Conservation status and overview of threats to seabirds

Richard Phillips, Jérôme Fort, Maria Dias

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Richard A Phillips, Jérôme Fort, and Maria P Dias

Non-print items

Abstract

Seabirds are amongst the most threatened of all vertebrate groups. Here we review their conservation status and key aspects of the main threats and some emerging threats. Bycatch in fisheries and overfishing are pervasive, but potentially soluble with improved governance. Invasive alien species at breeding sites remain a major threat despite notable recent successes in eradication campaigns. Changing climatic conditions continue to have multiple, increasing, direct and indirect effects on seabirds. The full impacts of disease and chemical pollution are less clear because effects may be sub-lethal. Impacts of other anthropogenic processes that currently concern relatively few species are probably increasing. As seabird populations are affected by multiple threats that may be additive or synergistic, addressing population declines will often require a suite of management measures, and potentially compensatory mitigation for climate change.

Key Words

Climate change; Discarding; Disease; Disturbance; Habitat loss; Invasive alien species; Overfishing; Pollution; Seabird bycatch; Wind farms

Seabird status and trends

Seabirds are one of the most threatened groups of vertebrates, with almost half of species listed as globally threatened with extinction or as Near threatened by the International Union for Conservation of Nature (IUCN) (Dias et al. 2019). Overall, 19 (5%), 36 (10%), 58 (16%) and 42 (12%) of a total of 362 species of seabirds are classified as Critically Endangered, Endangered, Vulnerable and Near Threatened, respectively (Figure 2.1). Over half (56%) of the 314 seabird species for which the population trend is known are in decline, including 80 species currently classified as Least Concern. The latter comprise 39% of the 205 seabird species in the Least Concern category. Declining trends are common across taxonomic groups, applying to the global populations of at least half the species in most seabird orders (Figure 2.2). Based on IUCN Red List categorizations, more species of albatrosses, petrels, and storm-petrels (Procellariiformes), and penguins (Sphenisciformes) are at higher risk of extinction than in other orders (Figure 2.2).

[Insert Figure 2.1 here]

[Insert Figure 2.2 here]

The main causes leading to poor conservation status of seabirds are generally well known and affect both their marine and terrestrial habitats (Dias et al. 2019; Phillips et al. 2016; Rodríguez et al. 2019; Trathan et al. 2015). The top three causes of population declines in seabirds are invasive alien species, incidental mortality (bycatch) in fisheries, and climate change, followed by overfishing, direct harvesting (hunting and trapping), and disturbance. Many other human activities also have negative impacts on their populations through sub-lethal or lethal effects (Dias et al. 2019: Figure XX.3). Although research and conservation often focus on threats with obvious impacts on survival or reproduction, many climate or human-mediated stressors affecting physiology, energetics, or behaviour have synergistic effects, likely enhancing sensitivity of seabirds to other environmental pressures and increasing vulnerability in a world that is increasingly perturbed by human activities.

[Insert Figure 2.3]

Bycatch, climate change, and, to a less extent, overfishing and invasive alien species have a high impact[1] across many groups (Figure 2.4). Direct harvesting and disturbance also affect a wide range of species from different orders, but typically with lower impacts. Albatrosses and petrels face a more limited number of threats than other taxa - each species is affected by 2.4 threats on average - although

[1] Impact is measured as the product of the scope of the threat (percentage of the total population affected) and its severity (rate of population decline caused by the threat over three generations; see Garnett et al. 2018, Dias et al. 2019).

usually with high impacts. In contrast, penguin species are on average affected by >5 different threats (Figure 2.4). A high percentage (>60%) of species in most groups other than albatrosses and petrels is affected by both marine and terrestrial threats (Figure 2.4).

[Insert Figure 2.4 here]

Threats to seabirds

Bycatch

Bycatch in fisheries is amongst the most pervasive and severe threats to seabirds, and a major cause of population declines in many species, particularly albatrosses, large petrels, and penguins in southern oceans, and sea ducks in northern latitudes (Dias et al. 2019; Phillips et al. 2016; Trathan et al. 2015; Chapter 3). Scavenging seabirds are attracted to vessels by the prospect of an easy meal in the form of unwanted catch, bait, and other offal discarded at any point during fishing operations, or bait taken from longlines during setting. In longline fisheries, most seabird bycatch occurs during setting, when birds swallow the hook or are entangled, then dragged under and drowned (Da Rocha et al. 2021; Jiménez et al. 2014). However, live captures, mainly during hauling, are also common, amounting to 40% and 11% of all birds bycaught in demersal and pelagic longline fisheries, respectively; this is also a serious problem given that over half of the birds may die subsequently from their injuries (Phillips and Wood 2020). In trawl fisheries, the main issue is injury or collision with trawl warp and monitoring cables during hauling, although birds can also be trapped in the net (Sullivan et al. 2006; Watkins et al. 2008).

Although there are many limitations in observer data, the minimum level of mortality in longline and gillnet fisheries worldwide is estimated at >160,000 and >400,000 seabirds per year, respectively (Anderson et al. 2011; Žydelis et al. 2013). Seabird mortality is likely of a similar order in trawl and artisanal fisheries, given the high levels of bycatch recorded for some fleets and the huge fishing effort in many regions (Alfaro-Shigueto et al. 2010; Da Rocha et al. 2021; Watkins et al. 2008). Demographic studies often find relationships between annual changes in fishing effort in seabird foraging areas - likely correlated with bycatch rates if mitigation measures are inadequate - and adult or juvenile survival (Cleeland et al. 2021; Pardo et al. 2017; Rolland et al. 2008). Impacts of this mortality at the population level are exacerbated if the bycatch is strongly biased towards one sex (Gianuca et al. 2017; Mills and Ryan 2005).

