AGREEMENT ON THE CONSERVATION OF
AFRICAN-EURASIAN MIGRATORY WATERBIRDS

Doc. AEWA/MOP 7.28
Agenda item: 20
Original: English
06 September 2018

7th SESSION OF THE MEETING OF THE PARTIES
4 - 8 December 2018, Durban, South Africa

"Beyond 2020: Shaping flyway conservation for the future"

PLASTICS AND WATERBIRDS: INCIDENCE AND IMPACTS

*(Compiled by Peter Ryan, FitzPatrick Institute of African Ornithology,
University of Cape Town, South Africa, on behalf of RSPB)*

Background

Through Resolution 6.9, the Meeting of the Parties recognised the potential impacts to migratory seabirds resulting from the ingestion of plastics, microplastics and other forms of marine litter (marine debris), recalled the CMS Resolutions 10.4 and 11.30 on marine debris, requiring Parties to work collectively and with the relevant Regional Seas Conventions on reducing the impacts of marine debris on migratory species and requested the Technical Committee, *subject to the availability of financial and in-kind resources, in consultation with CMS, to assess any threats posed to migratory seabirds listed by AEWA from the ingestion of plastics, of microplastics and other forms of marine litter (marine debris) and to provide advice on appropriate responses in this regard to the Meeting of Parties*.

This task had required outsourcing and thanks to the generous funding provided by the Government of the Netherlands, the production of a review to assess the threats of plastics and microplastics to AEWA seabird populations was commissioned to RSPB and the BirdLife International Global Seabirds Programme, albeit late in the triennium. It was reviewed by the Technical and Standing Committees and approved for submission to MOP7 in August 2018.

Action Requested from the Meeting of the Parties

The Meeting of the Parties is invited to note this review and take its conclusions and recommendations into account in the decision-making process (Draft Resolution AEWA/MOP7 DR6 *Priorities for the conservation of seabirds in the AEWA area*).

PLASTICS AND AEWA WATERBIRDS: INCIDENCE AND IMPACTS

August 2018

Compiled by
Peter Ryan, FitzPatrick Institute of African Ornithology
University of Cape Town, South Africa

Table of Contents

Executive Summary

Waste plastics are ubiquitous, long-lasting pollutants that are particularly abundant in wetlands and the sea. Plastic items are ingested by waterbirds and their prey, with potentially significant physical and chemical impacts. Waterbirds can also become entangled in larger plastic items, restricting their movement and growth, often with lethal consequences unless the birds are caught and freed. Some birds also use plastic items to build their nests, increasing the risk of entanglement to adults and chicks. This report briefly summarises the major impacts of plastics on waterbirds, and gives a comprehensive list of AEWA species reported to have ingested plastics, be entangled in plastic, or use plastic items for nest material. It also suggests possible monitoring tools to track the interactions of AEWA-listed waterbirds with plastics.

Plastic ingestion

Ingestion poses a significant threat to some waterbird species because large proportions of individuals contain ingested plastic. A wide variety of plastic items is ingested, depending on the bird species, the habitat in which it lives, and its diet and foraging ecology. The type of ingested plastic is also influenced by the ingestion pathway; plastic is ingested by birds in three ways: when it is mistaken for food, when it is ingested accidentally along with prey items, or when it is contained within prey species (secondary ingestion).

Historically, industrial pellets dominated the plastic loads in many small and mid-sized seabirds, but increasingly they are being replaced by fragments of user plastics. Microplastics (<1 mm), and especially microfibers, are commonly found in many waterbird prey, and are ingested by large numbers of birds, but are most probably excreted quite rapidly, as they are small enough to pass through the pyloric sphincter.

Ingested plastic loads are reported as the proportion of birds containing plastic, as well as the average number and mass of plastic per bird. These measures are determined by the rate of ingestion (related to the foraging method, diet and abundance of plastics in the environment) and the rate of loss through regurgitation and excretion. Most birds seldom excrete solid items >1 mm across, but larger fibres and flexible plastic items are excreted by some species (e.g. ducks and geese). Some waterbirds regularly regurgitate pellets of indigestible prey remains (e.g. gulls, terns, skuas, cormorants, grebes) and thus are unlikely to accumulate large plastic loads. The species most likely to suffer adverse effects from ingestion are those that seldom, if ever, regurgitate ingested plastic (e.g. petrels, phalaropes), but further evidence is needed to assess whether these species regurgitate when they contain large plastic loads.

Physical impacts of ingestion

Ingested plastic can kill birds by blocking or severely injuring the digestive tract. However, this is rare, and has seldom been reported for any AEWA-listed species. Another physical impact arising from plastic ingestion results from reduced effective stomach volume in individuals that contain large plastic loads. Experiments with captive birds have shown that chicks fed large amounts of plastic grow more slowly than birds with no plastic, presumably because meal size is reduced.

Impacts on free-ranging birds have not been demonstrated but are likely to be subtle. Plastic loads in wild birds are right skewed, so even among populations where almost all individuals contain some plastic, relatively few birds contain very large plastic loads. This issue is unlikely to be significant for species that regularly regurgitate indigestible prey remains. Among species that do accumulate ingested plastic, chicks are most at risk if they are fed by regurgitation, because they receive stored plastic from both parents. In addition, very small plastic particles (e.g. nano-plastics <1 nm) may be able to migrate out of the digestive tract into other

tissues, where they could disrupt cellular functioning, but there have been no studies of this potential impact on birds.

Chemical impacts of ingestion

Among chemical impacts from ingested plastics are the release of toxic additives included in some plastics (e.g. phthalates, brominated flame retardants, etc.), as well as legacy persistent organic pollutants (POPs) that accumulate on plastics in the environment. These impacts are likely most severe in species which retain plastics in their stomachs for extended periods, because it apparently takes several days (or longer) for ingested items to transfer toxic chemicals.

In addition, species that accumulate ingested plastic gradually wear down plastic items in their stomachs, potentially releasing additional chemicals. However, additional evidence is needed on the rates of transfer from plastics to birds and vice versa. Ingesting ‘clean’ plastics may allow birds to offload accumulated POPs. POPs are expected to be more of an issue for marine species, because most freshwater plastics are probably too transient for user items containing toxic compounds to break up into small fragments, or for other items to accumulate large concentrations of legacy POPs.

Entanglement

Entanglement is a more visible impact of plastics on birds, but seldom impacts significant proportions of populations. One possible exception among AEWA-listed species is the Northern Gannet (*Morus* bassanu)s, which is often observed entangled at sea at its wintering area off west Africa, and 6-9% of birds stranded along the North Sea coast are entangled in plastic items. Auks can also suffer high rates of entanglement, with all six AEWA-listed species affected. Most entanglements result from fishing gear (fishing line, netting), and it is often hard to differentiate between captures in active or ‘ghost’ fishing gear. Other items frequently found to entangle birds include six-pack rings, balloon and kite strings, and other string-like materials. Plastic bags and miscellaneous ring-shaped items also occasionally entangle birds.

Use of plastic in nests

Several birds (e.g. gannets, cormorants, gulls) regularly incorporate plastic items in their nests. The incidence of plastics in nests varies among species, and regionally within species, linked to the abundance of plastic wastes in the immediate environment as well the local availability of natural materials for nest building. The items most often used for nest construction are long, thin items such as ropes, straps and fishing line. These items pose an entanglement threat to adults and chicks, and are known to cause mortality of Northern Gannets, endangered Bank Cormorants (*Phalacrocorax neglectus*) and other waterbird species. Plastic items may also accumulate in nests if they are regurgitated by adults or chicks at the nest.

Incidence among AEWA species

Of the 254 AEWA-listed waterbird species, 102 (40%) have been recorded to interact with waste plastics: 57 (22%) contain ingested plastic, 79 (31%) have been observed entangled in plastic debris, and 20 (8%) use plastic items in their nests. However, these are almost certainly underestimates, as not all species have been checked for interactions with plastics, and sample sizes for other species are modest. Most data come from Europe and South Africa, with few data from other parts of the AEWA region. More is known about the interactions of seabirds with plastics than freshwater birds.

Few AEWA-listed species have a high incidence of ingested plastic. The two phalaropes are probably most at risk from ingestion; globally, 46% of phalaropes have been found to contain plastic. Some studies have found

>40% of dabbling ducks to contain ingested plastic, but the fate of ingested plastic in these species is not known, and could be rapidly excreted with little impact on the birds. The only other taxa in which at least 10% of birds contain ingested plastic are gulls (15%), skuas (14%) and auks (10%). Gulls and skuas regularly regurgitate pellets of indigestible prey and thus probably ingest plastic items more often than this figure suggests.

Entanglement is most frequent among Northern Gannets; interestingly, Cape Gannets (*M.* capensis) are much less prone to entanglement, and to including debris in their nests, perhaps reflecting a lower density of marine debris in the Benguela region than in North Atlantic coastal waters. Great Cormorants (*Phalacrocorax carbo*) and gulls are also entangled fairly frequently in the North Sea. Waterfowl, and especially Mute Swans (*Cygnus olor*), are often caught on fishing gear in some areas, but most records probably represent bycatch rather than entanglement. Sulids, cormorants, gulls and, to a lesser extent, ibises and herons, are the species that most often include plastic materials in their nests, but there is generally little data on this topic apart from in the case of Northern Gannets.

