www.lesjoursdelanuit.re/; https://web.archive.org/web/20221019115223/https://birdlifemalta.org/wp-content/uploads/2020/07/Guidelines-for-Ecologically-Responsible-Lighting.pdf), and Kaua'i (Hawai'i, USA) residents are encouraged to place stranded shearwaters in "Shearwater Aid Stations" for care and safe release (Telfer et al. 1987). Such measures could complement information campaigns to reduce stranding events and rescue stranded birds (Ainley et al. 2001, Le Corre et al. 2003, Wilhelm et al. 2021).

Disturbance

Recreational disturbance was considered a threat, and some survey respondents added researcher disturbance to the threat list. Effects of disturbance can be difficult to quantify. Nonetheless, visitors and people handling birds at colonies of burrow-nesting seabirds can negatively affect fledgling body mass, cause nestling mortality, or provoke nest abandonment by incubating or provisioning adults (Blackmer et al. 2004, Albores-Barajas et al. 2009, Watson et al. 2014). Active burrows can collapse from trampling. Some seabird colonies are difficult to access, which limits human disturbance, but some colonies, such as in the Faroe Islands, are situated near human settlements and experience seasonal influxes of tourists (A. Ausems, *personal observation*). Using paleo-ecological records, Duda et al. (2020) documented a severe decline in a North American colony once European settlers arrived in the area in the early 1800s, and the colony has yet to fully recover.

Recently, unmanned aerial vehicles (drones) have been used to limit disturbance from researchers surveying surface-nesting

Fig. 3. Ranks of at-sea threats during the non-breeding season for Leach's Storm-Petrel (*Hydrobates leucorhous*) evaluated for extant colonies studied by the authors. Threats are presented for each ocean basin sector (top) and state/province/country (bottom).



birds and even burrow-nesting birds when vegetation cover is minimal (Borrelle and Fletcher 2017, Albores-Barajas et al. 2018). Breeding status of burrow-nesting birds can be assessed with burrow-scopes (i.e., endoscopic cameras), but human presence is still required within colonies to operate them (Surman and Nicholson 2009). Researchers are attempting to reduce disturbance (trampling, repeated grubbing) in study plots where long-term monitoring of population demography occurs by developing remote methods such as Passive Integrated Transponders (PIT) tag burrow-monitoring technology (Zangmeister et al. 2009; D. Fifield, *personal communication*) and acoustic monitoring (Orben et al. 2019).

Offshore light attraction and collisions

Lights at offshore oil and gas platforms are responsible for seabird strandings or collisions at structures or incineration from contact with flames (Wiese et al. 2001, Montevecchi 2006, Ronconi et al. 2015; Davis et al. 2017). In Nova Scotia and Newfoundland and Labrador, Canada, offshore structures occur within the foraging ranges of major Leach's Storm-Petrel colonies (Hedd et al. 2018), and Leach's Storm-Petrels are by far the most numerous species reported stranded, with 6920 individuals reported between 1998 and 2018 (87% of all reported birds), which undoubtedly is an underestimate of the total numbers stranded (Gjerdrum et al. 2021). Leach's Storm-Petrels breeding at Gull Island, Newfoundland and Labrador, flew within the light catch-basin of an oil platform in 17.5% of trips, although they tended to transit rapidly past platforms during the day (when light attraction may be minimal), whereas exposure to oil platforms at night occurred in only 1.1% of trips but represents a very large number of individual trips considering the number trips each bird takes during a season (Collins et al. 2022).

Lighting at offshore operations is important for worker safety and for maritime and air navigation, so mitigation strategies must not increase human risks. In Canadian offshore industries, 76% of stranded storm-petrels are found alive (Gjerdrum et al. 2021), presenting opportunities for mitigation through search and release. In addition to offshore oil and gas platforms, offshore lights can also originate from emerging offshore wind facilities, vessels in transit or working offshore, as well as cruise and cargo ships. Squid-fishing fleets in particular use powerful lights to attract squid to the surface (Waluda et al. 2004), and the location and timing of squid-fishing season can coincide with either the breeding or the migration of storm-petrels (McIver et al. 2016). The extent and magnitude of strandings on vessels is largely unknown with respect to potential population-level impacts.

Spatial shifts in prey and climate change

Spatial shifts in seabird prey can be an indirect consequence of climate change. Changing environmental conditions, such as rising sea surface temperature, can induce a spatial shift of marine species because they gravitate to their preferred thermal preferences (Grémillet and Boulinier 2009, Kleisner et al. 2016). During marine heat waves, some Leach's Storm-Petrels can temporarily shift their feeding habits and forage on or near shore (D'Entremont et al. 2021). During breeding seasons, seabirds in general are central place foragers and thus limited in their foraging range by the necessity to return to their colony (Elliott et al. 2009). The foraging range of Leach's Storm-Petrels is 400–800 km depending on the colony (Hedd et al. 2018, Mauck et al. 2022), which is a great distance considering they only weigh ~45g. If preferred prey species shift outside of maximum viable foraging range, seabirds must switch to alternative prey species that might not provide sufficient nutrition or extend their foraging trips, with the associated energy expenditure potentially leading to breeding failure (Ponchon et al. 2014, Fayet et al. 2020). Some dietary shifts in Leach's Storm-Petrels have been observed at various timescales (Hedd et al. 2009, Fairhurst et al. 2015). Ecological impacts of these dietary shifts are not clear, though they may be related to decreases in breeding success (Mauck et al. 2018).

Some survey participants included prey depletion and climate change as additional threats, and it is difficult to differentiate spatial shifts in prey from prey depletion. Extreme weather events were not provided as a threat category in the survey but were added by several participants. Severe storms during the breeding season may flood burrows and drown or chill chicks. Moreover, the start of fall migration and the fledging of storm-petrel chicks coincides with the peak of the hurricane season in the Atlantic, and hurricanes and onshore winds may force storm-petrels onshore (Boyd 1954, Teixeira 1987, Wilhelm et al. 2021).

Mercury

Mercury is a globally distributed, toxic metal that, at sufficient concentrations, can have negative effects on neuroendocrine systems, lead to reduced reproductive success, and induce motor and behavioral problems (Wolfe et al. 1998, Scheuhammer et al. 2015, Evers 2018). In aquatic environments, mercury is transformed by bacteria into methylmercury (Lehnherr 2014). Methylmercury biomagnifies in food webs, and, during periods of stress or poor body condition, may be released from tissue reserves at concentrations that create physiological, physical, or behavioural problems (Fort et al. 2015). Storm-petrels, and Procellariiformes in general, have some of the highest tissue mercury levels among seabirds (Carravieri et al. 2014, Becker et al. 2016). Mercury exposure also varies spatially, and in the Gulf of Maine, Leach's Storm-Petrels have high mercury concentrations compared to other sympatric seabirds (Goodale et al. 2008, Bond and Diamond 2009). Mercury exposure in the western North Atlantic, particularly in deep offshore waters, appears to be high for some species, including Leach's Storm-Petrels (Goodale et al. 2008, Mallory et al. 2018; N. Burgess et al. 2019, *personal communication*) and Little Auks (*Alle alle*), another planktivore (Fort et al. 2014). Mercury has been considered a potential problem for Leach's Storm-Petrels for decades (Pearce et al. 1979, Elliott et al. 1992), but to date there is little evidence of deleterious effects (Pollet et al. 2017, submitted; Krug et al. 2021).

In recent years, reductions of mercury emissions in some regions (North America and the European Union) and industrial sectors (e.g., energy production) have been encouraging yet, in 2015, global emissions were still 20% higher than in 2010 (UN Environment Programme 2019). Increasing mercury emissions and legacy mercury already in soil, sediments, and aquatic systems will continue to produce methylmercury for millennia; therefore, monitoring concentrations in biota should continue.

Pesticides and other contaminants

This broad category could include hydrocarbons, trace elements, hydrophobic persistent organic pollutants, and plastics. Most of these substances are poorly studied in Leach's Storm-Petrels, but, in Atlantic Canada, Elliott et al. (1992) found high levels of selenium and cadmium in Leach's Storm-Petrels relative to other sympatric seabirds. However, the high levels of metallothionein that Leach's Storm-Petrels produce endogenously may enable them to limit effects of high tissue concentrations of heavy metals (Osborn 1978, Elliott et al. 1992). Organic compounds and organochlorines also vary spatially in concentration (Megson et al. 2014) and were at low concentrations in eggs of Fork-tailed Storm-Petrels (*Hydrobates furcata*) and Leach's Storm-Petrels in Alaska, with PCB concentrations below toxicity thresholds (D. D. Rudis and B. L. Slater 2009, *personal communication*). None of these contaminant studies evaluated toxicological effects of measured concentrations.

Like many seabird species, Leach's Storm-Petrels ingest plastic (Bond and Lavers 2013). Krug et al. (2021) found high frequencies of occurrence (87.5%) of plastic debris in recently fledged storm-petrels in Atlantic Canada, and when using emetics (which recover all plastic in the gastrointestinal tract), 48% of adults sampled at Gull Island, Newfoundland and Labrador had also ingested plastic (Bond and Lavers 2013). Leach's Storm-Petrels spend most of their time at sea in contact with the ocean surface, either to feed or rest. This makes them vulnerable to hydrocarbons discharged from vessels or offshore platforms and to more voluminous oil spills (Fraser et al. 2006, Wilhelm et al. 2007, Ellis et al. 2013, Morandin and O'Hara 2016).

Bycatch

The unintentional killing of seabirds in fishing gear (seabird bycatch), causes significant global mortality for medium-large tubenose species (such as albatrosses and shearwaters) and divers (e.g., alcids and diving ducks), killing hundreds of thousands of individuals per year (Anderson et al. 2011, Croxall et al. 2012, Zydelis et al. 2013, Montevecchi 2022), though bycatch appears rare for Leach's Storm-Petrels (Hedd et al. 2016, Jannot et al. 2021). Presumably this is related to their foraging mode and dietary preferences and a lack of strong attraction to vessels, fishing bait, or prey in nets.