The burgeoning of tracking studies in the early 2000s resulted in a huge increase in knowledge of where and when adult seabirds overlap with particular fisheries in the breeding and nonbreeding seasons (Clay et al. 2019; Delord et al. 2014; Grémillet et al. 2018; Phillips et al. 2006). In contrast, details on the fisheries representing the highest risk for juveniles and immatures is generally lacking (Carneiro et al. 2020). Once problematic fisheries or fleets have been identified, pressure can be exerted on management authorities to mandate the use of bycatch mitigation measures, of which the most effective are: heavier line weighting, streamer (tori) lines, and night-setting in demersal and pelagic longline fisheries (Jiménez et al. 2020); streamer lines, net binding, and banning of offal discharge during hauling in trawl fisheries (Da Rocha et al. 2021; Maree et al. 2014); and restriction of setting times and areas in gillnet fisheries, for which technical solutions have proven more challenging (O'Keefe et al. in press). If compliance is high, seabird bycatch can be reduced to low or negligible levels (Collins et al. 2021; Da Rocha et al. 2021) (Maree et al. 2014; Melvin et al. 2019). However, progress has been very slow in some fisheries, particularly in the High Seas under the jurisdiction of the Regional Fisheries Management Organisations (RFMOs), where mitigation regulations are not best-practice, and the levels of observer coverage in terms of monitoring compliance and bycatch rates remain woefully inadequate (Phillips 2013).

Overfishing

The depletion of stocks by excessive fishing is a major threat to seabirds because of the direct competition for food resources (Grémillet et al. 2018; Chapter 3). Overfishing can have a high impact on seabird populations, particularly during the breeding season when foraging ranges are restricted by central-place constraints (Barbraud et al. 2018; Carroll et al. 2017; Grémillet et al. 2016; Pichegru et al. 2009). Overfishing is the main cause of population declines of at least 24 species (Dias et al. 2019); penguins, cormorants, frigatebirds, gannets, boobies, and sea ducks are particularly vulnerable (Figure 2.4). The effect of overfishing is often aggravated by other causes of prey depletion, such as those resulting from changes in oceanographic conditions (Grémillet and Boulinier 2009, and see below). Given difficulties in quantifying the effects of overfishing on seabird populations, the magnitude can be underestimated. Nevertheless, it is clearly a growing problem – the number of globally threatened species affected by overfishing increased from 10 to 22 in less than a decade (Croxall et al. 2012; Dias et al. 2019), and fishing pressure on stocks of shoaling, coastal fish species (forage fish), a food resource shared between humans and seabirds, is likely to intensify in the future (Grémillet et al. 2018). Of major concern is also the predicted expansion of fisheries targeting mesopelagic species (Sutherland et al. 2019), which are an important component of the diet of many pelagic seabirds (Waap et al. 2017; Watanuki and Thiebot 2018). Ensuring sustainable harvesting of fish stocks and minimization of impacts on non-target species such as seabirds are at the heart of ecosystem-based fisheries management, but will require much improved governance, and a more effective national and international policy framework (Garcia and Rosenberg 2010).

Invasive alien species

Invasive alien species at breeding colonies represent a huge threat to seabirds (Chapter 4), worldwide, affecting almost ⅔ of all species (Dias et al. 2019). The impacts are particularly severe on islands, which often host endemic seabird species that evolved in the absence of mammalian ground-predators and have limited natural defenses (Courchamp et al. 2003). Invasive alien species affect all seabird groups, with a particularly high impact on small petrels (including storm-petrels), shearwaters, and albatrosses (Dias et al. 2019). The invasive species with the greatest impacts are predators, particularly rats *Rattus* spp., house mice *Mus musculus*, and cats *Felis cattus*, which affect seabird species ranging in size from small, burrow-nesting petrels, to large, surface-nesting albatrosses (Angel et al. 2009; Barbraud et al. 2021b; Cleeland et al. 2021). Other problematic invasive alien species include ants, which can attack nesting seabirds (Plentovich et al. 2009), and mammalian herbivores and plants, which damage habitats and reduce breeding propensity or success (Cleeland et al. 2020; McChesney and Tershy 1998).

Although the scale of the threat to seabirds from invasive alien species remains high, there have been many notable successes in eradication or control in recent decades (Russell et al. 2017). Despite the many challenges, areas ranging in size from small islands to entire island groups have been cleared of one or more of rats, mice, cats, and rabbits through spreading of poison bait (often by helicopter), trapping, or shooting campaigns (Martin and Richardson 2019; Nogales et al. 2004; Springer 2016). Although this sometimes results in high levels of non-target mortality of scavenging seabirds, the impacts tend to be short-lived (Alderman et al. 2019; Travers et al. 2021). Often the overall benefits become very clear in terms of population recovery or recolonization in the following years (Barbraud et al. 2021a; Benkwitt et al. 2021; Brooke et al. 2018). However, the restoration process can be slow, particularly for burrow-nesting petrels, if other invasive meso-predators are still present (Dilley et al. 2017), underlining the advantages of eradicating all invasive predators simultaneously (Baker et al. 2020). Single or multispecies eradications are now technically feasible over very large areas, but the barriers include funding, garnering support from locals on inhabited islands (White et al. 2008), and the need on some islands to take vulnerable species into captivity that would otherwise suffer major non-target mortality (Oppel et al. 2016).