Monitoring plastic interactions with waterbirds

The best monitoring tool to assess regional or temporal changes in plastic ingestion is checking dead birds for ingested plastic. Hunted species, or those killed accidentally (e.g. fishery bycatch) offer the opportunity to regularly examine large numbers of individuals. Birds found dead (e.g. stranded seabirds) also provide useful information, but they are a non-random sample of the population; their levels of interactions with plastics might be inflated if the interactions increase the chance of death (e.g. starvation resulting from blockage of the digestive tract) or the birds display abnormal behaviour prior to dying (e.g. during storms, birds might ingest more plastic because they are struggling to find food).

As a result, comparisons of rates of interaction with randomly sampled birds need to be interpreted with caution. Standardised comparison of regurgitations offers a useful tool to track plastic interactions among species such as gulls and skuas that regularly regurgitate indigestible prey remains. Long-term studies of ingestion show an increase in the proportion of birds containing plastic through the 1960s and 1970s, stabilising in the 1980s and 1990s.

Sampling preen gland oil is a non-destructive method for monitoring levels of plastic-associated toxic compounds in birds but requires strict quality control measures and sophisticated analytical techniques.

Entanglement tends to occur infrequently in most species, making it hard to detect changes in rates over time. Long-term surveys of stranded birds in Europe provide a useful tool to monitor entanglement rates, and similar programmes could be initiated elsewhere. The proportion of entangled birds stranding in the Netherlands increased after 2003, but there are no published data since 2007. Numerous novel entanglement records were obtained for this review by searching the internet, particularly Google images. Setting up a website to encourage members of the public to submit images of entangled birds might prove a valuable tool to track the problem. Monitoring plastic use in nests, particularly among colonial species, offers a simple, non-destructive method to estimate encounter rates with plastic debris.

Conclusions and recommendations

Of all the potential impacts of plastic pollution, plastic ingestion is thought to have the greatest impact on birds at a population level, but few AEWA-listed species accumulate large plastic loads. Phalaropes are likely to be most impacted by plastic ingestion, although high levels of ingestion have been reported from a few duck species. Despite increasing amounts of plastic being produced annually, there is little evidence of an increase in the incidence of plastic ingestion over the last few decades in seabird species that regularly ingest plastics.

More information is needed on the residence time of ingested plastics in the digestive tracts of birds, given the importance of this parameter for the dynamics of ingested plastic and the transfer of toxic compounds. Reducing the risks of plastic ingestion is complicated by the wide range of items ingested by birds. The most effective measure is to support broad-scale programmes to reduce the amounts of waste plastic entering the environment.

All waterbirds are at risk of entanglement, mainly from fishing gear, but also balloon strings, bags, packing straps, six-pack rings and other ring-shaped items. Because entanglement typically involves a more limited suite of plastic products, more focused mitigation measures are possible. Effective steps to reduce entanglement include banning high-risk applications where there are other alternatives (e.g. six-pack rings), discouraging the use of high-risk items (e.g. balloons on strings), and encouraging users to not discard particularly risky materials such as waste fishing line by providing specific receptacles and associated educational signage in areas frequented by fishers.

The impact of bycatch on fishing lines can also be reduced by educating fishers on how best to deal with hooked or entangled birds. However, the impact of entanglement on AEWA-listed species is probably minor compared to accidental bycatch in fishing gear as well as deliberate catching of birds. More data are needed on accidental entanglement, bycatch and targeted captures of waterbirds from developing countries in the AEWA region, because most data presented in this report are from western Europe and South Africa.

1. Introduction

Plastics are a complex set of synthetic polymers that are largely immune to biological degradation. Their relatively low cost, light weight, long lifespan and excellent barrier properties makes them the first choice of material for a wide range of applications (Andrady & Neal 2009). Global production has increased rapidly over the last 70 years to currently more than 300 million tonnes per year (~400 million tonnes if you include synthetic fibre production) and continues to grow at around 8% per year (Geyer et al. 2017).

Unfortunately, the characteristics that make plastics such versatile materials also make them excellent pollutants that persist in the environment for many years, and that can disperse far from source areas (GESAMP 2015). The diverse nature of plastics, with not only many different polymers, but also different grades within polymers, each with subtly different physical characteristics, greatly complicates the recycling of plastics. As a result, only some 9% of waste plastic is recycled and 12% incinerated to generate electricity or converted by pyrolysis into liquid fuels (petrol or diesel), globally (Geyer et al. 2017).

Most waste plastics (79%) are either disposed of in landfills or released into the environment (Geyer et al. 2017). Much of this waste plastic ends up in water bodies. Jambeck et al. (2015) estimated that 4-12 million tonnes of plastic entered the sea in 2010, and predicted that this amount was likely to continue to increase unless there is a paradigm shift in the way we treat plastic wastes.

As a result, waste plastic items are now ubiquitous marine pollutants that have significant economic and environmental impacts (Gregory 2009, Kühn et al. 2015), and have been targeted for action by the United Nations (UNEP 2014). More recently there has been concern about waste plastics in freshwater systems (e.g. Eerkes-Medrano et al. 2015, Wagner & Lambert 2018), partly because most marine plastics derive from land-based sources. Rivers, in particular, are major vectors of waste plastics into the sea (Lebreton et al. 2017). However, there also is concern about the impacts of plastics on freshwater biota. Local accumulation of plastics in freshwater wetlands (e.g. Di & Wang 2018, Eriksen et al. 2013) suggests that at least some freshwater animals might also be at risk from plastics.

The main impacts of waste plastics on birds arise from ingestion of small plastic items, and entanglement in larger items (Ryan 1990a, Laist 1997, Gall & Thompson 2015, Kühn et al. 2015). Seabirds were first reported to contain ingested plastics in the 1960s, but it was only in the late 1970s and 1980s that the potential impacts at a population level started to be considered (Ryan 2015a). The most recent reviews suggest that at least 40% of all seabird species contain ingested plastic, and 25% have been recorded entangled in plastic (Gall & Thompson 2015, Kühn et al. 2015, Ryan 2016). Less is known about the impacts of plastics on freshwater birds (Wagner & Lambert 2018), but several ducks and other waterbirds have been recorded to ingest or become entangled in waste plastics (e.g. Laist 1997, Hong et al. 2013, English et al. 2015, Faure et al. 2015, Holland et al. 2016, Gil-Delgado et al. 2017, Reynolds & Ryan 2018). As a result of their vagility, birds help to disperse plastics, and can import them to otherwise plastic-free environments (e.g. petrels import plastics to terrestrial habitats on uninhabited islands and to remote colonies at high latitudes; Buxton et al. 2013, Kühn et al. 2015).

This report summarises the main impacts of plastics on waterbirds, and then reports the incidence and likely impacts of waste plastics on waterbirds covered under the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA). It concludes by suggesting approaches to monitor temporal and spatial patterns of interaction between AEWA-listed waterbirds and plastics.

2. Ingestion

Ingestion is perhaps the main concern regarding plastics and waterbirds, because it can affect large proportions of some populations, and has the potential for both physical and chemical impacts (Gregory 2009, Kühn et al. 2015, Ryan 2016). Ingestion can be direct (primary ingestion) or indirect (secondary ingestion via contaminated prey). The size of plastic items relative to prey species probably offers the best way to differentiate these two ingestion routes. Plastic items ingested directly tend to be roughly similar in size to prey items, whereas secondary ingested items tend to be much smaller than prey items. However, direct ingestion can result from deliberate ingestion, when plastic items are mistaken for prey items, or accidental ingestion, when plastics are consumed passively along with prey items (Ryan 2016).

The latter category might include items appreciably smaller than the main prey species, and thus be confused with secondary ingestion. Dabbling ducks probably ingest most plastic accidentally (e.g. English et al. 2015, Gil-Delgado et al. 2017, Reynolds & Ryan 2018). It also can be hard to distinguish ingestion from entanglement when live birds are seen trailing fishing line – this could result from ingestion of a hook or entanglement in a hook or line. Ingestion of a fishing hook and line (e.g. Hong et al. 2013) is perhaps better treated as bycatch than ingestion, although birds can digest fishing hooks, leaving only the line in their stomachs, and thus be indistinguishable from ingestion (Ryan 2015b).