KNOWLEDGE GAPS AND PRIORITIES FOR FUTURE RESEARCH

Survey participants agreed that predation and light attraction represent major population threats to Leach's Storm-Petrels across their breeding range, with perhaps less importance in the eastern North Atlantic. With relatively easy access to colonies by researchers or predators (compared to following birds at sea), documenting predation seems an obvious and useful task, and carcasses collected at colonies can provide clear evidence (Pollet and Shutler 2019, Hoeg et al. 2021). Because storm-petrels spend approximately 90% of their life at sea (Pollet et al. 2021), there is significant impetus for quantifying impacts of threats away from colonies. Offshore light attraction appears to be an important threat, but the combined ranking of climate change effects (the spatial shift and depletion in prey items and the weather events) would rank higher than light attraction in many jurisdictions. Low apparent adult annual survival and population declines at several colonies sharing the same wintering areas suggest that threats during the non-breeding season are highly important and are areas of active investigation.

Some participants were unable to identify at-sea threats, but that does not mean threats are not present, and, in the Pacific, more research is required to evaluate the population status and to identify threats faced by Leach's Storm-Petrels (Figs. 1 and 2). Threats at sea are more difficult to observe, and the effects of some threats may not be independent of other threats (e.g., Tartu et al. 2013). Increasingly, however, development of miniature tracking technology is enabling researchers to study at-sea distribution and foraging ranges (Pollet et al. 2014a, 2014b, 2019, Hedd et al. 2018) and to begin identifying threats to storm-petrels in pelagic environments (Collins et al. 2022). Studying Leach's Storm-Petrels during the non-breeding season would involve international collaboration because of the widespread distribution of the species during that time (Halpin et al. 2018, Pollet et al. 2019).

Differences in perceived threats in different jurisdictions and the agreement of survey participants within each jurisdiction but not within each basin (Tables A1.S3, A1.S4, and A1.S5) highlight the need to carefully tailor conservation measures in a context-dependent way. Terrestrial threats are probably colony-specific, and conservation measures implemented at a global scale might have different results depending on the colony.

In the western North Atlantic, tracking studies show little overlap in foraging areas for Leach's Storm-Petrels breeding at adjacent colonies (Hedd et al. 2018), so threats encountered at sea during the breeding season by birds from one colony might differ from those of a neighboring colony. The spatial distribution of risk varies in the seascape, and compared to other seabird species in eastern Canada, Leach's Storm-Petrels have high cumulative risks from threats, which include marine traffic, light pollution, and ship-source oil pollution (Lieske et al. 2020). During migration, birds from different colonies within the same ocean basin may follow similar routes, thereby being exposed to the same threats during this portion of their annual cycle (Pollet et al. 2019). Similarly, the degree of migratory connectivity in over-wintering areas may provide common, or divergent, exposure to risk at both the individual and colony levels (González-Solís et al. 2007, Frederiksen et al. 2012, 2016).

Seabirds have a diverse range of foraging strategies, body sizes, and diets. Thus, threats will affect each species or guild differently. For example, Lieske et al. (2019) concluded that Leach's Storm-Petrels had the highest species-specific risk score for sensitivity to light pollution in the western North Atlantic (i.e., most sensitive of all seabird species in the study). In contrast, in the same study, Leach's Storm-Petrels were ranked least sensitive to fisheries bycatch. Survey participants in the present study ranked offshore lights as the top offshore threat (Table 3). In our study, each threat was considered separately, but, of course, threats are not mutually exclusive and can have additive, synergistic, or antagonistic effects (Crain et al. 2008, Piggott et al. 2015, Dias et al. 2019, Lieske et al. 2020). For example, in a given breeding colony, Leach's Storm-Petrels could suffer from both predation and difficulties finding enough prey to feed their chicks.

The current assessment of spatial variation in threats affecting Leach's Storm-Petrels could be applied to some other storm-petrel species living sympatrically because they share many life-history traits. This includes European Storm-Petrels (*Hydrobates pelagicus)* in the eastern North Atlantic and Fork-tailed Storm-Petrels, Ashy Storm-Petrel (*H. homochroa*), and Least (*H. microsoma*) and Black Storm-Petrels (*H. melania*) in the Pacific (Carter et al. 2016, Halpin et al. 2018, Ausems et al. 2021, Bedolla-Guzmán et al. 2021). In cases where a conservation planning framework is developed to implement and monitor conservation initiatives, spatial variation in threats should be considered to direct conservation actions and biosecurity measures that are most relevant to a particular colony or population (Russell et al. 2008). In this way, cumulative threats can be mitigated on a case-by-case basis, contributing to an overall conservation strategy of cumulative actions that maximize positive benefits to the global Leach's Storm-Petrel population.

Author Contributions:

Conceptualization: ILP, MLM Data curation: ILP Formal Analysis: ILP Methodology: ILP, MLM Visualization: ILP, AKL Writing - original draft: ILP, MLM, ALB, LAMT, RAR Writing - review and editing: ILP, ANMA, CB, YBG, AMJB, MB, ALB, KD, AWD, DAF, CG, LRH, ESH, AH, RH, AKL, HLM, RAM, GTWM, LAMT, WAM, MP, IP, JFR, GJR, JR, RAR, DS, IJS, AT, YW, LJW, SIW, SNPW, MLM

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LITERATURE CITED

Ainley, D. G., R. Podolsky, L. Deforest, G. Spencer, and N. Nur. 2001. The status and population trends of the Newell's shearwater on Kaua'i: insights from modeling. Studies in Avian Biology 22:108-123.

Albores-Barajas, Y. V., C. Soldatini, and R. W. Furness. 2009. Are burrow nesting seabird chicks affected by human disturbance? Waterbirds 32:572-578. https://doi.org/10.1675/063.032.0410

Albores-Barajas, Y. V., C. Soldatini, A. Ramos-Rodríguez, J. E. Alcala-Santoyo, R. Carmona, and G. Dell'Omo. 2018. A new use of technology to solve an old problem: estimating the population size of a burrow nesting seabird. PLoS One 13:e0202094 https://doi.org/10.1371/journal.pone.0202094

Anderson, O. R. J., C. J. Small, J. P. Croxall, E. K. Dunn, B. J. Sullivan, O. Yates, and A. Black. 2011. Global seabird bycatch in longline fisheries. Endangered Species Research 14:91-106. https://doi.org/10.3354/esr00347

Ausems, A. N. M., G. Skrzypek, K. Wojczulanis-Jakubas, and D. Jakubas. 2021. Birds of a feather moult together: differences in moulting distribution of four species of storm-petrels. PLoS One 16:e0245756. https://doi.org/10.1371/journal.pone.0245756

Baker, G. B., R. Gales, S. Hamilton, and V. Wilkinson. 2002. Albatrosses and petrels in Australia: a review of their conservation and management. Emu 102:71-97. https://doi.org/10.1071/MU01036

Baud, A., J.-P. Jenny, P. Francus, and I. Gregory-Eaves. 2021. Global acceleration of lake sediment accumulation rates associated with recent human population growth and land-use changes. Journal of Paleolimnology 66:453-467 https://doi.org/10.1007/s10933-021-00217-6

Becker, P. H., V. Goutner, P. G. Ryan, and J. González-Solís. 2016. Feather mercury concentrations in Southern Ocean seabirds: variation by species, site and time. Environmental Pollution 216:253-263. https://doi.org/10.1016/j.envpol.2016.05.061

Bedolla-Guzmán, Y., J. F. Masello, A. Aguirre-Muñoz, B. E. Lavaniegos, C. C. Voigt, J. Gómez-Gutiérrez, L. Sánchez-Velasco, C. J. Robinson, and P. Quillfeldt. 2021. Year-round niche segregation of three sympatric *Hydrobates* storm-petrels from Baja California Peninsula, Mexico, Eastern Pacific. Marine Ecology Progress Series 664:207-225. https://doi.org/10.3354/meps13645

Bicknell, A. W., D. Oro, K. C. J. Camphuysen, and S. C. Votier. 2013. Potential consequences of discard reform for seabird communities. Journal of Applied Ecology 50:649-658. https://doi.org/10.1111/1365-2664.12072

Bicknell, A. W. J., B. W. Walker, T. Black, J. Newton, J. M. Pemberton, R. Luxmoore, R. Inger and S. C. Votier. 2020. Stable isotopes reveal the importance of seabirds and marine foods in the diet of St Kilda field mice. Scientific Reports 10:6088. https://doi.org/10.1038/s41598-020-62672-x

Bicknell, T. W. J, J. B. Reid, and S. C. Votier. 2009. Probable predation of Leach's Storm-Petrel *Oceanodroma leucorhoa* eggs by St Kilda field mice *Apodemus sylvaticus hirtensis*. Bird Study 56:419-422. https://doi.org/10.1080/00063650903216618

BirdLife International. 2018. *Hydrobates leucorhous*. The IUCN Red List of Threatened Species. BirdLife International. 2021. https://www.iucnredlist.org/search?query=Hydrobates%20leucorhous&searchType=species

BirdLife International 2021. European Red List of Birds. Office for Official Publications of the European Communities, Luxembourg, Luxembourg. https://www.birdlife.org/wp-content/uploads/2022/05/BirdLife-European-Red-List-of-Birds-2021.pdf.pdf

Blackmer, A. L., J. T. Ackerman, and G. A. Nevitt. 2004. Effects of investigator disturbance on hatching success and nest-site fidelity in a long-lived sea bird, Leach's storm-petrel. Biological Conservation 116:141-148. https://doi.org/10.1016/S0006-3207(03)00185-X

Bolton, M., A. Stanbury, A. M. M. Baylis, and R. Cuthbert. 2014. Impact of introduced house mice (*Mus musculus*) on burrowing seabirds on Steeple Jason and Grand Jason Islands, Falklands, South Atlantic. Polar Biology 37:1659-1668. https://doi.org/10.1007/s00300-014-1554-2

Bond, A., and A. W. Diamond. 2009. Mercury concentrations in seabird tissues from Machias Seal Island, New Brunswick, Canada. Science of the Total Environment 407:4340-4347 https://doi.org/10.1016/j.scitotenv.2009.04.018

Bond, A. L., and J. L. Lavers. 2013. Effectiveness of emetics to study ingestion by Leach's Storm-Petrels (*Oceanodroma leucorhoa*). Marine Pollution Bulletin 70:171-175. https://doi.org/10.1016/j.marpolbul.2013.02.030

Borrelle, S. B., P. H. Boersch-Supan, C. P. Gaskin, and D. R. Towns. 2018. Influence on recovery of seabirds on islands where invasive predators have been eradicated, with a focus on Procellariiformes. Oryx 52:346-358. https://doi.org/10.1017/S0030605316000880

Borrelle, S. B., and A. T. Fletcher. 2017. Will drones reduce investigator disturbance to surface-nesting birds? Marine Ornithology 45:89-94. http://www.marineornithology.org/PDF/45_1/45_1_89-94.pdf

Bourgeois, K., S. Dromzée, and E. Vidal. 2015. Are artificial burrows efficient conservation tools for seabirds? A case study of two sympatric shearwaters on neighbouring islands and guidelines for improvement. Biological Conservation 191:282-290. https://doi.org/10.1016/j.biocon.2015.07.002

Bowman, J., K. Beauclerc, A. H. Farid, H. Fenton, C. F. C. Klütsch, and A. I. Schulte-Hostedde. 2017. Hybridization of domestic mink with wild American mink (*Neovison vison*) in eastern Canada. Canadian Journal of Zoology 95:443-451. https://doi.org/10.1139/cjz-2016-0171

Boyd, H. 1954. The “wreck” of Leach’s petrels in the autumn of 1952. British Birds 5:137-163.