Changing climate

Changing climatic conditions are likely to have multiple, increasing, direct and indirect effects on seabird populations (Chapter 8). Hence, around 100 seabird species (27%), of which penguins and albatrosses are considered to be the most vulnerable, are expected to be impacted by changes to oceanography or other aspects of climatic variation (Dias et al. 2019). Warming temperatures will likely have direct physiological impacts, particularly on thermoregulatory processes in seabirds given they are endothermic (Oswald and Arnold 2012). Heat-stress events will increase, impacting behavior, reproduction, and survival (Cook et al. 2020; Oswald et al. 2008). Polar species, which are often ill-adapted to cope with heat stress and inhabit regions where temperatures are warming twice as fast as much of the rest of the planet, are expected to be more vulnerable to changes in their thermal landscape (Blix 2016; Choy et al. 2021; Oswald and Arnold 2012). Forecasted changes in precipitation patterns may also affect seabird reproduction and chick survival through increased thermoregulatory costs or flooding of nests (Chambers et al. 2011; Demongin et al. 2010). In polar regions, nesting seabirds can be affected by heavy snowfall, particularly in the early breeding period, reducing nest-site accessibility and delaying egg-laying, or entombing incubating adults, all of which reduce reproductive output (Michielsen et al. 2019; Moe et al. 2009; Schmidt et al. 2019). Finally, the prevailing winds affect energy balance of seabirds, year round (Amélineau et al. 2014; Fort et al. 2009). As such, predicted increases in storm frequency in some regions will have major consequences for flight costs and survival (Clairbaux et al. 2021; Guéry et al. 2019).

There are also multiple indirect effects of climate change, including warming temperatures which can result in habitat loss or fragmentation. Sea-level rise and storm surges are increasing threats on tropical atolls and other low-lying islands (Hatfield et al. 2012; Reynolds et al. 2015; VanderWerf et al. 2019; Von Holle et al. 2019). Melting sea ice can affect access to sympagic prey resources (Amélineau et al. 2019), reduce availability of floating ice for resting (Lovvorn et al. 2009), modify exposure to predators (Chaulk et al. 2007; Dey et al. 2018), and, ultimately, determine population trajectories (Descamps and Ramírez 2021; Dey et al. 2017). Warming temperatures will modify the energetic landscape of seabirds, thus altering their movements and distribution at large spatial scales (Clairbaux et al. 2021; Clairbaux et al. 2019), generating new threats to seabird populations such as increased inter-specific competition (Bonnet-Lebrun et al. in press), or the introduction of new pathogens (see below). Finally, changing climate greatly impacts physical and biological oceanography, thereby altering abundance and distribution of the prey of seabirds (Cheung et al. 2009; Poloczanska et al. 2013). This can result in spatial and temporal mismatches between seabird demand and their favoured resources, with major impacts on species or populations unable to adjust to new environmental conditions (Keogan et al. 2018). Such effects include decreased breeding success (Cury et al. 2011; Frederiksen et al. 2006) or increased adult mortality (Jones et al. 2018), and can leading to population decline (Descamps et al. 2017; Erasmus et al. 2021).

Disease

Although potential pathogen or vectors (viruses, bacteria, fungi, protozoa, gastrointestinal parasites, and ectoparasites) are widespread among seabirds (Barbosa and Palacios 2009; Uhart et al. 2018), disease is considered to be a current threat for only 15 species, predominantly albatrosses and penguins, with a high impact in most cases (Dias et al. 2019: Figure XX.4). However, there are many knowledge gaps in terms of prevalence and effects of pathogens (Chapter 5). Of the pathogens, avian cholera is the most widespread spatially and taxonomically among seabirds, and is responsible for most disease outbreaks that have involved high mortality (Barbosa and Palacios 2009). In recent decades, avian cholera has been the main driver of steep population declines of albatrosses and penguins breeding at Amsterdam Island (Jaeger et al. 2018). Some viruses also cause diseases in seabirds, typically showing a pattern of high variability among years in prevalence and in the level of impact on chicks, and generally with sub-lethal effects on adults (VanderWerf and Young 2016; Work et al. 1998; Young and VanderWerf 2008). However, avian pox reduced first-year survival and recruitment probability in the Laysan Albatross *Phoebastria immutabilis* (VanderWerf and Young 2016). Pathogens can be spread through various routes, including ectoparasites, invasive alien species such as rats, physical contact, ingestion of infected carcasses (by skuas in particular), and by aerosol transmission (Gamble et al. 2020; Uhart et al. 2018; VanderWerf and Young 2016; Young and VanderWerf 2008). Diseases are potentially a worsening problem for seabirds as pathogens or vectors are likely to become more widespread, or pathogens more virulent as a consequence of climatic and other environmental changes, such as increased pollution and other stressors, and higher connectivity associated with expanding human activities (Grimaldi et al. 2015). Although there are some partial solutions such as vaccination programmes for some species at specific sites (Bourret et al. 2018), or application of avian insecticide to kill ectoparasite vectors (Alderman and Hobday 2017; VanderWerf et al. 2019), the first line of defense should be to minimize transfer risks associated with human activities by stringent biosecurity measures.