Most plastic ingestion by birds – at least at the size range of items that are readily detected in their stomach contents – appears to be ingested directly. Secondary ingestion has been inferred for terns (Hays & Cormons 1974) and skuas (Ryan & Fraser 1988, Hammer et al. 2016), based on the presence of plastic in regurgitated pellets, and may be regular in piscivorous species (e.g. gannets, cormorants, divers, herons, auks, etc.) given the frequent occurrence of plastic recorded in both marine and freshwater fish, at least in Europe (e.g. Sanchez et al. 2014, Faure et al. 2015, Gall & Thompson 2015, Kühn et al. 2015, Rummel et al. 2016, Collard et al. 2017, Murphy et al. 2017, Compa et al. 2018, but see also Hermsen et al. 2017). However, most plastics ingested by fish that are small enough to be eaten by birds are likely to be small enough to be excreted rapidly by birds. Skua pellets containing ingested plastics mainly come from eating other seabirds (e.g. Ryan 2008, Hammer et al. 2016).

The likelihood of accidental ingestion may be increased when plastic is associated with prey species. For example, (*Phoebastria*) albatrosses in the North Pacific Ocean often eat flying fish egg masses, which stick to floating debris (Pettit et al. 1981). Gulls scavenging at refuse dumps probably consume plastic bags, food wrappings and other debris (e.g. aluminium foil) that are associated with human food wastes (cf. Witteveen et al. 2017). However, the evidence from petrels (Procellariiformes), the bird order that most often contain ingested plastic, suggests that most plastic items found in their gizzards are ingested deliberately, as a result of confusion with prey items (Ryan 2016). This is supported by the apparent selection of conspicuously-coloured plastic items, when compared to the incidence of plastic items collected at sea (e.g. Day et al. 1985, Ryan 1987a). Petrels are known to select for red items at sea (Harper 1979), and it is likely that most foraging decisions are largely visual. Savoca et al. (2016) argued that scent might play a role in plastic ingestion by petrels, but this has been questioned (Dell'Ariccia et al. 2016).

2.1 Incidence: the balance between ingestion and regurgitation/excretion

The ingestion of plastics by birds or other animals is usually reported as the proportion of individuals containing plastic (= incidence or prevalence of ingestion), and the average plastic load per individual, expressed in terms of numbers of items, mass of items, or both. These measures are assumed to be a proxy for ingestion rate (i.e. the rate at which animals encounter and ingest plastic). However, they are also influenced by the residence time of plastics in the animal (Figure 1, Ryan 1988a, Ryan 2016). Small plastic fragments and fibres have been reported from bird faeces (e.g. van Franeker & Law 2015, Gil-Delgado et al. 2017, Reynolds & Ryan 2018, Provencher et al. in press), but most birds seldom excrete solid items >1 mm diameter, so only very small hard plastic fragments are excreted (Ryan & Jackson 1987, Ryan 2015b). Fibres and flexible plastics might be excreted at somewhat larger sizes (fragments up to 4 mm and fibres to 12 mm, Gil-Delgado et al. 2017), but there is little information on the size and type of plastics in bird faeces.

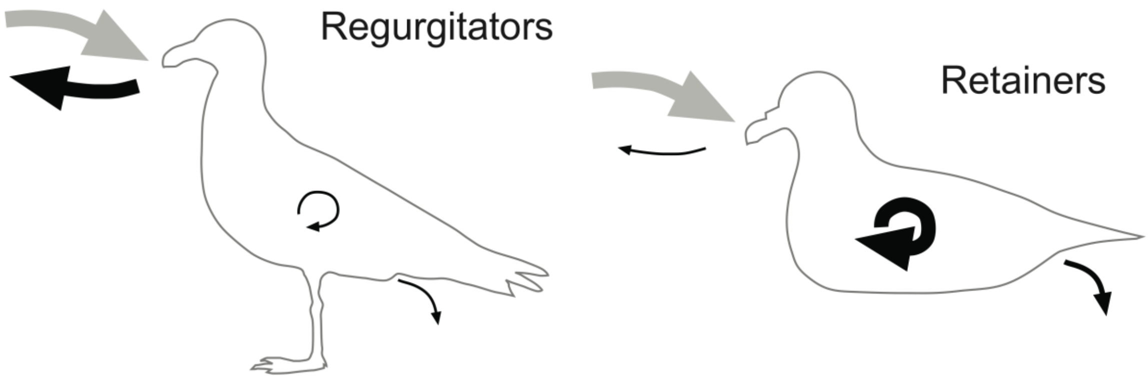

Figure 1. The two extremes among birds in terms of ingested plastic dynamics: species such as gulls (left) regularly regurgitate pellets of indigestible prey items, including plastics, and thus for a given ingestion rate, contain less plastic in their stomachs than species such as petrels (right) that seldom regurgitate and so accumulate ingested plastics in their gizzards, where it is gradually eroded until it is small enough to be excreted (from Ryan 2016).

Plastic residence time in bird stomachs presumably varies with item size, type of plastic, the amount and composition of other persistent stomach contents (which is likely to affect wear rates), and the size at which items are excreted, which may vary among taxa (Ryan 2015b). Excretion is likely to be more important in accumulators because they gradually wear down ingested fragments of plastic in their muscular stomachs (Ryan 1988a, van Franeker et al. 2011). At least for hard plastic pellets and fragments, this process is likely to take months (Ryan & Jackson 1987, Ryan 2015b). but even among seabirds there is ongoing debate as to residence times (e.g. van Franeker & Law 2015, Ryan et al. 2015b).

There are virtually no data on residence times in freshwater birds. For example, there is conflicting evidence for ducks, with the high frequency of relatively large fibres and fragments in the faeces of Common Shelducks (*Tadorna tadorna*) and Mallards (*Anas platyrhynchos*) (Gil-Delgado et al. 2017) implying fairly rapid excretion in these species, whereas Faure et al. (2015) suggested that plastic items were retained in the gizzards of Mute Swans for long enough to become worn and polished.

Ingestion rate is determined by the foraging mode, diet and the abundance of plastics in the environment. Many seabirds have been recorded to contain plastic items at least occasionally (Gall & Thompson 2015, Kühn et al. 2015), but species that forage near the water surface, such as storm petrels, phalaropes and many petrels, are more likely to ingest plastics than species that forage at deeper depths and tend to have more specialised diets, such as penguins, auks and diving petrels (Day et al. 1985, Ryan 1987a). Similarly, among ducks, dabbling species tend to ingest plastic more often than diving species (English et al. 2015, Reynolds & Ryan 2018).

The impact of geographic differences in the abundance of plastic in the environment on plastic ingestion is nicely demonstrated by regional differences in plastic loads within species. Perhaps the best example comes from the Northern Fulmar (*Fulmarus glacialis*), which exhibits decreasing plastic loads at colonies farther away from human population centres (van Franeker & Law 2015). In the Pacific Ocean, Young et al. (2009) showed how Laysan Albatrosses (*Phoebastria immutabilis*) feeding in different regions of the North Pacific bring very different amounts of plastic to their chicks, with birds spending more time in the vicinity of the North Pacific 'garbage patch' delivering more plastic. However, for most species we have limited data on plastic loads, and these show broadly consistent patterns across bird groups in relation to diet and foraging mode.

Table 1 summarises the proportion of seabirds by family/sub-family recorded to ingest plastic as well as the average incidence of plastic based on a review of the literature up to 2015 (Ryan 2016). Only phalaropes and three families of petrels have an average of >20% of birds across all species containing plastic, reflecting the accumulation of plastics in the stomachs of these species. Among families and sub-families, the proportion of individuals containing plastic generally increases with the proportion of species recorded to ingest plastic (Figure 2). However, there is considerable variation among groups, linked in part to the large variance in sample size among groups (number of species) and species (numbers of individuals).

Table 1. Numbers of seabird species reported to ingest plastic items, the proportions of each family (or sub-family) affected (expressed as a function of all species, and of those species specifically checked for ingestion), and the mean incidence of ingestion per species (the proportion of individuals within each species containing plastic, restricted to species with at least 10 individuals examined) [from Ryan 2016].

Taxon	N species with ingested plastic	N species (n examined)	% species ingested (% examined)	% incidence (range)
Sea ducks *Anatidae*	1	14 (4)	7 (25)	<1 (0-1)
Loons (divers) *Gaviidae*	1*	5 (3)	20 (33)	<1 (0-1)
Penguins *Spheniscidae*	5	18 (12)	28 (42)	3 (0-27)
Austral storm petrels *Oceanitidae*	5	9 (6)	56 (83)	34 (0-82)
Albatrosses *Diomedeidae*	17	21 (18)	81 (94)	16 (1-88)
Northern storm petrels *Hydrobatidae*	6	15 (7)	40 (86)	26 (0-92)
Petrels *Procellariidae*	56	90 (59)	62 (95)	36 (0-96)
Diving petrels *Pelecanoididae*	2	4 (3)	50 (67)	1 (0-2)
Frigatebirds *Fregatidae*	1	5 (1)	20 (100)	<1 (0-1)
Cormorants *Phalacrocoracidae*	6	40 (13)	15 (46)	3 (0-15)
Gannets and boobies *Sulidae*	5	10 (8)	50 (63)	1 (0-3)
Tropicbirds *Phaethontidae*	2	3 (3)	67 (67)	4 (0-9)
Phalaropes *Scolopacidae*	2	3 (2)	67 (100)	46 (23-68)
Gulls Larinae (*Laridae*)	25	54 (30)	46 (83)	15 (0-33)
Terns Sterninae (*Laridae*)	7	45 (19)	16 (37)	2 (0-5)
Skuas *Stercoraridae*	6	7 (6)	86 (100)	14 (5-23)
Auks *Alcidae*	14	24 (18)	58 (78)	10 (0-59)

*Kühn et al. 2015 list three divers as having ingested plastic, but two of these records refer to ingestion of fishing gear (Hong et al. 2013), which are more likely bycatch than plastic ingestion.