Bugoni, L., P. L. Mancini, D. S. Monteiro, L. Nascimento, and T. S. Neves. 2008. Seabird bycatch in the Brazilian pelagic longline fishery and a review of capture rates in the southwestern Atlantic Ocean. Endangered Species Research 5:137-147. https://doi.org/10.3354/esr00115.

Burt, T. V. 2022. Influence of anthropogenic light on the attraction and mortality of Leach’s Storm-Petrels. Where, when, why and which birds. Thesis, Memorial University of Newfoundland, St John’s, Newfoundland and Labrador, Canada.

Buxton, R. T., C. J. Jones, P. O. B. Lyver, D. R. Towns, and S. B. Borrelle. 2016. Deciding when to lend a helping hand: a decision-making framework for seabird island restoration. Biodiversity and Conservation 25:467-484. https://doi.org/10.1007/s10531-016-1079-9

Carravieri, A., Y. Cherel, P. Blévin, M. Brault-Favrou, O. Chastel, and P. Bustamante. 2014. Mercury exposure in a large subantarctic avian community. Environmental Pollution 190:51-57. https://doi.org/10.1016/j.envpol.2014.03.017

Carter, H. R., A. E. Burger, P. V. Clarkson, Y. Zharikov, M. S. Rodway, S. G. Sealy, R. W Campbell, and D. F. Hatler. 2012. Historical colony status and recent extirpations of burrow-nesting seabirds at Seabird Rocks, British Columbia. Wildlife Afield 9:13-48. http://www.wildlifebc.org/pdfs/9_1%20Seabird%20Rocks%20R.pdf

Carter, H. R., T. M. Dvorak, and D. L. Whitworth. 2016. Breeding of the Leach’s Storm-Petrel *Oceanodroma leucorhoa* at Santa Catalina Island, California. Marine Ornithology 44:83-92. http://www.marineornithology.org/PDF/44_1/44_1_83-92.pdf

Collins, S. M., A. Hedd, D. A. Fifield, D. R. Wilson, and W. A. Montevecchi. 2022. Foraging paths of breeding Leach’s Storm-petrels in relation to offshore oil platforms, breeding stage, and year. Frontiers in Marine Science 9:816659. https://doi.org/10.3389/fmars.2022.816659

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2020. COSEWIC assessment and status report on the Leach’s Storm-Petrel (Atlantic population) *Oceanodroma leucorhoa* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario, Canada. https://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Leach-s_Storm-Petrel_2020_e.pdf

Crain, C. M., K. Kroeker, K., and B. S. Halpern. 2008. Interactive and cumulative effects of multiple human stressors in marine systems. Ecology Letters 11:1304-1315. https://doi.org/10.1111/j.1461-0248.2008.01253.x

Croxall. J. P., S. H. M. Butchart, B. Lascelles, A. J. Stattersfield, B. Sullivan, A. Symes, and P. Taylor. 2012. Seabird conservation status, threats and priority actions: a global assessment. Bird Conservation International 22: 1-34. https://doi.org/10.1017/S0959270912000020

Davis, R. A, A. L. Land, and B. Mactavish. 2017. Study of seabird attraction to the Hebron Production Platform: a proposed study approach. LGL Limited Report, Hebron Project Exxon-Mobil, St. John’s, Newfoundland and Labrador, Canada. https://www.cnlopb.ca/wp-content/uploads/hebron/studyplan.pdf

Deakin, Z., E. S. Hansen, R. Luxmoore, R. J. Thomas, M. J. Wood, O. Padget, R. Medeiros, R. Aitchison, M. Ausden, R. Barnard, V. Booth, B. R. Hansen, E. A. Hansen, J. Hey, J. O. Hilmarsson, P. Hoyer, W. Kirby, A. Luxmoore, A-M. McDevitt, F. M. Meulemans, P. Moore, F. Sanderson, M. Sigursteinsson, P. R. Taylor, P. Thompson, D. Trotman, K. Wallisch, N. Wallisch, D. Watson, and M. Bolton. 2021. Decline of Leach’s storm petrels *Hydrobates leucorhous* at the largest colonies in the northeast Atlantic. Seabird 33:74-106. https://orca.cardiff.ac.uk/id/eprint/147465/1/seabird-33-74.pdf

D'Entremont, K. J. N., R. J. Blackmore, S. M. Collins, D. Brown, I. L. Jones, B. Mactavish, S. I. Wilhelm, and W. A. Montevecchi. 2021. On-land foraging by Leach’s Storm-petrels *Oceanodroma leucorhoa* coincides with anomalous weather conditions. Marine Ornithology 49:247-252. http://www.marineornithology.org/PDF/49_2/49_2_247-252.pdf

D'Entremont, K. J. N., L. Minich Zitxke, A. J. Gladwell, N. K. Elliott, R. A. Mauck, and R. A. Ronconi. 2020. Breeding population decline and associations with nest site use of Leach’s Storm-Petrels on Kent Island, New Brunswick from 2001 to 2018. Avian Conservation and Ecology 15(1):11. https://doi.org/10.5751/ACE-01526-150111

De León, A., E. Mínguez, P. Harvey, E. Meek, J. E. Crane, and R. W. Furness. 2006. Factors affecting breeding distribution of storm-petrels *Hydrobates pelagicus* in Orkney and Shetland. Bird Study 53:64-72. https://doi.org/10.1080/00063650609461417

Dias, M. P., R. Martin, E. J. Pearmain, I. J. Burfield, C. Small, R. A. Phillips, O. Yates, B., Lascelles, P. G. Borboroglu, and J. P. Croxall. 2019. Threats to seabirds: a global assessment. Biological Conservation 237:525-537. https://doi.org/10.1016/j.biocon.2019.06.033

Drummond, B. A., and M. L. Leonard. 2010. Reproductive consequences of nest site use in fork-tailed storm-petrels in the Aleutian Islands, Alaska: potential lasting effects of an introduced predator. Avian Conservation and Ecology 5(2):4. https://doi.org/10.5751/ACE-00414-050204

Duda, M. P., S. Allen-Mahé, C. Barbraud, J. M. Blais, A. Boudreau, R. Bryant, K. Delord, C. Grooms, L. E. Kimpe, B. Letournel, J. E. Lim, H. Lormée, N. Michelutti, G. J. Robertson, F. Urtizbéréa, S. I. Wilhelm, and J. P. Smol. 2020. Linking 19th century European settlement to the disruption of a seabird’s natural population dynamics. Proceedings of the National Academy of Sciences of the United States of America 117:32484-32492. https://doi.org/10.1073/pnas.2016811117

Elliott, J. E., A. M. Scheuhammer, F. A. Leighton, and P. A. Pearce. 1992. Heavy metals and metallothionein concentrations in Atlantic Canadian seabirds. Archives of Environmental Contamination and Toxicology 22:63-73. https://doi.org/10.1007/BF00213303

Elliott, K. H., K. J. Woo, A. J. Gaston, S. Benvenuti, L. DallAntonia, and G. K. Davoren. 2009. Central-place foraging in an Arctic seabird provides evidence for Storer-Ashmole’s halo. Auk 126:613-625. https://doi.org/10.1525/auk.2009.08245

Ellis J., S. I. Wilhelm, A. Hedd, G. S. Fraser, G. J. Robertson, J.-F. Rail, M. Fowler, and K. H. Morgan. 2013. Mortality of migratory birds from marine commercial fisheries and offshore oil and gas production in Canada. Avian Conservation and Ecology 8(2):4 http://dx.doi.org/10.5751/ACE-00589-080204

Evers, D. 2018. The effects of methylmercury on wildlife: a comprehensive review and approach for interpretation. Pages 181-194 in D. A. DellaSala, and M. I. Goldstein, editors. Encyclopedia of the Anthropocene, volume 5. Elsevier, Oxford, UK.

Fairhurst, G. D., A. L. Bond, K. A. Hobson, and R. A. Ronconi. 2015. Feather-based measures of stable-isotopes and corticosterone reveal a relationship between trophic position and physiology in a pelagic seabird over a 153-year period. Ibis 157:273-283. https://doi.org/10.1111/ibi.12232

Fayet, A. L., G. V. Clucas, T. Anker-Nilssen, M. Syposz, and E. S. Hansen. 2020. Local prey shortages drive foraging costs and breeding success in a declining seabird, the Atlantic puffin. Journal of Animal Ecology 90:1152-1164 https://doi.org/10.1111/1365-2656.13442

Fife, D. T., I. L. Pollet, G. J. Robertson, M. L. Mallory, and D. Shutler. 2015. Apparent survival of adult Leach's Storm-petrels (*Oceanodroma leucorhoa*) breeding on Bon Portage Island, Nova Scotia. Avian Conservation and Ecology 10(2):1. http://dx.doi.org/10.5751/ACE-00771-100201

Fort, J., T. Lacoue-Labarthe, H. L. Nguyen, A. Boué, J. Spitz, and P. Bustamante. 2015. Mercury in wintering seabirds, an aggravating factor to winter wrecks? Science of the Total Environment 527:448-454. https://doi.org/10.1016/j.scitotenv.2015.05.018

Fort, J., G. J. Robertson, D. Grémillet, G. Traisne, and P. Bustamante. 2014. Spatial ecotoxicology: migratory Arctic seabirds are exposed to mercury contamination while overwintering in the northwest Atlantic. Environmental Science and Technology 48:11560-11567. https://doi.org/10.1021/es504045g

Fraser G. S., J. Russell, and W. M. Von Zharen. 2006. Produced water from offshore oil and gas installations on the Grand Banks, Newfoundland and Labrador: are the potential effects of seabirds sufficiently known? Marine Ornithology 34:147-156. https://sora.unm.edu/sites/default/files/MO_34_2_147-156.pdf