Pollution

Environmental pollution can have a major impact on seabirds, which are exposed to thousands of anthropogenic contaminants (Chapter 6). Chemical or light pollution are considered to be a threat to >50 seabird species, particularly penguins, cormorants, and small petrels (Dias et al. 2019). Effects are likely to worsen, given the global increase in chemical production (Wilson and Schwarzman 2009), loss of plastic into the environment (Borrelle et al. 2020; Ostle et al. 2019), and the development of coastal or offshore structures and associated artificial lights (Davies et al. 2016).

Seabirds are long-lived species at the apex of marine food webs and thus show very high levels of some chemical contaminants, which magnify along food chains and accumulate in their tissues (Cherel et al. 2018). As a consequence, these contaminants can have substantial sub-lethal effects on seabirds, affecting their physiology and behavior, and ultimately their reproduction, survival, and population dynamics (Mills et al. 2020). Contaminant exposure can affect bird metabolism through endocrine disruption (Blévin et al. 2017; Melnes et al. 2017), or reduce hatching success due to an inability to sustain energetically-intensive incubation behavior (Blévin et al. 2017; Tartu et al. 2014). Laboratory evidence from Herring Gulls *Larus argentatus* suggest that neurotoxic contaminants could impair learning and cognition in developing birds (Burger and Gochfeld 2005), with potential effects on the capacity for behavioral plasticity and thus survivorship. Beyond these sub-lethal impacts, thousands of seabirds suffer direct mortality annually as a consequence of acute pollution of the environment following oil spills that resulted from illegal or accidental discharges from shipping, oil and gas exploitation (Chilvers et al. 2021; Wiese and Robertson 2004; Wilhelm et al. 2007), with potentially substantial impacts on demography (Votier et al. 2005).

Plastic pollution is an increasing threat to seabirds, with plastic ingestion recorded all over the world and in diverse species (Baak et al. 2020; Kühn and Van Franeker 2020; Phillips and Waluda 2020). Although there are still few examples to-date of well-documented population-level impacts (Lavers et al. 2014; Roman et al. 2019), plastic ingestion has various effects from physical damage such as gastrointestinal obstruction (Ryan and Jackson 1987), to toxicological, as the original additives or the organic pollutants adsorbed on floating plastics from the surrounding seawater transfer to seabird tissues after ingestion (Tanaka et al. 2019; Yamashita et al. 2021).

Artificial lights can be a major source of pollution, and there are frequent records of major mortality events involving collisions, particularly of shearwaters, petrels, and storm-petrels attracted to ships, oil platforms, and other structures at sea, and buildings and streetlights in coastal areas (Reed et al. 1985; Rodríguez et al. 2019; Rodríguez et al. 2017; Chapter 6). Environmental conditions, such as the phase of the moon and weather conditions, can have a strong influence on the collision probability, with most incidents on darker nights, in fog or rain (Montevecchi 2006; Rodríguez et al. 2012). Artificial lights may also alter the navigational ability of birds migrating along coastal areas (Van Doren et al. 2017). By disrupting sleep, light pollution could also have cascading behavioral and physiological impacts, as shown experimentally and in free-living birds (Dominoni et al. 2013; Sanders et al. 2021; Svechkina et al. 2020). Whether the faculties of seabirds are similarly impaired by artificial lights has not been tested. Human communities on islands, and responsible shipping operators and crew, are increasingly aware of the problem of light pollution, and change the types of light or its orientation, use shields, or turn off lights during sensitive periods (chick fledging, or on vessels at night) to reduce impacts (Raine et al. 2017; Rodríguez et al. 2019; Rodríguez et al. 2017). However, the impacts of light pollution on birds at sea through shipping and offshore infrastructure remain greatly underestimated (Montevecchi 2006; Rodríguez et al. 2019).

Habitat loss and development

Seabird habitat loss has been accelerated by the combined effect of climate change and the expansion of human populations and industries. At-sea foraging habitats used during both the breeding and non-breeding periods are threatened by the growing number of offshore wind farms that exclude seabirds from foraging areas (Peschko et al. 2020a; Chapter 7), although the impacts of this habitat loss on populations are currently unknown (see below). In the polar regions, melting sea ice leads to the loss of essential foraging and resting habitats, with clear impacts on seabird populations (see above). The main effects of habitat loss are at breeding sites on land. Agriculture or the introduction of grazing animals substantially change vegetation cover, affecting the breeding success and survival (Trathan et al. 2015). Likewise, seabirds nesting in forests, such as the marbled murrelet *Brachyramphus marmoratus*, can be impacted by the timber industry (Betts et al. 2020). The continued urbanization of coastlines by humans also destroys breeding habitat, forcing nesting seabirds to relocate, and impacting productivity of birds that rely on spatial knowledge to find food (Kavelaars et al. 2020; Salas et al. 2020). Breeding habitats on tropical atolls and other low-lying coastal areas will be further impacted in coming decades by climate-induced rises in global sea level and storm surges (Hatfield et al. 2012; Reynolds et al. 2015; VanderWerf et al. 2019; Von Holle et al. 2019).