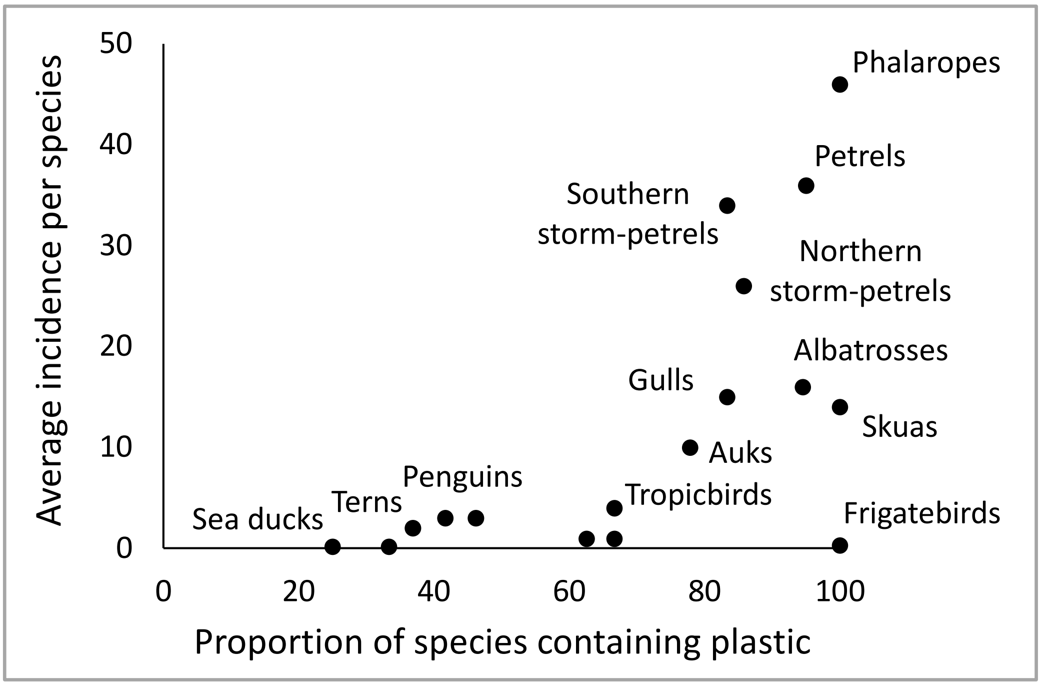

Figure 2. The relationship between the proportion of species in each seabird family or sub-family containing ingested plastic (excluding species not examined) and the average incidence of plastic load per species, based on data in Table 1. Groups not labelled = cormorants, sulids, loons, diving petrels.

Less is known about plastic ingestion by freshwater birds. It appears to occur most frequently among ducks and geese (Faure et al. 2015, Holland et al. 2016, Gil-Delgado et al. 2017, Reynolds & Ryan 2018), with up to 40% of some dabbling ducks containing plastic (English et al. 2015, Gil-Delgado et al. 2017). Most ingested plastics are microfibres (Gil-Delgado et al. 2017, Reynolds & Ryan 2018), which are likely to be excreted rapidly, with little impact on the birds. Surprisingly, there are apparently no records of plastic ingestion for flamingos, which as filter feeders, might be expected to regularly ingest microplastics, but it is not clear whether flamingos have been checked and found not to contain plastics.

There are occasional records of plastic ingestion from herons (Hong et al. 2013, Faure et al. 2015) and pelicans (Kühn et al. 2015), although many of these records involve ingesting fishing gear and should perhaps be regarded as bycatch rather than ingestion. Grebes have not been recorded to ingest plastic, although there are images of birds trailing fishing line (Google images), presumably after swallowing fishing hooks. There are no records of plastic ingestion for storks or cranes, and among rallids it is only known from the Common Coot (*Fulica atra*) (fibres in 60% of faeces; Gil-Delgado et al. 2017) and Inaccessible Island Rail (*Atlantisia rogersi*) (plastic pellets and fragments possibly gleaned from Brown Skua (*Catharacta Antarctica*) pellets; PG Ryan unpubl. data). Apart from the two marine phalaropes, shorebirds seldom appear to ingest plastic items. Robards et al. (1997) recorded plastic fragments in a Bar-tailed Godwit (*Limosa lapponica*), but there are no other records of ingestion among scolopacids (excluding the two marine phalaropes), plovers, or other shorebird families (apart from sheathbills (*Chionidae*)). It is not clear whether this is due to a lack of checking shorebird stomach contents for plastic items, but data from the Western Cape of South Africa in the early 1980s suggests that there is a real absence of plastic ingestion by these taxa (Table 2).

Table 2. The incidence of ingested plastic in the stomachs of shorebirds collected in the Western Cape, South Africa, 1981-1984 for an investigation of internal parasites (PG Ryan unpubl. data).

Taxon		n	% with plastic
Family Recurvirostridae (avocets, stilts)			
Pied Avocet	*Recurvirostra avosetta*	10	0%
Black-winged Stilt	*Himantopus himantopus*	10	0%
Family Charadriidae (plovers)			
Grey Plover	*Pluvialis squatarola*	1	0%
Kittlitz's Plover	*Charadrius pecuarius*	20	0%
African Three-banded Plover	*Charadrius tricollaris*	10	0%
White-fronted Plover	*Charadrius marginatus*	58	0%
Chestnut-banded Plover	*Charadrius pallidus*	10	0%
Crowned Lapwing	*Vanellus coronatus*	2	0%
Blacksmith Lapwing	*Vanellus armatus*	11	0%
Family Scolopacidae (sandpipers & allies)			
Ruddy Turnstone	*Arenaria interpres*	30	0%
Red Knot	*Calidris canutus*	5	0%
Curlew Sandpiper	*Calidris ferruginea*	14	0%
Sanderling	*Calidris alba*	25	0%
Wilson’s Phalarope	*Phalaropus tricolor*	1	0%
Red Phalarope	*Phalaropus fulicarius*	1	100%
Terek Sandpiper	*Xenus cinereus*	1	0%
Marsh Sandpiper	*Tringa stagnatilis*	2	0%
Total		211	<1%

2.2 Physical Impacts of Ingestion

Plastic ingestion has several impacts on birds. Until recently, impacts have focused on relatively large plastic particles that remain in the digestive tract. The most obvious impact of these items is physical damage or blockage of the digestive tract (e.g. Fry et al. 1987). Such blockages can have severe consequences at the individual level but are unlikely to occur frequently enough to have adverse demographic impacts. Blockages have seldom been reported among AEWA waterbirds, with only a few records for Northern Gannets (*Morus bassanus*) (Dickerman & Goelet 1987, Pierce et al. 2004).

In both instances, the entrance to the intestine was blocked by a large item (4 cm bottle cap and 8 cm piece of a polystyrene lobster pot float). Death might also occur following perforation of the digestive tract. This appears to be even less frequent; the only case known for an AEWA species is a Crowned Cormorant (*Microcarbo coronatus*) killed after a plastic straw pierced its oesophagus, apparently resulting in its death (Two Oceans Aquarium unpubl. data). Birds can survive significant internal injuries. For example, a Tristan Albatross (*Diomedea dabbenena*) was photographed incubating on Gough Island with an old tuna hook protruding from its neck, and albatrosses and petrels have been found with hooks encased in ‘cysts’ where they have penetrated the stomach wall without causing the birds’ deaths (PG Ryan unpubl. data). Procellariiform seabirds are able to digest fish hooks, but not the associated monofilament lines (Phillips et al. 2010, Ryan 2015b).

Reduced stomach volume, which occurs when large volumes of plastic accumulate in bird stomachs, probably affects more birds than blockage or injury to the digestive tract. Large plastic accumulations can create a false sense of satiation, reducing appetite and hence food intake. Chicks experimentally fed large plastic loads grow more slowly than those not containing any plastic (Ryan 1988b), and reduced meal size has been demonstrated for marine turtles (e.g. McCauley & Bjorndal 1999) but impacts on free-ranging birds have not been demonstrated.

Reduced food intake has been inferred from lower body condition among individuals containing ingested plastic (e.g. Connors and Smith 1982, Spear et al. 1995, Lavers et al. 2014), although other studies have found no effect of plastic load on condition (e.g. Yamashita et al. 2011). However, care is needed in interpreting correlations between plastic ingestion and body condition, because individuals may ingest more plastic because they are in poor body condition, rather than vice versa (Ryan 1987b, Auman et al. 1997).