Frederiksen, M., S. Descamps, K. E. Erikstad, A. J. Gaston, H. G. Gilchrist, D. Grémillet, K. L. Johansen, Y. Kolbeinsson, J. F. Linnebjerg, M. L. Mallory, L. McFarlane Tranquilla, F. R. Merkel, W. A. Montevecchi, A. Mosbech, T. K. Reiertsen, G. J. Robertson, H. Steen, H. Strøm, and T. L. Thórarinsson. 2016. Migration and wintering of a declining seabird, the thick-billed murre *Uria lomvia*, on an ocean basin scale: conservation implications. Biological Conservation 200:26-35. https://doi.org/10.1016/j.biocon.2016.05.011

Frederiksen, M., B. Moe, F. Daunt, R. A. Phillips, R. T. Barrett, M. I. Bogdanova, T. Boulinier, J. W. Chardine, O. Chastel, L. S. Chivers, S. Christensen-Dalsgaard, C. Clément-Chastel, K. Colhoun, R. Freeman, A. J. Gaston, J. González-Solís, A. Goutte, D. Grémillet, T. Guilford, G. H. Jensen, Y. Krasnov, S-H. Lorentsen, M. L. Mallory, M. Newell, B. Olsen, D. Shaw, H. Steen, H. Strøm, G. H. Systad, T. L. Thórarinsson, and T. Anker-Nilsen. 2012. Multicolony tracking reveals the winter distribution of a pelagic seabird on an ocean basin scale. Diversity and Distributions 18:530-542. https://doi.org/10.1111/j.1472-4642.2011.00864.x

Fuentes, M. M. P. B., L. Chambers, A. Chin, P. Dann, K. Dobbs, H. Marsh, E. S. Poloczanska, K. Maison, M. Turner, and R. L. Pressey. 2014. Adaptive management of marine mega-fauna in a changing climate. Mitigation and Adaptation Strategies for Global Change. 21:209-224. https://doi.org/10.1007/s11027-014-9590-3

Furness, R. W. 1988. Predation on ground-nesting seabirds by island populations of red deer *Cervus elaphus* and sheep *Ovis*. Journal of Zoology 216:566-573. https://doi.org/10.1111/j.1469-7998.1988.tb02451.x

Gjerdrum, C., R. A. Ronconi, K. L. Turner, and T. E. Hamer. 2021. Bird strandings and bright lights at coastal and offshore industrial sites in Atlantic Canada. Avian Conservation and Ecology 16(1):22 https://doi.org/10.5751/ACE-01860-160122

Goodale, M. W., D. C. Evers, S. E. Mierzykowski, A. L. Bond, N. M. Burgess, C. I. Otorwoski, L. J. Welch, S. Hall, J. C. Ellis, R. B. Allen, A. W. Diamond, S. W. Kress, and R. J. Taylor. 2008. Maine foraging birds as bioindicators of mercury in the Gulf of Maine. EcoHealth 5:409-425. https://doi.org/10.1007/s10393-009-0211-7

Grémillet, D., and T. Boulinier. 2009. Spatial ecology and conservation of seabirds facing global climate change: a review. Marine Ecology Progress Series 391:121-137. https://www.jstor.org/stable/24873660

Halpern, B. S., M. Frazier, J. Afflerbach, J. S. Lowndes, F. Micheli, C. O'Hara, C. Scarborough, and K. A. Selkoe. 2019. Recent pace of change in human impact on the world's ocean. Scientific Reports 9:11609 https://doi.org/10.1038/s41598-019-47201-9

Halpern, B. S., S. Walbridge, K. A. Selkoe, C. V. Kappel. F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert, H. E. Fox, R. Fujita, D. Heinemann, H. S. Lenehian, E. M. P. Madin, M. T. Perry, E. R. Selig, M. Spalding, R. Steneck, and R. Watson. 2008. A global map of human impact on marine ecosystems. Science 319:948-952. https://doi.org/10.1126/science.1149345

Halpin, L. R., I. L. Pollet, C. Lee, K. H. Morgan, and H. R. Carter. 2018. Year-round movements of sympatric Fork-tailed (*Oceanodroma furcata*) and Leach's (*O. leucorhoa*) storm-petrels. Journal of Field Ornithology 89:207-220. https://doi.org/10.1111/jofo.12255

Hammer, S., and A. L. Bond. 2022. Do the 'viking mice' threaten the storm petrels on Nólsoy? Pages 76-79 in J.-K. Jensen and J. Thomsen, editors. The Faroe Islands' European Storm Petrel. Forlagið í Støplum, Reykjavík, Iceland.

Hedd, A., W. A. Montevecchi, G. K. Davoren, and D. A. Fifield. 2009. Diets and distributions of Leach's storm-petrel (*Oceanodroma leucorhoa*) before and after an ecosystem shift in the northwest Atlantic. Canadian Journal of Zoology 87:787-801. https://doi.org/10.1139/Z09-060

Hedd, A., I. L. Pollet, R. A. Mauck, C. M. Burke, M. L. Mallory, L. A. McFarlane Tranquilla, W. A. Montevecchi, G. J. Robertson, R. A. Ronconi, D. Shutler, S. I. Wilhelm, and N. M. Burgess. 2018.

Foraging areas, offshore habitat use, and colony overlap by incubating Leach's Storm-petrels *Oceanodroma leucorhoa* in the Northwest Atlantic. PLoS One 13:e0194389. https://doi.org/10.1371/journal.pone.0194389

Hedd, A., P. M. Regular, S. I. Wilhelm, J.-F. Rail, B. Drolet, M. Fowler, C. Pekarik, and G. J. Robertson. 2016. Characterization of seabird bycatch in eastern Canadian waters, 1998-2011, assessed from onboard fisheries observer data. Aquatic Conservation: Marine and Freshwater Ecosystems 26(3):530-548. https://doi.org/10.1002/aqc.2551

Hervías, S., A. Henriques, N. Oliveira, T. Pipa, H. Cowen, J. A. Ramos, M. Nogales, P. Geraldes, C. Silva, R. Ruiz de Ybáñez, and S. Oppel. 2013. Studying the effects of multiple invasive mammals on Cory's shearwater nest survival. Biological Invasions 15:143-155. https://doi.org/10.1007/s10530-012-0274-1

Hey, J., E. S. Hansen, and M. Bolton. 2019. Gull predation on Leach's *Hydrobates leucorhous* and European Storm-petrels *H. pelagicus* on Elliðaey Island, Iceland. Seabirds 32:59-71. http://www.seabirdgroup.org.uk/seabird-32-59

Hoeg, R., D. Shutler, and I. L. Pollet. 2021. Levels of predation at two Leach's Storm Petrel *Hydrobates leucorhous* breeding colonies. Marine Ornithology 49:119-125. http://www.marineornithology.org/PDF/49_1/49_1_119-125.pdf

Insley, H., M. Hounsome, P. Mayhew, and S. Elliott. 2014. Mark-recapture and playback surveys reveal a steep decline of European Storm Petrels *Hydrobates pelagicus* at the largest colony in western Scotland. Ringing & Migration 29:29-36. https://doi.org/10.1080/03078698.2014.936230

Jannot, J. E., A. Wuest, T. P. Good, K. A. Somers, V. J. Tuttle, K. E. Richerson, R. S. Shama, and J. T. McVeigh. 2021. Seabird bycatch in U.S. West Coast fisheries, 2002-18. Northwest Fisheries Science Center, NOAA technical memorandum NMFSC-165, Washington, D.C., USA. https://doi.org/10.25923/78vk-v149

Jiménez, S., A. Domingo, M. Abreu, A. Brazeiro. 2011. Structure of the seabird assemblage associated with pelagic longline vessels in the southwestern Atlantic: implications for bycatch. Endangered Species Research 15:241-254. https://doi.org/10.3354/esr00378

Jones, H. P. 2010. Seabird islands take mere decades to recover following rat eradication. Ecological Applications 20:2075-2080. https://doi.org/10.1890/10-0118.1

Jones, H. P., N. D. Holmes, S. H. M. Butchart, B. R. Tershy, P. J. Kappes, I. Corkery, A. Aguirre-Muñoz, D. P. Armstrong, E. Bonnaud, A. A. Burbidge, K. Campbell, F. Courchamp, P. E. Cowan, R. J. Cuthbert, S. E. Ebbert, P. Genovesi, G. R. Howald, B. S. Keitt, S. W. Kress, C. M. Miskelly, S. Oppel, S. Poncet, M. J. Rauzon, G. Rocamora, J. C. Russell, A. Samaniego-Herrera, P. J. Seddon, D. R. Spatz, D. R. Towns, and D. A. Croll. 2016. Invasive mammal eradication on islands results in substantial conservation gains. Proceedings of the National Academy of Sciences of the United States of America 113:4033-4038. https://doi.org/10.1073/pnas.1521179113

Jones, H. P., B. R. Tershy, E. S. Zavaleta, D. A. Croll, B. S. Keitt, M. E. Finkelstein, and G. R. Howald. 2008. Severity of the effects of invasive rats on seabirds: a global review. Conservation Biology 22: 16-26. https://doi.org/10.1111/j.1523-1739.2007.00859.x

Kleisner, K. M., M. J. Fogarty, S. McGee, A. Barnett, P. Fratantoni, J. Greene, J. A. Hare, S. M. Lucey, C. McGuire, J. Odell, V. S. Saba, L. Smith, K. J. Weaver, and M. L. Pinsky. 2016. The effects of sub-regional climate velocity on the distribution and spatial extents of marine species assemblages. PLoS One 11: e0149220 https://doi.org/10.1371/journal.pone.0149220

Krug, D. M., R. Frith, S. N. P. Wong, R. A. Ronconi, S. I. Wilhelm, N. J. O'Driscoll, and M. L. Mallory. 2021. Marine pollution in fledged Leach's storm-petrels (*Hydrobates leucorhous*) from Baccalieu Island, Newfoundland and Labrador, Canada. Marine Pollution Bulletin 162:111842. https://doi.org/10.1016/j.marpolbul.2020.111842

Le Corre, M., T. Ghestemme, M. Salamolard, and F.-X. Couzi. 2003. Rescue of the Mascarene Petrel, a critically endangered seabird of Réunion Island, Indian Ocean. Condor 105:387-391. https://doi.org/10.1093/condor/105.2.387