Seabird and egg harvesting

The legal consumption of seabirds and their eggs has been much reduced worldwide over the last century, following the implementation of protective regulations (Chapter 7). This reduction likely led to rapid population recoveries (Merkel 2010), although the full impacts of legal harvest on populations dynamics still remain poorly evaluated, particularly as there are often other pressures involved (Chen et al. 2015; Frederiksen et al. 2019; Wiese et al. 2004). Nonetheless, hunting of seabirds at colonies is still considered to be the second largest threat on land in terms of number of species affected, and the top threat to coastal species that are globally threatened (Dias et al. 2019). For instance, traditional hunting of seabirds and egg harvesting is still a common practice in the Arctic where this resource can be fundamental (Naves 2018; Renner and Huntington 2014). Additionally, because many seabirds are long-distance migrants, multiple breeding populations over a wide area could be impacted by local hunting during the non-breeding season, as demonstrated recently for Thick-billed Murre *Uria lomvia*, with local hunting pressure in West Greenland and Eastern Canada during winter affecting growth rates, and potentially causing declines in populations from Svalbard to Canada (Frederiksen et al. 2019). Moreover, populations may also suffer from unquantified illegal hunting, the impact of which is even harder to estimate. Highly threatened or small populations of seabirds are particularly at risk from illegal consumption (Awkerman et al. 2006; Mondreti et al. 2018; Smart et al. 2020). Management of seabird and egg harvesting is a complex issue, and ensuring sustainability requires conservation measures to be developed in close consultation between local communities and authorities.

Disturbance

Disturbance at colonies can have a negative impact on the breeding success of seabird or even result in the abandonment of colonies (Carney and Sydeman 1999; Giese 1996; Chapter 7). It is a widespread problem that affects more than 20% of seabird species (Figure 2.4), particularly terns, gulls, and cormorants, and including half of the 26 coastal species that are globally threatened and many penguin species (Dias et al. 2019; Trathan et al. 2015). There are growing concerns that widespread increases in ecotourism activities have exacerbated this threat (Ellenberg et al. 2006).

Loss of subsurface predators in tropics

Loss of subsurface predators is an indirect threat to many seabirds, particularly boobies, shearwaters, frigatebirds, and terns in the tropics. There, most species are unable to dive more than a few metres and forage over large areas of relatively unproductive ocean; hence they take advantage of forage fish driven to the surface by tuna, billfishes, and dolphins (Au and Pitman 1986; Danckwerts et al. 2014; Jaquemet et al. 2004). Long-term declines in tuna abundance following over-exploitation in purse-seine, longline and, until they were banned in the 1990s, long-drift-net fisheries in High Seas (which also bycaught numerous dolphins and whales) (Lotze and Worm 2009) have greatly reduced accessibility of prey for tropical seabirds. Commercial whaling is likely to have had a similar effect on surface-feeding seabirds over wide areas. More emphasis on ecosystem-based management of tuna fisheries, which also considers indirect impacts, would improve the situation, but progress at RFMOs has been slow (Juan-Jordá et al. 2018). On the plus side, the recovery of great whales (Lotze and Worm 2009), and associated facilitation of surface feeding by seabirds may to some extent offset other threats in temperate and polar regions.

Guano harvesting

Guano reserves - the accumulated excrement of seabirds and bats rich in nutrients such as nitrogen or phosphate - has a high value as organic fertilizer (Chapter 7). The guano harvesting industry boomed during the 19th and 20th century in seabird colonies of Peru and Chile, declining when replaced by industrial manufacture of fertilizers (Schnug et al. 2018). Peru is still the largest producer of guano in the world, originating mostly from colonies of Guanay Cormorants *Phalacrocorax bougainvillii*, Peruvian Pelicans *Pelecanus thagus* and Peruvian Boobies *Sula variegata* (Weimerskirch et al. 2012). Guano harvesting can disturb breeding birds and lead to nest abandonment, chick mortality, or loss of entire colonies (Du Toit et al. 2003; Duffy 1994), and is considered to be the main driver of the historical population decline of the Peruvian Diving-petrel *Pelecanoides garnotii* (Cristofari et al. 2019).

Emerging and under-studied threats

Hybridization

Hybridization may be a threat to seabirds of conservation concern because introgression degrades the gene pool (Seehausen 2006). However, mixed-species pairing and production of hybrid offspring is uncommon in seabirds other than gulls and terns, probably because of behavioral barriers and generally high natal philopatry (Brown et al. 2015; Phillips et al. 2018). As such, hybridisation probably represents a potential threat only to a few, very rare species, such as the Chinese Crested Tern *Thalasseus bernsteini* (Yang et al. 2018).

Offshore wind farms

The number and extent of offshore wind farms is expected to grow substantially over the next decades at a global scale (Chapter 7). The turbines can affect seabirds via collision or, more often, displacement from good-quality habitats (Cook et al. 2018; Furness et al. 2013). However, the consequences of these and other offshore marine infrastructures for seabird populations are still poorly understood (Green et al. 2016). Coastal species, including sea ducks, terns, and shags are particularly affected (Dias et al. 2019), but highly migratory species can also be at risk due to cumulative impacts across their ranges (Busch and Garthe 2016). Advances in tracking technology have greatly increased our understanding of potential risks of new offshore windfarms on seabird populations (Lane et al. 2020; Peschko et al. 2020b); however, there is a clear need to expand knowledge to less studied regions, including Asia and South America, where the offshore wind market is expected to grow exponentially.