The impact of reduced stomach volume is most likely to be detected in birds with very large plastic loads. Species that do not regurgitate indigestible prey remains are most likely to demonstrate this effect, and among these species, chicks are particularly susceptible if they are fed by regurgitation, because they receive stored plastic from both parents (e.g. Ryan 1988a, Rodríguez et al. 2012). However, plastic loads in wild birds are right skewed (Ryan 2016), so even among populations where almost all individuals contain some plastic, relatively few birds are likely to contain sufficiently large plastic loads to greatly reduce stomach volume.

There is increasing concern about the impacts of very small plastic particles on organisms. Nanoparticles can migrate out of the digestive tract (Browne et al. 2008), or enter animals across respiratory surfaces (Watts et al. 2014), possibly disrupting cellular metabolic pathways at the sub-micron scale (Lundqvist et al. 2008). Ingestion of plastic particles <10μm diameter reportedly altered the activity levels and foraging behaviour of fish in experimental trials (Mattsson et al. 2015), but the mechanisms underpinning these changes are unclear. There are no studies of these possible impacts on birds.

2.3 Chemical Impacts of Ingestion

Ingested plastics can transfer other pollutants into marine organisms including persistent organic pollutants (POPs) and heavy metals that are either included in the plastics during manufacture or adsorb to them at sea (e.g. Teuten et al. 2009, Rochman et al. 2013a, Koelmans et al. 2014). This could be the most serious impact of plastic ingestion at a population level, but there is relatively little information on this issue for birds. There is some evidence that both legacy pollutants such as poly-chlorinated biphenyls (PCBs) and plastic-specific compounds such as polybrominated diphenyl ethers (PBDEs) and at least three phthalates (dimethyl, dibutyl and diethylhexyl phthalate) found in seabirds are derived from ingested plastics (Ryan et al. 1988, Hardesty et al. 2014, Tanaka et al. 2013, 2015). However, more information is needed on the importance of plastic dose and exposure period on the transfer of these pollutants to birds.

The rate at which pollutants leach out of contaminated plastics depends on the plastic polymer and the structure of the toxic compound, with half-lives for different PCB congeners diffusing into water ranging from 10-10,000 days (Endo et al. 2013). Leaching of toxic compounds is facilitated by oils in the stomach contents, and thus probably occurs more rapidly than these figures suggest. Leaching is expected to be most rapid in species such as petrels that use oils to transfer food to offspring during their protracted foraging trips (Tanaka et al. 2015). However, PBDE flame retardants still took several days to reach equilibrium in petrel stomachs (Tanaka et al. 2015). As a result, transfer of toxic compounds is likely to be most severe in species that accumulate ingested plastics rather than regurgitating indigestible prey remains. The release of toxic compounds incorporated into plastics during their manufacture is likely to be exacerbated if the plastic items are gradually eroded in the stomach, again suggesting that plastic ‘accumulators’ (cf. Figure 1) are most at risk. Interestingly, ingesting ‘clean’ plastics may offer a mechanism for birds to reduce POP loads. POP sorption-desorption from plastics follow simple diffusion dynamics, and thus plastics which contain few if any toxic compounds (e.g. food packaging) can take up POPs circulating in bird bodies.

There are no data on the transfer of POPs to freshwater birds from ingested plastic, but the more transient nature of plastic items in freshwater systems suggests that this mechanism is likely to be less important for freshwater bird species. Compounds such as flame retardants are mostly incorporated into user items, which are typically made of thick, rigid plastics that require long exposure to UV light in order to become brittle and fragment. As a result, they typically need to be in the environment for a long time to break up into fragments small enough to be ingested by birds or their prey. Similarly, the sorption of POPs onto plastic items requires substantial exposure periods (months-years; Mato et al. 2000, Rochman 2013b), and thus unless trapped in lakes or dams, most plastics probably are not retained in freshwater systems long enough to accumulate significant POP concentrations (cf. Wagner & Lambert 2018). Finally, legacy pollutants should be less of a problem in freshwater systems, because constant flushing should gradually transfer these long-lasting pollutants (which have been banned for decades under the Stockholm Convention) from freshwater systems into the sea.

3. Entanglement, Bycatch and Ghost Fishing

Entanglement of birds in plastic debris is more often reported than ingestion, but this mostly reflects the greater ease of detection of entanglement (Gall & Thompson 2015). The impacts of entanglement are also more obvious, including injury, impeded mobility (with consequences for the ability to obtain sufficient food or avoid predators) and drowning (Laist 1997, Kühn et al. 2015). As a result, a much higher proportion of entanglements can be linked to direct harm or death of individuals than can ingestion records (Gall & Thompson 2015).

Most entanglements result from fishing gear, with fishing line or netting accounting for the entanglement of at least 189 waterbird species globally (Table 3). It is often impossible to differentiate between captures in active or ‘ghost’ fishing gear. Birds found entangled in fishing line could have been caught by discarded line, or in active gear (Taylor 2004, Abraham et al. 2010). Records involving the ingestion of fishing hooks might probably be best treated as bycatch rather than entanglement or ingestion (Ryan 2018). However, some birds that are caught on light-weight fishing tackle either break free or are cut from the line and fly off, only to become entangled by the trailing line in trees or other vegetation (e.g. frigatebirds; Gauger Metz & Schreiber 2002, Tirtaningtyas & Hennicke 2015).

And in some instances, bycatch can result in the subsequent entanglement of other individuals (Figure 3). Similar problems of interpretation occur with fragments of gill nets that wash ashore containing birds (e.g. Good et al. 2009, Moore et al. 2009), or birds that break free from snares set to deliberately catch birds (Figure 4). Given the difficulty in teasing apart these various causes of entanglement, all cases involving fishing hooks/lines and fishing nets of indeterminate provenance have been included in this report as entanglement (Appendix 1). However, birds definitely caught in active fishing gear as well as netting designed to keep birds out of fish ponds have been excluded (Nemtzov & Olsvig-Whittaker 2003).

Figure 3. Three Cape Gannets (Morus capensis) *entangled in monofilament fishing line at Bird Island, Algoa Bay, in November 2006 (Leshia Upfold). The central bird was foul hooked by the red and white lure on its breast, and thus probably caught on active fishing gear (= bycatch), but the other two birds were presumably entangled subsequently. Camphuysen (1990a) reported how four Northern Gannets* (M. bassanus) *struggling to free themselves from a net fragment attracted other gannets that also became entangled*.

Reviews of seabird entanglement indicate that the number of species reported entangled in plastic items doubled from 51 species in the mid-1990s (Laist 1997) to 103 species by the end of 2014 (Kühn et al. 2015). Further species have been reported since then and combined with a search of Google Images there are now records for 144 species of seabirds (comparable to the groups covered by Laist 1997 and Kühn et al. 20015; PG Ryan unpubl. data). Across all birds, 255 species from 52 families were found to be entangled in synthetic materials, of which 211 were waterbirds (Table 3, PG Ryan unpubl. data). As Kühn et al. (2015) note, any waterbird is at risk from entanglement, and the number of affected species is bound to continue to increase. However, some families appear to be at greater risk than others. Across all seabirds, 35% of species have been recorded entangled, compared to only 10% of freshwater and coastal birds.

Darters (*Anhingidae*) are particularly prone to entanglement, thanks, in part, to their serrated bills which get caught on fibrous bags and ropes; all four species have been recorded entangled. All six AEWA-listed auks also have been recorded as entangled, sometimes in worryingly large numbers (Camphuysen 2000). Among other seabird families, more than half of all species have been recorded as entangled in the Gaviidae (loons 80%), Stercorariidae (skuas and jaegers 71%), Pelecanidae (pelicans 63%), Sulidae (gannets and boobies, 60%) and Fregatidae (frigatebirds 60%). Among coastal birds, Haematopodidae (oystercatchers) have the highest proportion of impacted species (45%). Entanglement rates are disproportionately low among the Rallidae (only 2% of rails, crakes and allies), although this might be partly due to the cryptic nature of many species in this family.

Fishing line is responsible for most entanglements among both marine and freshwater birds, whereas netting affects twice as many seabirds as freshwater and coastal birds (Table 3). Balloon strings also appear to be more problematic for seabirds, perhaps because those that end up freshwater systems tend to become caught in vegetation and are thus less likely to entangle birds. Kite strings are mainly a problem for land birds (particularly ‘manja’ kites in Asia; Babu et al. 2015). Other items frequently found to entangle birds include six-pack rings, plastic bags, lid rings and other ring-shaped items including packing straps and pipes (Table 3).

Table 3. The debris items responsible for entangling birds in different habitats, scored as the proportions of species entangled by different types of items (Ryan 2018).