Lehnherr, I. 2014. Methylmercury biochemistry: a review with special reference to Arctic aquatic ecosystems. Environmental Reviews 22:229-243 https://doi.org/10.1139/er-2013-0059

Libois, E., O. Gimenez, D. Oro, E. Mínguez, R. Pradel, and A. Sanz-Aguilar. 2012. Nest boxes: a successful management tool for the conservation of an endangered seabird. Biological Conservation 155:39-43. https://doi.org/10.1016/j.biocon.2012.05.020

Lieske, D. J., L. McFarlane Tranquilla, R. Ronconi, and S. Abbott. 2019. Synthesizing expert opinion to assess the at-sea risks to seabirds in the western North Atlantic. Biological Conservation 233:41-50. https://doi.org/10.1016/j.biocon.2019.02.026

Lieske, D. J., L. McFarlane Tranquilla, R. A. Ronconi, and S. Abbott. 2020. "Seas of risk": assessing the threats to colonial-nesting seabirds in Eastern Canada. Marine Policy 115:103863. https://doi.org/10.1016/j.marpol.2020.103863

Lormee, H., K. Delord, B. Letournel, and C. Barbraud. 2012. Population survey of Leach's Storm-petrels breeding at Grand Colombier Island, Saint-Pierre and Miquelon Archipelago. Wilson Journal of Ornithology 124:245-252. https://doi.org/10.1676/11-084.1

Mallory, M. L., J. F. Provencher, G. J. Robertson, B. M. Braune, E. R. Holland, S. Klapstein, K. Stevens, and N. J. O'Driscoll. 2018. Mercury concentrations in blood, brain and muscle tissues of coastal and pelagic birds from northeastern Canada. Ecotoxicology and Environmental Safety 157:424-430. https://doi.org/10.1016/j.ecoenv.2018.04.004

Marques, A., I. S. Martins, T. Kastner, C. Plutzar, M. C. Theurl, N. Eisenmenger, M. A. Huijbregts, R. Wood, K. Stadler, M. Bruckner, and J. Canelas. 2019. Increasing impacts of land use on biodiversity and carbon sequestration driven by population and economic growth. Nature Ecology and Evolution 3:628-637. https://doi.org/10.1038/s41559-019-0824-3

Massaro, M., J. W. Chardine, I.L. Jones, and G. J. Robertson. 2000. Delayed capelin (*Mallotus villosus*) availability influences predatory behaviour of large gulls on black-legged kittiwakes

(*Rissa tridactyla*), causing a reduction in kittiwake breeding success. Canadian Journal of Zoology 78:1588-1596. https://doi.org/10.1139/z00-085

Mauck, R. A., D. C. Dearborn, and C. E. Huntington. 2018. Annual global mean temperature explains reproductive success in a marine vertebrate from 1955 to 2010. Global Change Biology 24:1599-1613. https://doi.org/10.1111/gcb.13982

Mauck, R. A., I. Pratte, A. Hedd, I. L. Pollet, P. L. Jones, W. Montevecchi, R. A. Ronconi, C. Gjerdrum, S. Adrianowyscz, C. McMahon, H. Acker, L. U. Taylor, J. McMahon, D. C. Dearborn, G. J. Robertson, and L. A. McFarlane Tranquilla. 2022. Female and male Leach's Storm Petrel (*Hydrobates leucorhous*) pursue different foraging strategies during the incubation period. Ibis 165:161-178. https://doi.org/10.1111/ibi.13112

McClelland, G. T. W., I. L. Jones, J. L. Lavers, and F. Sato. 2008. Breeding biology of Tristram's storm-petrels *Oceanodroma tristrami* at French Frigate Shoals and Laysan Island, Northwest Hawaiian Islands. Marine Ornithology 36:175-181. https://sora.unm.edu/sites/default/files/MO_36_2_175-181.pdf

McIver, W. R., H. R. Carter, A. L. Harvey, D. M. Mazurkiewicz, and J. W. Mason. 2016. Use of social attraction to restore Ashy Storm-Petrels *Oceanodroma homochroa* at Orizaba Rock, Santa Cruz Island, California. Marine Ornithology 44:99-112. https://sora.unm.edu/sites/default/files/44_1_99-112.pdf

Megson, D., T. A. Brown, G. W. Johnson, G. O'Sullivan, A. W. J. Bicknell, S. C. Votier, M. C. Lohan, S. Comber, R. Kalin, and P. J. Worsfold. 2014. Identifying the provenance of Leach's storm petrels in the North Atlantic using polychlorinated signatures derived from comprehensive two-dimensional gas chromatography with time-of-flight mass spectrometry. Chemosphere 114:195-202. https://doi.org/10.1016/j.chemosphere.2014.04.061

Miles, W., S. Money, R. Luxmoore, and R. W. Furness. 2010. Effects of artificial lights and moonlight on petrels at St Kilda. Bird Study 57:244-251. https://doi.org/10.1080/00063651003605064

Montevecchi, W. A., 2023. Interactions between fisheries and seabirds: prey modification, discards and bycatch. Pages 57-95 in L. Young and E. Vander Werf, editors. Conservation of Marine Birds. Elsevior, Amsterdam, Netherlands

Montevecchi, W. A. 2006. Influences of artificial light on marine birds. Pages 94-113 in C. Rich and T. Longcore, editors. Ecological consequences of artificial night lighting. IslandPress, Washington, D.C., USA. https://www.dfo-mpo.gc.ca/oceans/documents/conservation/advisorypanel-comiteconseil/submissions-soumises/Influences-of-Artificial-Light-on-Marine-Birds.pdf

Montevecchi, W. A., and L. M. Tuck. 1987. Newfoundland birds: exploitation, study, conservation. Nuttall Ornithological Club, Harvard University, Cambridge, Massachusetts, USA.

Morandin, L. A., and P. D. O'Hara. 2016. Offshore oil and gas, and operational sheen occurrence:Is there potential harm to marine birds? Environmental Reviews 24:1-34. https://dor.org/10.1139/er-2015-0086.

Olivier, F., and S. J. Wotherspoon. 2006. Distribution and abundance of Wilson's storm-petrels *Oceanites oceanicus* at two locations in East Antarctica: testing habitat selection mode. Polar Biology 29:878-892. https://doi.org/10.1007/s00300-006-0127-4

Orben, R. A., A. B. Fleishman, A. L. Borker, W. Bridgeland, A. J. Gladics, J. Porquez, P. Sanzenbacher, S. W. Stephensen, R. Swift, M. W. McKown, and R. M. Suryan. 2019. Comparing imaging, acoustics, and radar to monitor Leach's storm-petrel colonies. PeerJ 7:e6721 https://doi.org/10.7717/peerj.6721

Osborn, D. 1978. A naturally occurring cadmium and zinc binding protein from the liver and kidney of *Fulmarus glacialis*, a pelagic North Atlantic seabird. Biochemical Pharmacology 27:822-824. https://doi.org/10.1016/0006-2952(78)90535-x

Paleczny, M., E. Hammill, V. Karpouzi, and D. Pauly. 2015. Population trend of the world's monitored seabirds, 1950-2010. PLoS One 10:e0129342. https://doi.org/10.1371/journal.pone.0129342

Pearce, P. A., D. B. Peakall, and L. M. Reynolds. 1979. Shell thinning and residues of organochlorines and mercury in seabirds' eggs, Eastern Canada, 1970–76. Pesticides Monitoring Journal 13:61-68.

Peterson, T. S., A. Uesugi, and J. Lichter. 2005. Tree recruitment limitation by introduced snowshoe hares, *Lepus americanus*, on Kent Island, New Brunswick. Canadian Field-Naturalist 119:569:572. https://doi.org/10.22621/cfn.v119i4.189

Phillips, R. A., R. Gales, G. B. Baker, M. C. Double, M. Favero, F. Quintana, M. L. Tasker, H. Weimerskirch, M. Uhart, and A. Wolfaardt. 2016. The conservation status and priorities for albatrosses and large petrels. Biological Conservation 201:169-183. https://doi.org/10.1016/j.biocon.2016.06.017

Pierotti, R., and C. A. Annett. 1991. Diet choice in the herring gull: constraints imposed by reproductive and ecological factors. Ecology 72:319-328. https://doi.org/10.2307/1938925

Piggott, J. J., C. R. Townsend, and C. D. Matthaei. 2015. Reconceptualizing synergism and antagonism among multiple stressors. Ecology and Evolution 5:1538-1547. https://doi.org/10.1002/ece3.1465

Pollet, I. L., A. L. Bond, A. Hedd, C. E. Huntington, R. G. Butler, and R. Mauck. 2021. Leach's Storm-Petrel (*Hydrobates leucorhous*), version 1.1. In Birds of the World. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bow.lcspet.01.1

Pollet, I. L., A. Hedd, P. D. Taylor, W. A. Montevecchi, and D. Shutler. 2014a. Migratory movements and wintering areas of Leach's Storm-petrels tracked using geolocators. Journal of Field Ornithology 85:322-329. https://www.jstor.org/stable/24617813

Pollet, I. L., M. L. Leonard, N. J. O'Driscoll, N. M. Burgess, and D. Shutler. 2017. Relationship between blood mercury levels, reproduction, and return rate in a small seabird. Ecotoxicology 26:97-103. https://doi.org/10.1007/s10646-016-1745-4

Pollet, I. L., L. McFarlane Tranquilla, N. M. Burgess, A. W. Diamond, C. Gjerdrum, A. Hedd, R. Hoeg, P. L. Jones, R. A. Mauck, W. A. Montevecchi, I. Pratte, R. A. Ronconi, D. Shutler, S. I. Wilhelm, and M. L. Mallory. 2023. Factors influencing mercury levels in Leach's Storm-petrels at northwest Atlantic colonies. Science of the Total Environment 860:160464. https://doi.org/10.1016/j.scitotenv.2022.160464

Pollet, I. L., R. A. Ronconi, I. D. Jonsen, M. L. Leonard, P. D. Taylor, and D. Shutler. 2014b. Foraging movements of Leach's storm-petrels *Oceanodroma leucorhoa* during incubation. Journal of Avian Biology 45:305-314. https://doi.org/10.1111/jav.00361

Pollet, I. L, R. A. Ronconi, M. L. Leonard, and D. Shutler. 2019. Migration routes and stopover areas of Leach's Storm-petrels *Oceanodroma leucorhoa*. Marine Ornithology 47:55-65. http://www.marineornithology.org/PDF/47_1/47_1_55-65.pdf