Discarding

Commercial fisheries provide enormous quantities (>10 million tonnes) of supplementary food for scavenging seabirds in the form of discards (unwanted catch, spent bait, and offal), including from large, demersal species that would otherwise be unavailable (McInnes et al. 2017; Real et al. 2018; Tasker et al. 2000; Chapter 3). Discarding can be highly beneficial, depending on the balance between seabird bycatch that may result from increased vessel interactions, and higher breeding success associated with diets that include a high proportion of discards (McInnes et al. 2017; Oro et al. 1995; Phillips et al. 1999). As such, there are concerns that reductions in discarding associated with better fisheries management could have negative repercussions for some seabird populations (Bicknell et al. 2013; Real et al. 2018). However, availability of discards affects food web and community structure by increasing dietary overlap (Bugoni et al. 2010; Jiménez et al. 2017), and potentially influences distributions by concentrating seabirds in productive areas favoured by fisheries, exacerbating bycatch risk (Ryan and Moloney 1988). Discards may also be nutritionally poorer than natural prey, resulting in lower growth rates of chicks (Grémillet et al. 2008). There are also indirect effects from associated increases in abundance of predator-scavengers (particularly gulls and skuas) on smaller seabirds that are their alternative prey in years when availability of discards or natural prey resources such as forage fish are reduced (Stenhouse and Montevecchi 1999; Votier et al. 2004).

Conclusions

Although this overview has considered each threat largely as independent, it is important to note that many seabird populations are subject to multiple threats that may be additive or synergistic. As such, addressing population declines will often require a suite of management measures, and potentially compensatory mitigation for threats such as climate change that will only be alleviated by decades of human effort at a global scale. Moreover, much of the focus of conservation research has been on obvious impacts of human activities, and there are many sub-lethal or emerging threats that are likely undocumented or little understood. There have also been strong biases towards temperate and polar, rather than tropical species, and to surface-nesting and larger burrowing seabirds, rather than storm petrels. Hence more balance is required in terms of investment into both research and conservation action.

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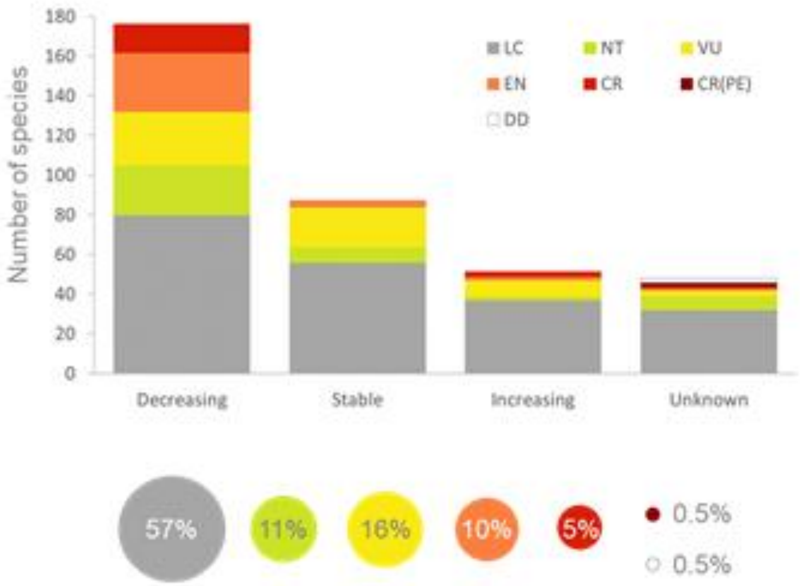

Figure 2.1. Population trends of seabirds, split by IUCN Red List categories (bars), and percentage of seabird species in each Red List category (circles). LC = Least Concern; NT = Near Threatened; VU= Vulnerable; EN = Endangered; CR = Critically Endangered; CR (PE) = Critically Endangered (Possibly Extinct); DD = Data Deficient. Data source: BirdLife International (2021) IUCN Red List for birds. http://www.birdlife.org.