	Seabirds		Freshwater birds		All waterbirds	
	n=147	%	n=69	%	n=216	%
Fishing gear*	128	88%	63	91%	191	88%
Fishing line	114	79%	57	83%	171	79%
Nets and netting	53	36%	12	17%	65	30%
Balloon strings	11	7%	3	4%	14	6%
Kite strings	1	1%	1	1%	2	1%
Other rope/string	16	11%	11	16%	27	13%
Six-pack ring	10	7%	5	7%	15	7%
Packing strap	5	3%	0	0%	5	2%
Bags	9	6%	4	6%	13	6%
Lid rings	5	3%	1	1%	6	3%
Other items	7	5%	8	12%	15	7%

* Fishing line and nets combined

For most bird species, entanglement is a rare event that is unlikely to impact a significant proportion of the population. One possible exception among AEWA-listed species is the Northern Gannet, which is fairly often observed entangled at sea (Camphuysen 1990a, Rodríguez et al. 2013). Rodríguez et al. (2013) found that entanglement rates at sea were greater for immature birds (1.9%) than adults (0.1%), and that entanglement was particularly common off Mauritania, where 20% of birds were observed with ropes or similar items caught on their bills. By comparison, entanglement rates farther north off Morocco and the Iberian Peninsula were only 0.0-0.4% (Rodríguez et al. 2013).

This is appreciably lower than the incidence of entanglement among stranded gannets in the North Sea (6-9% Camphuysen 2008 and data from the Assessment of Marine Debris on the Belgian Continental Shelf; vlis.be). However, the proportion of entangled stranded birds cannot be compared with the proportion observed at sea because entanglement probably significantly increases the risk of mortality (and thus washing ashore). In South Africa, there are at least two records of Cape Gannets (*Morus capensis*) that washed ashore with orange or red mesh bags caught on their bills, but entanglement has not been reported at sea. Rodríguez et al. (2013) also found red items to be involved in many of the entanglements of Northern Gannets, suggesting that gannets may mistake these items for potential prey, and become entangled by diving onto them. Alternatively, gannets may become entangled when they attempt to catch fish sheltering under floating debris. The risk of entanglement can be increased by utilizing plastic materials in nest construction, which Northern Gannets also do regularly (see Section 4).

Surveys of dead birds stranded on beaches provide a useful measure of relative entanglement risk, as well as a way to monitor long-term trends in entanglement. Overall, 27 species of birds stranded on the Netherlands and Belgian coasts were entangled, at an average rate of 0.24% of birds collected since 1970 (n = 550 of 225,500; Camphuysen 1990b, 2008, vlis.be). Gannets had the highest entanglement rate of all species (6-9%), followed by Great Cormorants (*Phalacrocorax carbo*) (1-3%), with >0.5% of Red-throated Loons (*Gavia stellate*), Great Black-backed Gulls (*Larus marinus*) and European Herring Gulls (*L. argentatus*). A large proportion of Brent Geese (*Branta bernicula*) stranded in Belgium were entangled (6%, vlis.be), but the sample size probably is small; none has been reported entangled in the Netherlands (Camphuysen 1990b, 2008). The entanglement rates of birds stranded on beaches in the Netherlands remained fairly constant from 1979-2003 (average 0.3% of all stranded birds) but increased markedly to 0.7% in 2004-2007 (Camphuysen 2008).

Apart from Northern Gannets, entanglement appears to be a relatively uncommon event for most AEWA-listed species. Deliberate trapping of birds for food (Figure 4) and accidental bycatch in fishing gear probably greatly exceeds the impact of entanglement on AEWA-listed waterbirds.

Figure 4. A Squacco Heron Ardeola ralloides *killed in a snare probably designed to catch birds in Benguelu Swamp, Zambia, in May 2011 (Peter Ryan). Birds escaping from such snares could be recorded as entangled.*

4. Use as Nest Material

Less is reported about the use of plastics in waterbird nests than ingestion or entanglement, perhaps in part because it is perceived to have little impact on birds. However, this is not always the case; plastic debris in Northern Gannet nests causes mortality through entanglement at some colonies (Camphuysen 1990a, Montevecchi 1991, Votier et al. 2011). At the large Northern Gannet colony on Grassholm, Wales, most nests contain some plastic items, resulting in the entanglement of 33-110 individuals per year, most of which would die if not freed (Votier et al. 2011).

Most entangled birds are fledglings, but some adults also are affected. Rope and netting dominated the average 470 g of plastic per nest at this site (range 0-1293 g; Votier et al. 2011). Entanglement in synthetic nesting material, leading to the death of seabirds, has also been reported for fledgling Kelp Gulls (*Larus dominicanus*) (Witteveen et al. 2017) and at least one endangered Bank Cormorant (*Phalacrocorax neglectus*) chick (Robinson et al. 2012).

It is not clear whether birds actively select plastic items to include in their nests. The evidence from Kelp Gulls suggests that the use of plastics is largely opportunistic, because the main factor determining the amount of plastic used in nest construction is the availability of nest building materials in the immediate vicinity of the nest site (Witteveen et al. 2017). At well-vegetated sites, little plastic is used in nest construction, whereas plastics are used regularly where gulls breed on open dunes close to the strand line (Figure 5). In the latter situations, they tend to choose long, thin items with which to build their nests, such as ropes and fishing line, which pose the greatest threat to gulls in terms of entanglement.

However, Common Noddies (*Anous stolidus*) breeding at Inaccessible Island occasionally include short lengths of green rope in their nests (PGR pers. obs.). No other plastics have been recorded in their nests, and they sometimes drape the ropes near the nest rather than incorporating them into the nest structure, suggesting that they specifically select for this type of debris (see cover image). Lavers et al. (2013) found no evidence of selection for the type of debris in Brown Booby (*Sula leucogaster*) nests compared to adjacent beach litter at Ashmore Reef in the Timour Sea. They reported a weak preference for black items (possibly because they resembled twigs), but their sample sizes were small.

Figure 5. A Kelp Gull Larus dominicanus *nest constructed largely from plastic at a site where there are few other natural materials for nest building; Strandfontein beach, December 2016 (Peter Ryan).*

Not all plastic items found in nests are used for nest construction. Species that regurgitate indigestible prey remains, such as gulls often end up with plastic items in their nests that were not used for the initial construction (Witteveen et al. 2017). This explains the presence of plastics at inland colonies far removed from local sources of plastic litter that could be used in nest construction.

The incidence of plastic in seabird nests may indicate regional differences in the availability of plastics. For example, Bond et al. (2012) found that the proportion of Northern Gannet nests that contain plastics in the Atlantic provinces of Canada ranges from 2-98% of nests and is correlated with local differences in fishing effort. In South Africa, Cape Gannets very seldom include plastics in their nests (systematic searches of 1,796 nests at five colonies found no plastics, but opportunistic observations have recorded occasional pieces of rope in a few nests; DEA unpubl. data), which is consistent with their much lower rates of entanglement compared to Northern Gannets (see Section 3). Interestingly, the incidence of plastic in Australasian Gannet (*M. serrator*) nests in Australia is more similar to that in Northern Gannets (24-35%, Norman et al. 1995). The amount of regurgitated plastic in Kelp Gull nests is influenced by the proximity to human settlements, and particularly dump sites (Witteveen et al. 2017). However, caution is needed in interpreting such patterns, because as the Kelp Gull example shows, regional differences may be influenced as much by differences in the availability of natural nesting material as by the abundance of plastic material in the immediate vicinity of the colony, and a similar pattern has been found among Brown Boobies (Lavers et al. 2013).

Assuming the availability of natural material is more or less constant at a site, monitoring plastic in birds' nests over successive seasons offers a useful way to track changes in the relative abundance of plastics in the environment (Ryan et al. 2009). For example, the proportion of Black-legged Kittiwake nests containing plastic at a colony in Denmark increased from 39% in 1992 to 57% in 2005 (Hartwig et al. 2007). However, comparisons need to take place at the same stage of the breeding season, because of the often transient nature of nests (Lavers et al. 2013) and the addition of regurgitated plastics by some species during the breeding cycle (Witteveen et al. 2017).

Little has been reported about the incidence of plastic in the nests of waterbirds other than seabirds, although it probably is regular at least at some sites. In Korea, a juvenile Black-faced Spoonbill (*Platalea minor*) was found entangled in plastic 'string', possibly obtained in the nest environment (Hong et al. 2013). Subsequent conservation actions, including the provision of additional natural nesting material, have reduced the amount of plastic in the nests of this endangered species (Lee et al. 2015). There are numerous internet records of ospreys (*Pandion* spp.) becoming entangled in plastic items used in nest construction (see also Laist 1997).

5. Summary of Plastic Interactions with AEWA Waterbirds

The Online Supplement 1 in Kühn et al. (2015) provides a comprehensive review of ingestion and entanglement records for seabirds globally and was used for the starting point for a summary of plastic interactions between AEWA waterbirds and plastics (Appendix 1). More recently, O'Hanlon et al. (2017) summarised plastic interactions for north-east Atlantic seabirds. There are no reviews of plastic interactions with freshwater bird species (cf. Wagner and Lambert 2018), so a literature search was conducted using a diverse array of search terms to locate as many published records as possible.