Pollet, I. L., and D. Shutler. 2018. Leach's Storm Petrel *Oceanodroma leucorhoa* population trends on Bon Portage Island, Canada. Seabirds 31:75-83. http://www.seabirdgroup.org.uk/journals/seabird-31/seabird-31-75.pdf

Pollet, I. L, and D. Shutler. 2019. Effects of Great horned owls (*Bubo virginianus)* on a Leach's Storm-Petrel (*Oceanodroma leucorhoa*) population. Wilson Journal of Ornithology 131:152-155. https://doi.org/10.1676/18-13

Ponchon, A., D. Grémillet, S. Christensen-Dalsgaard, K. E. Erikstad, R. T. Barrett, T. K. Reiertsen, K. D. McCoy, T. Tveraa, and T. Boulinier. 2014. When things go wrong: inter-season dynamics of breeding failure in a seabird. Ecosphere 5:1-19. https://doi.org/10.1890/ES13-00233.1

Pott, C., and D. A. Wiedenfeld. 2017. Information gaps limit our understanding of seabird bycatch in global fisheries. Biological Conservation 210:192-204. https://doi.org/10.1016/j.biocon.2017.04.002

Rayner, M. J., M. E. Hauber, M. J. Imber, R. K. Stamp, and M. N. Clout. 2007. Spatial heterogeneity of mesopredator release within an oceanic island system. Proceedings of the National Academy of Science of the USA. 104:20862-20865. https://doi.org/10.1073/pnas.0707414105

Regular, P. M., W. A. Montevecchi, A. Hedd, G. J. Robertson, and S. I. Wilhelm. 2013. Canadian fishery closures provide a large-scale test of gillnet bycatch on seabird populations. Biology Letters 9:20130088. https://doi.org/10.1098%2Frsbl.2013.0088

Rennie, I. R. F., D. J. Green, E. A. Krebs, and A. Harfenist. 2020. High apparent survival of adult Leach's Storm-petrels *Oceanodroma leucorhoa* in British Colombia. Marine Ornithology 48:133-140. https://www.sfu.ca/biology/wildberg/NewCWEPage/papers/RennieetalMarOrn2020.pdf

Rodríguez, A., J. M. Arcos, V. Bretagnolle, M. P. Dias, N. D. Holmes, M. Louzao, J. Provencher, A. F. Raine, F. Ramírez, B. Rodríguez, R. A. Ronconi, R. S. Taylor, E. Bonnaud, S. B. Borrelle, V. Cortés, S. Descamps, V. L. Friesen, M. Genovart, A. Hedd, P. Hodum, G. R. W. Humphries, M. Le Corre, C. Lebarbenchon, R. Martin, E. F. Melvin, W. A. Montevechhi, P. Pinet, I. L. Pollet, R. Ramos, J. C. Russell, P. G. Ryan, A. Sanz-Aguilar, D. R. Spatz, M. Travers, S. C. Votier, R. M. Wanless, E. Woehler, and A. Chiaradia. 2019. Future directions in conservation research on petrels and shearwaters. Frontiers in Marine Science 6:94. https://doi.org/10.3389/fmars.2019.00094

Rodríguez, A., P. Dann, and A. Chiaradia. 2017. Reducing light-induced mortality of seabirds: high pressure sodium lights decrease the fatal attraction of shearwaters. Journal for Nature Conservation 39:68-72. https://doi.org/10.1016/j.jnc.2017.07.001

Rodríguez, A., D. García, B. Rodríguez, E. Cardona, L. Parpal, and P. Pons. 2015. Artificial lights and seabirds: is light pollution a threat for the threatened Balearic petrels? Journal of Ornithology 156:893-902. https://doi.org/10.1007/s10336-015-1232-3

Roesler, I., S. Imberti, H. Casañas, and N. Volpe. 2012. A new threat for the globally endangered hooded grebe *Podiceps gallardoi*: the American mink *Neovison vison*. Bird Conservation International 22:383-388. https://doi.org/10.1017/S0959270912000019

Ronconi, R. A., K. A. Allard, and P. D. Taylor. 2015. Bird interactions with offshore oil and gas platforms: review of impacts and monitoring techniques. Journal of Environmental Management 147:34-45. https://doi.org/10.1016/j.jenvman.2014.07.031

Russell, J. C., B. M. Beaven, J. W. B. MacKay, D. R. Towns, and M. N. Clout. 2008. Testing island biosecurity systems for invasive rats. Wildlife Research 35:215-221. https://doi.org/10.1071/WR07032

Samaniego-Herrera, A., D. P. Anderson, J. P. Parkes, and A. Aguirre-Muñoz. 2013. Rapid assessment of rat eradication after aerial baiting. Journal of Applied Ecology 50:1415-1421. https://doi.org/10.1111/1365-2664.12147

Sanz-Aguilar, A., A. Martínez-Abraín, G. Tavecchia, E. Mínguez, and D. Oro. 2009. Evidence-based culling of a facultative predator: efficacy and efficiency components. Biological Conservation 142:424-431. https://doi.org/10.1016/j.biocon.2008.11.004

Scheuhammer, A., B. Braune, H. M. Chan, H. Frouin, A. Krey, R. Letcher, L. Loseto, M. Noël, S. Ostertag, P. Ross, and M. Wayland. 2015. Recent progress on our understanding of the biological effects of mercury in fish and wildlife in the Canadian Arctic. Science of the Total Environment 509-510:91-103. https://doi.org/10.1016/j.scitotenv.2014.05.142

Scopel, L. C., and A. W. Diamond. 2018. Predation and food–weather interactions drive colony collapse in a managed metapopulation of Arctic terns (*Sterna paradisaea*). Canadian Journal of Zoology 96:13-22. https://doi.org/10.1139/cjz-2016-0281

Sklepkovych, B. O., and W. A. Montevecchi. 1996. Food availability and food hoarding behaviour by Red and Arctic foxes. Arctic 49:228-234. https://www.jstor.org/stable/40512000

Stanbury, A., M. Eaton, N. Aebisher, D. Balmer, A. Brown, A. Douse, P. Lindley, N. McCulloch, D. Noble, and I. Win. 2021. The status of our bird populations: the fifth Birds of Conservation Concern in the United Kingdom, Channel Islands, and Isle of Man and second IUCN REdList assessment of extinction risk for Great Britain. British Birds 114:723-747. https://www.bto.org/our-science/publications/birds-conservation-concern/status-our-bird-populations-fifth-birds

Steenweg, R. J., R. A. Ronconi, and M. L. Leonard. 2011. Seasonal and age-dependent dietary partitioning between the great black-backed and herring gulls. Condor 113:795-805. https://doi.org/10.1525/cond.2011.110004

Stenhouse, I. J., and W. A. Montevecchi. 1999. Indirect effects of the availability of capelin and fishery discards: gull predation on breeding storm-petrels. Marine Ecology Progress Series

184:303-307. https://www.int-res.com/articles/meps/184/m184p303.pdf

Stenhouse, I. J., G. J. Robertson, and W. A. Montevecchi. 2000. Herring gull *Larus argentatus* predation on Leach's Storm-petrels *Oceanodroma leucorhoa* breeding on Great Island, Newfoundland. Atlantic Seabirds 2:35-44. https://research.library.mun.ca/1996/1/Herring_Gull_predation_on_Leach_s_Storm-Petrels_breeding_-on_Great_Island_Newfoundland.pdf

Surman, C. A., and L. W. Nicholson. 2009. A survey of the breeding seabirds and migratory shorebirds of the Houtman Abrolhos, Western Australia. Corella 33:81-98. https://absa.asn.au/corella_documents/a-survey-of-the-breeding-seabirds-and-migratory-shorebirds-of-the-houtman-abrolhos-western-australia/

Syposz, M., O. Padget, J. Willis, B. M. Van Doren, N. Gillies, A. L. Payet, M. J. Wood, A. A. Alejo, and T. Guilford. 2021. Avoidance of different durations, colours and intensities of artificial light by adult seabirds. Scientific Reports 11:18941 https://doi.org/10.1038/s41598-021-97986-x

Tartu, S., A. Goutte, P. Bustamante, F. Angelier, B. Moe, C. Clément-Chastel, C. Bech, G. W. Gabrielsen, J. O. Bustnes, and O. Chastel. 2013. To breed or not to breed: endocrine response to mercury contamination by an Arctic seabird. Biology Letters 9:20130317. https://doi.org/10.1098/rsbl.2013.0317

Teixeira, A. M. 1987. The wreck of Leach's Storm-petrels on the Portuguese coast in the autumn of 1983. Ringing and Migration 8:27-28. https://doi.org/10.1080/03078698.1987.9673898

Telfer, T. C., J. L. Sincock, G. V. Byrd, and J. R. Reed. 1987. Attraction of Hawaiian seabirds to lights: conservation efforts and effects of moon phase. Wildlife Society Bulletin 15:406-413. https://www.jstor.org/stable/3782548

Thomsen, S. K., D. M. Mazurkiewicz, T. R. Stanley, and D. J. Green. 2018. El Niño/Southern Oscillation-driven rainfall pulse amplifies predation by owls on seabirds via apparent competition with mice. Proceedings of the Royal Society B: Biological Sciences 285:20181161. https://doi.org/10.1098/rspb.2018.1161

Towns, D. R., I. A. E. Atkinson, and C. H. Daugherty. 2006. Have the harmful effects of introduced rats on islands been exaggerated? Biological Invasions 8:863-891. https://doi.org/10.1007/s10530-005-0421-z

Troy, J. R., N. D. Holmes, J. A. Veech, and M. C. Green. 2013. Using observed seabird fallout records to infer patterns of attraction to artificial light. Endangered Species Research 22:225-234. https://doi.org/10.3354/esr00547

UN Environment Programme. 2019. Global mercury assessment 2018. UN Environment Programme, Chemicals and Health Branch Geneva, Switzerland. https://www.unep.org/resources/publication/global-mercury-assessment-2018

Veitch, B. G., G. J. Robertson, I. L. Jones, and A. L. Bond. 2016. Great black-backed gull (*Larus marinus*) predation on seabird populations at two colonies in Eastern Canada. Waterbirds 39:235-245. https://doi.org/10.1675/063.039.sp121

Votier, S. C., J. E. Crane, S. Bearhop, A. de León, C. A. McSorley, E. Mínguez, I. P Mitchell, M. Parsons, R. A. Phillips, and R. W. Furness. 2006. Nocturnal foraging by great skuas *Stercorarius skua*: implications for conservation of storm-petrel populations. Journal of Ornithology 147:405-413. https://doi.org/10.1007/s10336-005-0021-9