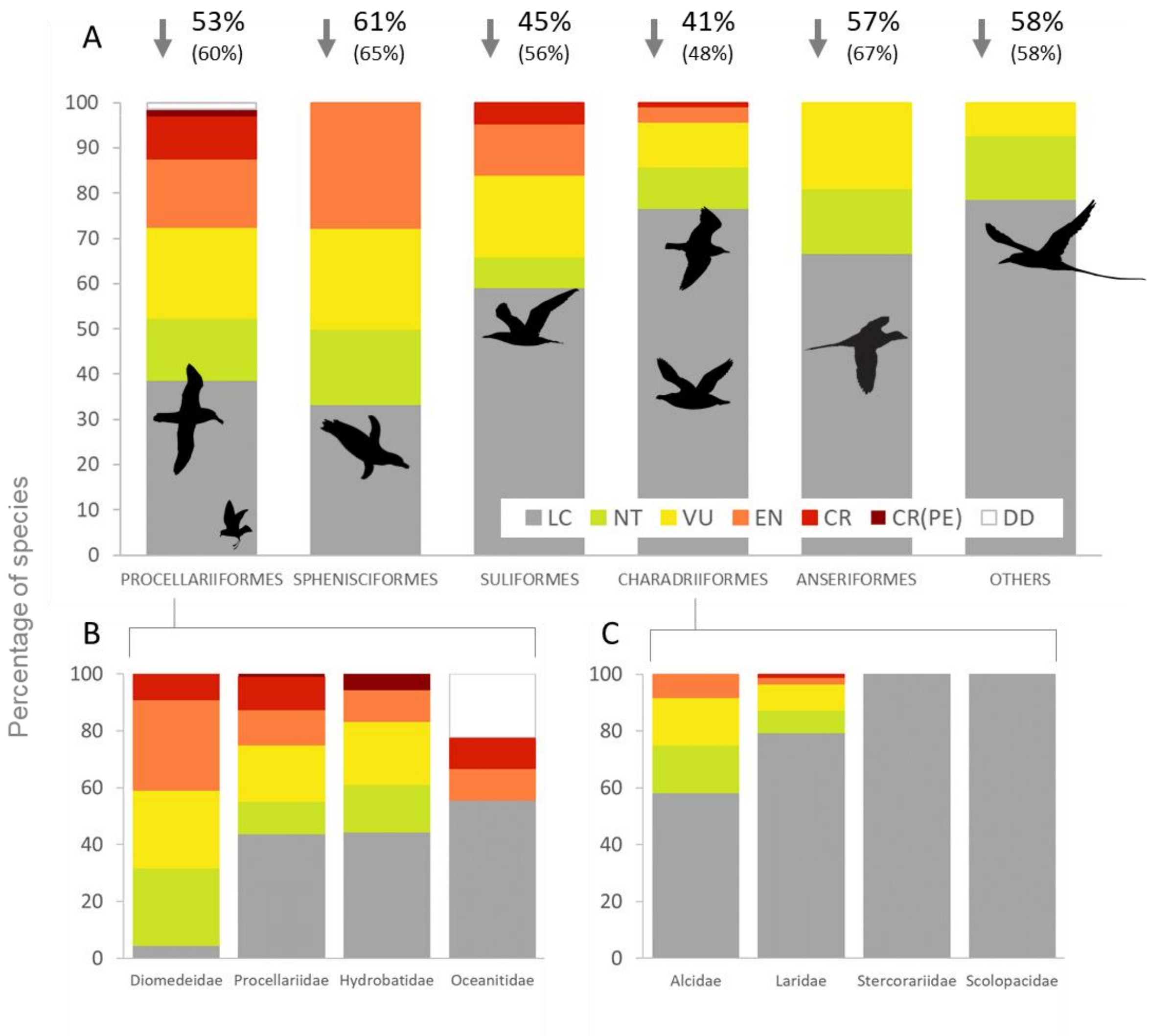

Figure 2.2. Percentage of seabird species by taxonomic order in each IUCN Red List category. A. All species. "Others" include Gaviiformes, Pelecaniformes, Phaethontiformes and Podicipediformes. B. Families within the order Procellariiformes. C. Families within the order Charadriiformes. Values at the top represent the percentage of species with declining trends, with the percentage of declining species among those with known trends in parentheses. LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered; CR(PE) = Critically Endangered (Possibly Extinct); DD = Data Deficient. Data source: BirdLife International (2021).