Entanglement tends to be a fairly rare event, but the graphic nature of entanglements lends them to being recorded by members of the public. Accordingly, I used Google searches (initially focusing on Google Images, but then more broadly) to locate entanglement records that had not been published or captured in reviews to date. Google Images can be a useful resource for collecting biologically relevant data (e.g. on the distribution and abundance of colour morphs, see Leighton et al. 2016). This generated not only data on freshwater species, but also some seabirds that had not been reported to be entangled before, including the first record from a tropicbird (Red-billed Tropicbird (*Phaethon aethereus*) in Bermuda).

Of the 254 AEWA-listed waterbird species, 57 (22%) have been recorded to contain ingested plastic, 79 (31%) to be entangled in plastic debris, and 20 (8%) to use plastic items in their nests (Table 4, Appendix 1). Overall, 102 species (40%) have some recorded interaction with plastics, but these are almost certainly underestimates. Most data come from Europe and South Africa, with few data from other parts of the AEWA region, and more is known about the interactions of seabirds with plastics than freshwater birds. Not all species have been checked for plastics, and sample sizes for other species are too small to have a reasonable chance of detecting rare events.

As Kühn et al. (2015) noted, all waterbirds are at risk from entanglement, and given the increasingly ubiquitous occurrence of plastics in aquatic ecosystems, it is almost inevitable that all waterbirds ingest some plastics if only through eating contaminated prey. Only where there has been a reasonable search effort and no plastics detected, is there some degree of confidence in the absences in Appendix 1. For example, no ingested plastic has been found in 67 Arctic Terns (*Sterna paradisaea*) (Ainley et al. 1990, Moser & Lee 1992, Provencher et al. 2014). By comparison, there are no records of anyone having checked White-cheeked Terns (*S. repressa*) for ingested plastic, and thus the absence of ingestion records for this species is less meaningful than the absence from Arctic Terns.

At a family/sub-family level, the proportion of species recorded to ingest plastic is highest in the skuas and auks, with more than 50% of tropicbird, loon, sulid and gull species recorded to ingest plastic (Table 4). However, the average proportion of individuals containing plastic in most of these groups is low (<10%, Table 1), and in some species includes bycatch on fishing lines (e.g. loons). Among AEWA-listed species, the two phalaropes (and especially Red Phalarope (*Phalaropus fulicarius*) are probably most at risk from ingestion. There are few data on these species from the AEWA region, but globally, 46% of marine phalaropes have been found to contain plastic (Table 1), often containing large accumulated plastic loads that might reduce meal size and promote the transfer of toxic compounds. Connors and Smith (1982) reported lower body condition among phalaropes containing ingested plastic but plastic ingestion may simply be consequence of poor condition (see Section 2.1).

Some dabbling duck populations have also been reported to have >40% of individuals with ingested plastic (English et al. 2015, Gil-Delgado et al. 2017), but the impacts on these species are unclear, with much of the plastic probably being excreted soon after ingestion. The only other taxa in which at least 10% of birds contain ingested plastic are gulls (15%), skuas (14%) and auks (10%; Table 1). Gulls and skuas regularly regurgitate pellets of indigestible prey and thus probably ingest plastic items more often than this figure suggests, especially near urban areas (gulls) or when breeding in burrowing petrel colonies (skuas). Shorebirds appear to seldom ingest plastics – at least in terms of fragments large enough to readily detect in stomach contents (Tables 2 and 4).

Table 4. The proportions of AEWA-listed waterbird species reported to ingest plastic items, be entangled in them, or use them in their nests, summarised by family or sub-family (see Appendix 1 for species-level details and sources). Proportions of affected species are minimum estimates because not all species have been checked for interactions with plastic items.

Family	n species	Ingestion		Entanglement		Nest material	
		n	%	n	%	n	%
Anatidae (ducks, geese, swans)	51	11	22%	17	33%	1	2%
Podicipedidae (grebes)	5	0	0%	2	40%	0	0%
Phoenicopteridae (flamingos)	2	0	0%	0	0%	0	0%
Phaethontidae (tropicbirds)	3	2	67%	1	33%	0	0%
Rallidae (rails, gallinules, coots)	17	1	6%	1	6%	1	6%
Gruidae (cranes)	7	0	0%	1	14%	0	0%
Gaviidae (loons/divers)	4	3	75%	3	75%	0	0%
Spheniscidae (penguins)	1	0	0%	1	100%	1	100%
Ciconiidae (storks)	7	0	0%	2	29%	1	14%
Threskiornithidae (ibises, spoonbills)	5	0	0%	1	20%	1	20%
Ardeidae (herons)	17	2	12%	4	24%	2	12%

Balaenicipitidae (shoebill)	1	0	0%	0	0%	0	0%
Pelecanidae (pelicans)	3	1	33%	1	33%	1	33%
Fregatidae (frigatebirds)	2	1	50%	1	50%	0	0%
Sulidae (gannets, boobies)	3	2	67%	3	100%	2	67%
Phalacrocoracidae (cormorants)	6	3	50%	4	67%	4	67%
Burhinidae (thick-knees)	1	0	0%	0	0%	0	0%
Pluvianidae (Egyptian Plover)	1	0	0%	0	0%	0	0%
Haematopodidae (oystercatchers)	2	0	0%	2	100%	0	0%
Recurvirostridae (avocets, stilts)	2	0	0%	0	0%	0	0%
Charadriidae (plovers)	25	0	0%	3	12%	0	0%
Scolopacidae (sandpipers & allies)	31	3	10%	5	16%	0	0%
Dromadidae (Crab-plover)	1	0	0%	0	0%	0	0%
Glareolidae (coursers, pratincoles)	5	0	0%	0	0%	0	0%
Laridae (gulls, terns, skimmers)	44	20	45%	20	45%	6	14%
Gulls	22	14	64%	10	45%	3	14%
Terns, noddies, skimmers	22	6	27%	10	45%	3	14%
Stercorariidae (skuas)	2	2	100%	1	50%	0	0%
Alcidae (auks)	6	6	100%	6	100%	0	0%
Total	254	57	22%	79	31%	20	8%

Among the more speciose families, entanglement is most frequently recorded for sulids, cormorants, auks, and gulls and terns (Table 4). Northern Gannets in particular are frequently entangled, both at their colonies and at sea (see Sections 4 and 5), and auks may be killed in substantial numbers at least locally by ghost fishing (Camphuysen 2000). African Penguins (*Spheniscus demersus*) experienced high rates of entanglement in the 1980s (28% of 32 stranded birds entangled, Ryan 1990b), but are now very seldom found entangled (L. Pichegru pers. comm., pers. obs.). The relatively high proportion of species recorded to be entangled among loons and grebes reflects the inclusion of bycatch records. Bycatch on fishing gear is a significant problem for some waterfowl species, particularly Mute Swans (*Cygnus olor*) (Perrins et al. 2002). Plastic contamination of waterbird plumage was ignored in this summary, but microfibres have been found on the plumage of several duck species at higher frequencies than in their faeces (Reynolds & Ryan 2018).

The relatively low incidence of AEWA-listed species recorded to incorporate plastics in their nests probably reflects in part under-reporting of this phenomenon. Gannets and cormorants are the species that most often include plastic materials in their nests, although all species that construct nests from vegetation probably include some plastic materials at least occasionally.

6. Monitoring Plastic Interactions with Birds

Monitoring plastic interactions with birds provides a valuable tool for tracking changes in the amounts and types of plastics in aquatic ecosystems (Ryan et al. 2009). Because the species most likely to be impacted by ingested plastic accumulate most plastics in the gizzard, it is hard to sample their plastic loads non-destructively. The most reliable way to assess the amounts of ingested plastic is to examine the contents of the digestive tract from intact dead birds. Stomach pumping or emetics can be used, but neither approach reliably recovers all the ingested plastic (e.g. Ryan & Jackson 1987), and emetics in particular can cause mortality (Bond & Lavers 2013). Hunted species, or those killed accidentally (e.g. fishery bycatch), offer the opportunity to regularly examine adequate samples of individuals without having to resort to destructive sampling specifically to assess plastic loads (e.g. Bond et al. 2013).

Birds found dead, such as stranded seabirds, also provide useful information. The amounts of plastic in stranded Northern Fulmars is used as one of the Ecological Quality Objectives (EcoQOs) by OPSAR, the Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (van Franeker & Law 2015). Specifically, the policy target for an ecologically acceptable level of plastic litter in the North Sea is defined as fewer than 10% of stranded Fulmars in the North Sea having more than 0.1 g of plastic (OSPAR 2010).

However, stranded birds are a non-random sample of the population; their levels of interactions with plastics might be inflated if the interactions increase the chance of death (e.g. starvation resulting from blockage of the digestive tract) or the birds display abnormal behaviour prior to dying (e.g. during storms, birds might ingest more plastic because they are starving). As a result, comparisons of rates of interaction with randomly sampled birds need to be interpreted with caution. However, birds found dead have the advantage of being able to assess whether plastics have contributed directly to the cause of death (e.g. through blocking the digestive tract).