Votier, S. C., R. W. Furness, S. Bearhop, J. E. Crane, R. W. G. Caldow, P. Carry, K. Ensor, K. C. Hamer, A. V. Hudson, E. Kalmbach, N. I. Klomp, S. Pfeiffer, R. A. Phillips, I. Prieto, and D. R. Thompson. 2004. Changes in fisheries discard rates and seabird communities. Nature 427:727-730. https://doi.org/10.1038/nature02315

Waluda, C. M., C. Yamashiro, C. D. Elvidge, V. R. Hobson, and P. G. Rodhouse. 2004. Quantifying light-fishing for *Dosidicus gigas* in the eastern Pacific using satellite remote sensing. Remote Sensing of Environment 91:129-133. https://doi.org/10.1016/j.rse.2004.02.006

Watanuki, Y. 1986. Moonlight avoidance behavior in Leach's Storm-petrels as a defense against Slaty-backed Gulls. Auk 103:14-22. https://doi.org/10.1093/auk/103.1.14

Watson, H., M. Bolton, and P. Monaghan. 2014. Out of sight but not out of harm's way: human disturbance reduces reproductive success of a cavity-nesting seabird. Biological Conservation 174:127-133. https://doi.org/10.1016/j.biocon.2014.03.020

Weseloh, D. V., C. E. Hébert, M. L. Mallory, A. F. Poole, J. C. Ellis, P. Pyle, and M. A. Patten. 2020. Herring gull (*Larus argentatus*), version 1.0. In S. M. Billerman, editor. Birds of the World. Cornell Lab of Ornithology, Ithaca, New York, USA. https://birdsoftheworld.org/bow/species/hergul/cur/introduction

Wheelwright, N. T. 2016. Eradication of an ecosystem engineer. Frontiers in Ecology and the Environment 14:53-54. https://doi.org/10.1002/fee.1221

Wiese, F. K., W. A. Montevecchi, G. K. Davoren, F. Huettmann, A. W. Diamond, and J. Linke. 2001. Seabirds at risk around offshore oil platforms in the North-west Atlantic. Marine Pollution Bulletin 42:1285-1290. https://doi.org/10.1016/S0025-326X(01)00096-0

Wilhelm, S. I., S. M. Dooley, E. P. Corbett, M. G. Fitzsimmons, P. C. Ryan, and G. J. Robertson. 2021. Effects of land-based light pollution on two species of burrow-nesting seabirds in Newfoundland and Labrador, Canada. Avian Conservation and Ecology 16(1):12. https://doi.org/10.5751/ACE-01809-160112

Wilhelm, S. I., A. Hedd, G. J. Robertson, J. Mailhiot, P. M. Regular, P. C. Ryan, and R. D. Elliot. 2019. The world's largest breeding colony of Leach's Storm-petrel *Hydrobates leucorhous* has declined. Bird Conservation International 30:40-57. https://doi.org/10.1017/S0959270919000248

Wilhelm, S. I., J. Mailhiot, J. Arany, J. W. Chardine, G. J. Robertson, and P. C. Ryan. 2015. Update and trends of three important seabird populations in the western North Atlantic using a geographic information system approach. Marine Ornithology 43:211-222. http://www.marineornithology.org/PDF/43_2/43_2_211-222.pdf

Wilhelm, S. I., J.-F. Rail, P. M. Regular, C. Gjerdrum, and G. J. Robertson. 2016. Large scale changes in abundance of breeding Herring Gulls (*Larus argentatus*) and Great Black-backed Gulls (*Larus marinus*) relative to reduced fishing activities in southeastern Canada. Waterbirds 39:136-142. https://doi.org/10.1675/063.039.sp104

Wilhelm, S. I., G. J. Robertson, P. C. Ryan, and D. C. Schneider. 2007. Comparing an estimate of seabirds at risk to a mortality estimate from the November 2004 *Terra Nova* FPSO oil spill. Marine Pollution Bulletin 54:537-544. https://doi.org/10.1016/j.marpolbul.2006.12.019

Wolfe, M. F., S. Scwarzbach, and R. A. Sulaiman. 1998. Effects of mercury on wildlife: a comprehensive review. Environmental Toxicology and Chemistry 17, 146-160. https://doi.org/10.1002/etc.5620170203

Wynn, J., O. Padget, H. Mouritsen, C. Perrins, and T. Guilford. 2020. Natal imprinting to the Earth's magnetic field in a pelagic seabird. Current Biology 30:2869-2873. https://doi.org/10.1016/j.cub.2020.05.039

Yoda, K., T. Yamamoto, H. Suzuki, S. Matsumoto, M. Müller, and M. Yamamoto. 2017. Compass orientation drives naïve pelagic seabirds to cross mountain ranges. Current Biology 27: R1141-R1155. https://doi.org/10.1016/j.cub.2017.09.009

Zangmeister, J. L., M. F. Haussmann, J. Cerchiara, and R. A. Mauck. 2009. Incubation failure and nest abandonment by Leach's Storm-petrels detected using PIT tags and temperature loggers. Journal of Field Ornithology 80:373-379. https://doi.org/10.1111/j.1557-9263.2009.00243.x

Zydelis, R., C. Small, and G. French. 2013. The incidental catch of seabirds in gillnet fisheries: a global review. Biological Conservation 162:76-88. http://dx.doi.org/10.1016/j.biocon.2013.04.002

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Appendix 1

Experts' opinions on threats to Leach's Storm-Petrels across their global range

Survey sent to participants.

Question 1.
What is your professional affiliation?
- Non-governmental Organization
- Government
- Academic/ University
- Other (specify)

Question 2.
Number of years working with Leach's storm-petrels
- < 5 years
- 5 – 10 years
- 11 – 15 years
- 16 – 20 years
- > 21 years

Question 3.
In which region does your field work take place?
- Northwest Pacific
- Northeast Pacific
- Northwest Atlantic
- Northeast Atlantic
- Other (specify)

Question 4.
In which state/province/country does your field work take place?

Question 5.
What is the population size trend at your colony?
- Increasing
- Decreasing
- Unknown

Question 6.
Rank these onshore threats/pressures at your colony (1 = most important, 7 = least important).
If you think a threat is not applicable to the colony, you can leave that threat blank.
- Mammalian herbivores
- Mammalians predators
- Avian predators
- Recreational disturbance
- Habitat loss
- Onshore light attraction and collision
- Coastal development

Question 7.
If you answer "other" in the previous question, please explain what threat it is.

Question 8.
Rank these offshore threats/pressures at your colony (1 = most important, 5 = least important) during the breeding season.

If you think a threat is not applicable to the colony, you can leave that threat blank.

Mercury poisoning
Pesticides and contaminants (other than mercury)
Spatial shift in prey items
Offshore light attraction and collision
Bycatch

Question 9.
If you answer “other” in the previous question, please explain what threat it is.

Question 10.
Rank these offshore threats/pressures at your colony (1 = most important, 5 = least important) during the non-breeding season.
If you think a threat is not applicable to the colony, you can leave that threat blank.

Mercury poisoning
Pesticides and contaminants (other than mercury)
Spatial shift in prey items
Offshore light attraction and collision
Bycatch

Question 11.
If you answer “other” in the previous question, please explain what threat it is.

Table A1.S1. Number (percent) of northern and southern hemisphere storm-petrel species in each IUCN threat category.

	Number of species	Data Deficient	Least Concern	Near Threatened	Vulnerable	Endangered	Critically Endangered
Northern storm-petrels	18	0 (0)	8 (44)	3 (27)	4 (22)	2 (11)	1 (6)
Southern storm-petrels	9	2 (22)	5 (56)	0 (0.0)	0 (0)	1 (11)	1 (11)
Total	27	2 (7.5)	13 (48)	3 (11)	4 (15)	3 (11)	2 (7.5)

Table A1.S2. Example of hypothetical weighted score calculations with five threats and two survey participants. Participant 1 scored threat B the highest, so the score is the maximum out of the five threats = 5. Participant 2 scored only four of the five threats. For each threat, scores from both participants are added (i.e.: score = 9 for threat A). The sum of the scores is 29. The percent score for threat A is 9/29 (i.e.: 31.03%).

	Participant		Weighted score			
Threat	1	2	1	2	Σ of weighted scores	Percent
A	2	1	4	5	9	31.03
B	1	3	5	3	8	27.59
C	3	2	3	4	7	24.14
D	5	4	1	2	3	10.34
E	4		2	0	2	6.90
Total					29	100

Table A1.S3: Mean ± SD (median / IQR) ranking of each terrestrial threat at the global, basin, and jurisdiction scale (number of responses).