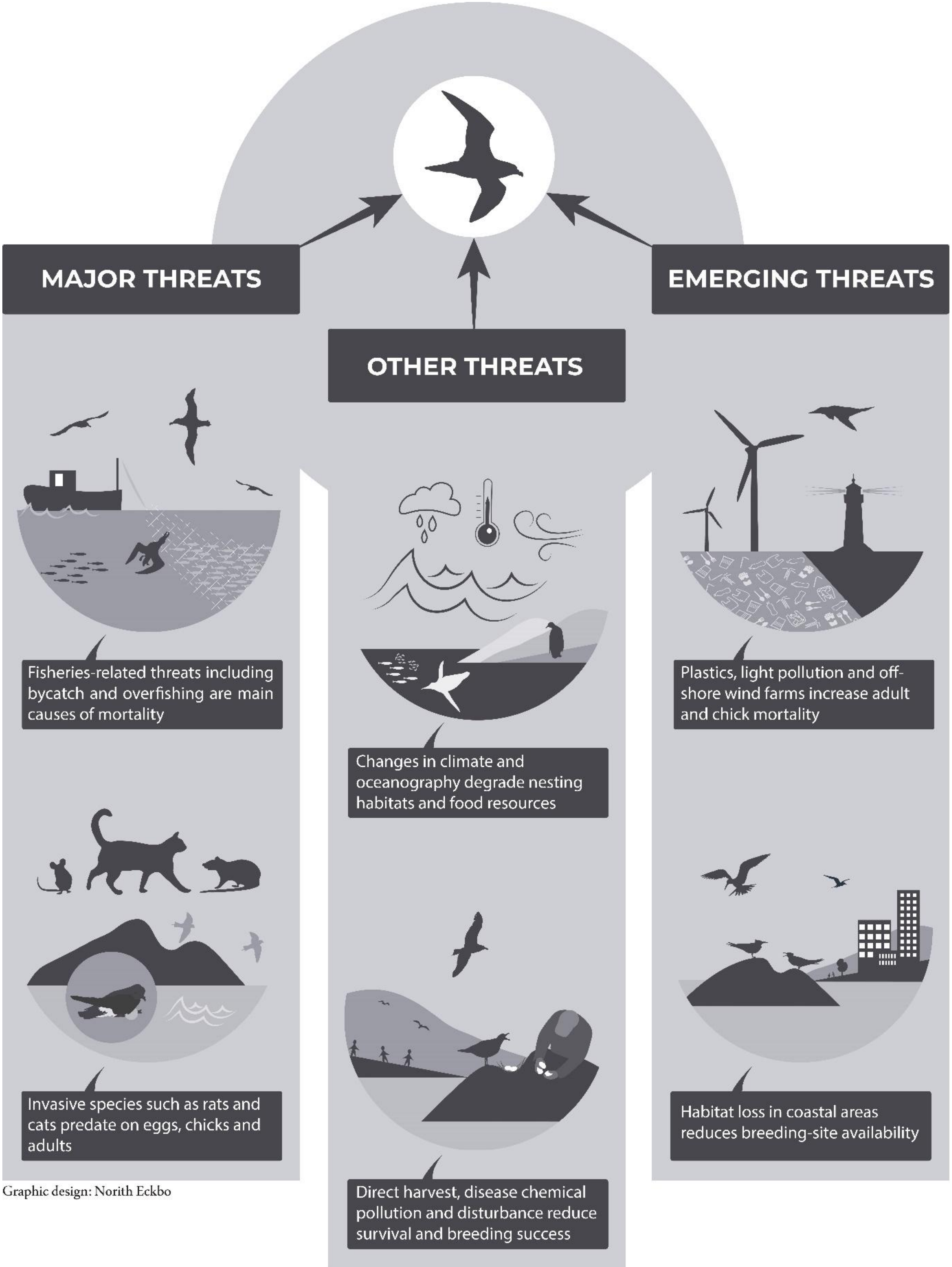

Figure 2.3. Infographic illustrating the most important threats and emerging threats to seabirds at sea and on land.

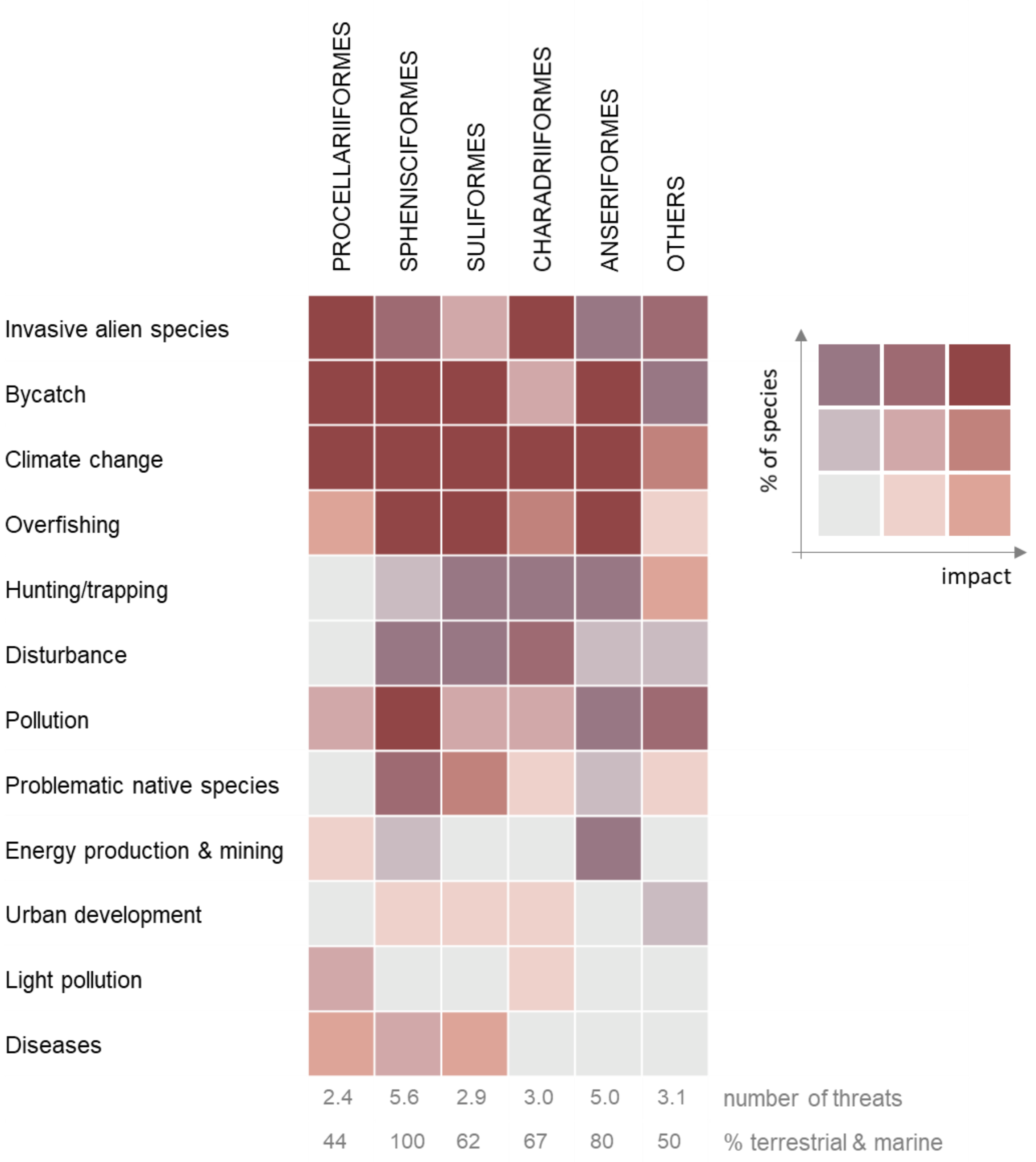

Figure 2.4. Threats affecting seabird species by taxonomic group. “Others” include Gaviiformes, Pelecaniformes, Phaethontiformes, and Podicipediformes. Color gradients represent, from lighter to darker colours, 1) the average impact of each threat (see Dias et al. 2019) in 3 classes: <4, 4-6, >6 (x axis in the legend), and 2) the percentage of species affected by each threat in 3 classes: <15%, 15%-30%, >30% (y axis in the legend). Values at the bottom (text in grey) represent the average number of threats affecting each species in that order and the percentage of species in each order that are affected by both marine and terrestrial threats, regardless of impact. Based on Dias et al. 2019 and sources mentioned therein.