	Mammalian Herbivore	Mammalian Predator	Avian predator	Disturbance	Habitat Loss	Coastal Development	Light Attraction	Unknown
Global (39)	4.7 ± 1.7 (5 / 2.2)	5.3 ± 1.7 (6 / 3.0)	6.3 ± 0.9 (6 / 1.0)	3.3 ± 1.8 (3 / 2.0)	4.8 ± 1.0 (5 / 1.0)	4.0 ± 2.0 (4 / 2.0)	4.9 ± 1.4 (5 / 2.0)	5.5 ± 2.1 (5.5 / 1.5)
West Pacific (2)	NA	NA	6.0 ± 1.4 (6 / 1.0)	NA	6.0	6.0	5.0	7.0
JP (2)	NA	NA	6.0 ± 1.4 (6 / 1.0)	NA	6.0	6.0	5.0	7.0
East Pacific (8)	2.0	6.8 ± 0.4 (7 / 0.0)	5.9 ± 0.7 (6 / 0.5)	4.0 ± 2.4 (4 / 1.5)	6.0	4.0	5.2 ± 1.3 (5 / 0.8)	4.0
AK (2)	NA	7.0 ± 0.0 (7 / 0.0)	6.0 ± 0.0 (6 / 0.0)	4.0	NA	NA	5.0	NA
BC (3)	2.0	6.5 ± 0.7 (6.5 / 0.5)	6.0 ± 1.4 (6 / 1.0)	1.0	NA	4.0	5.0 ± 2.8 (5 / 2.0)	NA
CA (2)	NA	7.0 ± 0.0 (7 / 0.0)	5.5 ± 0.7 (5.5 / 0.5)	4.0	NA	NA	5.5 ± 0.7 (5.5 / 0.5)	4.0
MX (1)	0.0	0.0	6.0	7.0	0.0	0.0	5.0	NA
West Atlantic (24)	4.6 ± 1.7 (5 / 2.5)	4.9 ± 1.8 (5 / 2.5)	6.4 ± 0.8 (6.5 / 1.0)	2.9 ± 1.3 (3 / 1.0)	4.7 ± 1.0 (5 / 1.0)	4.1 ± 2.0 (4 / 2.0)	5.1 ± 1.3 (5 / 2.0)	NA
NL (6)	2.0	4.5 ± 0.6 (4.5 / 1.0)	6.7 ± 0.5 (7 / 0.8)	1.7 ± 1.2 (1 / 1.0)	3.6 ± 0.5 (4.0 / 1.0)	3.6 ± 1.3 (3 / 2.0)	6.2 ± 0.8 (6 / 0.8)	NA
NB (5)	3.3 ± 1.2 (4 / 1.0)	4.2 ± 2.3 (5 / 2.0)	6.4 ± 0.5 (6 / 1.0)	3.3 ± 0.6 (3 / 0.5)	5.8 ± 1.3 (6 / 0.8)	4.0 ± 1.4 (4 / 1.0)	5.7 ± 1.2 (5 / 1.0)	NA
NS (8)	5.8 ± 0.4 (6 / 0.0)	4.9 ± 2.0 (5 / 3.0)	6.8 ± 0.5 (7 / 0.2)	3.7 ± 2.1 (3 / 2.0)	4.8 ± 0.5 (5 / 0.2)	1.0	4.2 ± 0.8 (4 / 1.0)	NA
ME (2)	7.0	6.5 ± 0.7 (6.5 / 0.5)	5.5 ± 0.7 (5.5 / 0.5)	4.0	5.0	NA	3.0	NA
PM (2)	3.0	NA	5.0 ± 1.4 (5 / 1.0)	2.5 ± 0.7 (2.5 / 0.5)	5.0 ± 0.0 (5 / 0.0)	7.0 ± 0.0 (7 / 0.0)	5.00 ± 1.4 (5 / 1.0)	NA

QC (1)	NA	7.0	6.0	NA	5.0	NA	4.0	NA
East Atlantic (5)	5.5 ± 0.6 (5.5 / 1.0)	5.0 ± 1.4 (5.5 / 1.5)	6.4 ± 1.3 (7 / 0.0)	4.0 ± 2.6 (3 / 2.5)	4.5 ± 0.7 (4.5 / 0.5)	1.0	3.0 ± 1.0 (3 / 1.0)	NA
UK (3)	5.3 ± 0.6 (5 /0.5)	5.7 ± 0.6 (6 / 0.5)	7.0 ± 0.0 (7 / 0.0)	2.5 ± 0.7 (2.5 / 0.5)	4.0	NA	3.5 ± 0.7 (3.5 / 0.5)	NA
IS (1)	NA	NA	7.0	NA	NA	NA	NA	NA
FO (1)	6.0	3.0	4.0	7.0	5.0	1.0	2.0	NA

Table A1.S4: Mean ± SD (median / IQR) ranking of each at/sea threat during the breeding season at the global, basin, and jurisdiction scale (number of responses).

	Mercury	Pesticide	Light attraction	Bycatch	Spatial Shift in prey	Weather events	Prey depletion	Unknown
Global (39)	3.7 ± 1.0 (4.0 / 1)	3.0 ± 1.0 (3 / 2.0)	3.6 ± 1.2 (4 / 3.0)	1.4 ± 0.9 (1 / 0.0)	4.3 ± 1.0 (5 / 1.2)	5.0	4.3 ± 0.6 (4 / 0.5)	5.0
West Pacific (2)	NA	NA	NA	NA	NA	NA	NA	5.0 ± 0.0 (5 / 0.0)
JP (2)	NA	NA	NA	NA	NA	NA	NA	5.0 ± 0.0 (5 / 0.0)
East Pacific (8)	2.7 ± 1.5 (3 / 1.5)	3.5 ± 1.3 (3.5 / 1.5)	4.4 ± 0.8 (5 / 1.0)	2.3 ± 1.5 (2 / 1.5)	4.2 ± 1.0 (4.5 / 1.2)	NA	NA	5.0
AK (2)	4.0	3.0	4.0 ± 1.4 (4 / 1.0)	4.0	5.0	NA	NA	NA
BC (3)	2.0 ± 1.4 (2 / 1.0)	3.0 ±1.4 (3 / 1.0)	5.0 ± 0.0 (5 / 0.0)	1.5 ± 0.7 (1.5 / 0.5)	3.5 ± 0.7 (3.5 / 0.5)	NA	NA	NA
CA (2)	NA	5.0	4.0	NA	NA	NA	NA	5.0
MX (1)	NA	NA	4.0	NA	5.0	NA	NA	NA
West Atlantic (22)	3.9 ± 0.9 (4 / 1.8)	2.8 ± 0.9 (3 / 1.0)	3.4 ± 1.2 (3 / 2.2)	1.0 ± 0.0 (1 / 0.0)	4.2 ± 1.0 (5 / 1.8)	NA	4.3 ± 0.6 (4 / 0.5)	NA
NL (6)	4.0 ± 0.7 (4 / 0.0)	2.7 ± 0.8 (2.5 / 1.0)	4.8 ± 0.4 (5 / 0.0)	1.0	3.2 ± 0.5 (3 / 0.2)	NA	NA	NA
NB (5)	4.0 ± 1.2 (4 / 2.0)	2.5 ± 0.6 (2.5 / 1.5)	2.5 ± 1.0 (2 / 0.5)	1.0 ± 0.0 (1 / 0.0)	4.2 ± 1.0 (4.5 / 1.2)	NA	4.5 ± 0.7 (4.5 / 0.5)	NA
NS (8)	3.6 ± 1.1 (4 / 1.0)	2.5 ± 0.6 (2.5 / 1.0)	3.2 ± 0.8 (3 / 0.8)	1.0 ± 0.0 (1 / 0.0)	4.4 ± 1.1 (5 / 0.5)	NA	NA	NA
ME (1)	3.0	4.0	2.0	NA	5.0	NA	NA	NA
PM (2)	4.5 ± 0.7 (4.5 / 0.5)	3.5 ± 0.7 (3.5 / 0.5)	2.5 ± 0.7 (2.5 / 0.5)	1.0	5.0	NA	NA	NA
East Atlantic (4)	3.0	4.0	2.0	NA	5.0 ± 0.0	5.0	NA	5.0

					(5 / 0.0)			
UK (3)	3.0	4.0	2.0	NA	5.0	5.0	NA	5.0
FO (1)	NA	NA	NA	NA	5.0	NA	NA	NA

Table A1.S5: Mean ± SD (median / IQR) ranking of each at/sea threat during the non-breeding season at the global, basin, and jurisdiction scale (number of responses).

	Mercury	Pesticide	Light attraction	Bycatch	Spatial Shift in prey	Weather events	Prey depletion	Unknown
Global (39)	3.3 ± 1.3 (4 / 2.0)	2.7 ± 1.1 (3 / 1.0)	3.9 ± 1.2 (4 / 2.0)	1.8 ± 1.1 (1 / 1.5)	3.9 ± 1.2 (4 / 2.0)	3.7 ± 1.2 (3 / 1.0)	3.8 ± 1.8 (5 / 2.0)	4.6 ± 0.5 (5 / 1.0)
West Pacific (2)	NA	NA	NA	NA	NA	NA	NA	5.0 ± 0.0 (5 / 0.0)
JP (2)	NA	NA	NA	NA	NA	NA	NA	5.0 ± 0.0 (5 / 0.0)
East Pacific (8)	2.7 ± 1.5 (3 / 1.5)	2.7 ± 0.6 (3 / 0.5)	4.5 ± 0.8 (5 / 0.8)	2.3 ± 1.5 (2 / 1.5)	4.5 ± 0.6 (4.5 / 1.0)	NA	NA	4.0
AK (2)	4.0	3.0	4.0 ± 1.4 (4 / 1.0)	4.0	5.0	NA	NA	NA
BC (3)	2.0 ± 1.4 (2 / 1.0)	2.5 ± 0.7 (2.5 / 0.5)	5.0 ± 0.0 (5 / 0.0)	1.5 ± 0.7 (1.5 / 0.5)	4.0 ± 0.0 (4 / 0.0)	NA	NA	NA
CA (2)	NA	NA	NA	NA	NA	NA	NA	4.0
MX (1)	NA	NA	4.0	NA	5.0	NA	NA	NA
West Atlantic (22)	3.5 ± 1.3 (4 / 2.0)	2.6 ± 1.1 (3 / 1.0)	3.9 ± 1.2 (4 / 2.0)	1.6 ± 0.9 (1 / 1.2)	3.7 ± 1.1 (4 / 1.5)	3.0 ± 0.0 (3 / 0.0)	3.5 ± 1.9 (4 / 2.5)	NA
NL (6)	3.0 ± 1.4 (2 / 2.0)	2.2 ± 1.0 (2.5 / 1.0)	4.7 ± 0.5 (5 / 0.8)	1.0	3.7 ± 1.0 (4 / 0.8)	3.0 ± 0.0 (3 / 0.0)	1.0	NA
NB (5)	3.2 ± 1.6 (4 / 2.0)	2.5 ± 0.6 (2.5 / 1.0)	3.8 ± 1.3 (4 / 2.0)	1.5 ± 1.0 (1 / 0.5)	4.0 ± 1.2 (4 / 1.0)	NA	3.0	NA
NS (8)	3.5 ± 1.0 (4 / 0.5)	2.0 ± 1.0 (2 / 1.0)	3.8 ± 1.2 (4 / 1.5)	3.0	3.8 ± 1.0 (3.5 / 1.8)	NA	5.0	NA
ME (1)	4.0	5.0	3.0	1.0	2.0	NA	NA	NA
PM (2)	5.0 ± 0.0 (5 / 0.0)	4.0 ± 0.0 (4 / 0.0)	2.0 ± 1.4 (2 / 1.0)	2.0	3.0	NA	NA	NA
East Atlantic (5)	3.0	4.0	2.0	NA	5.0 ± 0.0	5.0	NA	5.0

					(5 / 0.0)			
UK (3)	3.0	4.0	2.0	NA	5.0	5.0	NA	5.0
IS (1)	NA	NA	NA	NA	NA	NA	5.0	NA
FO (1)	NA	NA	NA	NA	5.0	NA	NA	NA