For species that regularly regurgitate indigestible prey remains such as gulls and skuas, checking pellets for plastic offers a valuable tool to track plastic interactions. This approach can use citizen scientists to sort the pellets provided they are well trained (Lindborg et al. 2012). However, the pellets have to be collected while still intact, and with due care to exclude plastic contamination from environmental sources after regurgitation. Fresh faecal samples also could be sampled for plastics (e.g. Provencher et al. in press), but here the risk of environmental contamination is even greater, and great care is needed in processing samples (cf. Hermsen et al. 2017).

Sampling preen gland oil offers a non-destructive method for monitoring the composition and concentrations of plastic-associated toxic compounds in birds, but the volumes of preen oil available are limited, especially for small birds, presenting significant analytical challenges. Great care has to be taken to avoid contamination of samples (Hardesty et al. 2014). Sampling adipose tissue from dead birds allows larger samples to be taken, with less risk of contamination (Tanaka et al. 2013, 2015).

Entanglement tends to occur infrequently in most species, making it hard to detect changes in rate over time. However, long-term data series of stranded beach birds provide a valuable tool to track changes in entanglement rates among species such as Northern Gannets and gulls (Camphuysen 2008). Numerous novel entanglement records were obtained for this review by searching the internet, particularly Google images. Setting up a website to encourage members of the public to submit images of entangled birds might prove a valuable tool to track the problem, while also raising awareness among members of the public of the dangers posed by plastic litter. Monitoring plastic use in nests, particularly among colonial species, offers a simple, non-destructive method to estimates encounter rates with plastic debris. However, comparisons need to be made of the same colonies, as local conditions (particularly the availability of natural nesting material) play an important role in determining the incidence of plastic in nests.

Conclusions and Recommendations

Many waterbirds interact with plastics through ingestion, entanglement or use of plastics in nest construction, but there is currently no evidence of population-level impacts for AEWA-listed species. Of the potential pathways for impact, plastic ingestion probably has the greatest impact at a population level, but few AEWA-listed species accumulate large plastic loads and there are few records of blockage or injury to the digestive tract. Phalaropes are probably most at risk from plastic ingestion because they accumulate large plastic loads in their stomachs, thus potentially reducing meal size and promoting the transfer of toxic compounds.

However, both AEWA-listed species are listed as Least Concern by the IUCN Red List of Threatened Species, and there is no evidence that plastics are having a population-level impact on these species.
High levels of ingested plastic have been reported from a few duck species, but they probably don't retain them long enough to have a major impact on their health. More information is needed on the residence time of ingested plastics in the digestive tracts of birds, given the importance of this parameter for the dynamics of ingested plastic (Section 2.1), the accumulation of sufficient loads to reduce meal size (Section 2.2), and the transfer of toxic compounds (Section 2.3).

More data also are need on plastic ingestion by freshwater bird species. Despite increasing amounts of plastic being produced annually, there is little evidence of an increase in the incidence of plastic ingestion over the last few decades in seabird species that regularly ingest plastics (e.g. Vlietstra & Parga 2000, Ryan 2008, Bond et al. 2013, van Franeker & Law 2015).

Quite why ingested plastic loads among seabirds have not continued to increase since the 1980s is unclear (Ryan et al. 2009). Reducing the risks of plastic ingestion is complicated by the wide range of items ingested by birds. <u>The most effective measure is to support broad-scale programmes to reduce the amounts of waste plastic entering the environment.</u>

All waterbirds are at risk of entanglement, and this might be problematic for species such as the Northern Gannet, which locally can have up to 20% of birds entangled (but generally the frequency of entanglement is much lower, and the species is listed as Least Concern). Entanglement rates of birds may have increased in the North Sea since 2003, but appear to have decreased off South Africa, at least for African Penguins. Entanglement typically involves a more limited suite of plastic products, and thus allows for more focused mitigation measures.

Effective steps to reduce entanglement include:

- <u>banning high-risk applications where there are other alternatives</u> (e.g. six-pack rings were replaced with shrink wrap in South Africa in the 1980s due to the risk of entanglement);
- <u>discouraging the use of high-risk items</u> (e.g. balloons on strings); and
- <u>educating users not to discard particularly risky materials such as waste fishing gear by providing specific receptacles</u> (and associated educational signage/campaigns) in areas frequented by recreational fishers or providing direct incentives to commercial fishers to return damaged gear to port.

The impact of bycatch on fishing lines can be reduced by educating fishers how best to deal with hooked or entangled birds. However, the impact of entanglement on AEWA-listed species probably is minor compared to accidental bycatch in fishing gear as well as deliberate catching of birds.

Specific programmes to monitor plastic ingestion rates among AEWA-listed species probably are not necessary at this stage but establishing baseline estimates for more species would be useful. Standardised surveys of stranded seabirds that record entanglement and ingestion rates provide a relatively cheap way to track changes in these impacts and should be encouraged.

Monitoring the use of plastic in nest material is another effective monitoring tool, provided comparisons are made within colonies. More data are needed on accidental entanglement, bycatch and targeted captures of waterbirds from developing countries in the AEWA region, because most data presented in this report are from western Europe and South Africa.

References

Abraham ER, Berkenbusch KN, Richard Y. 2010. The capture of seabirds and marine mammals in New Zealand non-commercial fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 64. Ministry of Fisheries, Wellington.

Ainley DG, Fraser WR, Spear LB. 1990. The incidence of plastics in the diets of Antarctic seabirds. Proc. Second Int. Conf. on Marine Debris, NOAA Tech. Mem., NMFS, SWFC 154: 682-691.

Andrady AL, Neal MA. 2009. Applications and societal benefits of plastics. Phil. Trans. R. Soc. B 364: 1977-1984.

Auman HJ, Ludwig JP, Giesy JP, Colborn T. 1997. Plastic ingestion by Laysan Albatross chicks on Sand Island, Midway Atoll, in 1994 and 1995. Pp. 239-244 in Robinson G, Gales R (Eds), Albatross Biology and Conservation. Surrey Beatty and Sons, Chipping Norton.

Babu S, Subramanya S, Dilawar M. 2015. Kite flying: effect of Chinese manja on birds in Bangalore, India. Indian Birds 10(1): 13-18.

Bond AL, Lavers JL. 2013. Effectiveness of emetics to study plastic ingestion by Leach’s Storm-petrels (*Oceanodroma leucorhoa*). Mar. Pollut. Bull. 70: 171-175.

Bond AL, Montevecchi WA, Guse N, Regular PM, Garthe S, Rail JF. 2012. Prevalence and composition of fishing gear debris in the nests of northern gannets (*Morus bassanus*) are related to fishing effort. Mar. Pollut. Bull. 64: 907-911.

Bond AL, Provencher JF, Elliot RD, Ryan PC, Rowe S, Jones IL, Robertson GJ, Wilhelm SI. 2013. Ingestion of plastic marine debris by common and thick-billed murres in the northwestern Atlantic from 1985 to 2012. Mar. Pollut. Bull. 77: 192-195.

Browne MA, Dissanayake A, Galloway TS, Lowe DM, Thompson RC. 2008. Ingested microscopic plastic translocates to the circulatory system of the mussel, *Mytilus edulis* (L). Environ. Sci. Technol. 42: 5026–5031.

Buxton RT, Currey CA, Lyver POB, Jones CJ. 2013. Incidence of plastic fragments among burrow-nesting seabird colonies on offshore islands in northern New Zealand. Mar. Pollut. Bull. 74: 420-424.

Camphuysen CJ. 1990a. Jan van Genten *Sula bassana* en plastics: waarnemingen op zee en op de kolonie. Sula 4: 66-70.

Camphuysen CJ. 1990b. Verstrikkingen van zeevogels in plastics: een probleem van toenemende omvang? Sula 4: 12-18.

Camphuysen CJ. 2000. Seabirds drowned in fishing nets off Jan Mayen (Greenland Sea). Atlantic Seabirds 2: 87-91.

Camphuysen CJ. 2008. Verstrikkingen van zeevogels in zwerfvuil en vistuig, 1970-2007. Sula 21: 88-92.

Collard F, Gilbert B, Compère P, Eppe G, Das K, Jauniaux T, Parmentier E. 2017. Microplastics in livers of European anchovies (*Engraulis encrasicolus*, L.). Environ. Pollut. 229: 1000-1005.

Compa M, Ventero A, Iglesias M, Deudero S. 2018. Ingestion of microplastics and natural fibres in *Sardina pilchardus* (Walbaum, 1792) and *Engraulis encrasicolus* (Linnaeus, 1758) along the Spanish Mediterranean coast. Mar. Pollut. Bull. 128: 89-96.

Connors PG, Smith KG. 1982. Oceanic plastic particle pollution: Suspected effect on fat deposition in Red Phalaropes. Mar. Pollut. Bull. 13: 18–20.

Day RH, Wehle DHS, Coleman FC. 1985. Ingestion of plastic pollutants by marine birds. Proc. Workshop Fate Impact of Marine Debris, NOAA Tech Memo. NMFS, NOAA-TM-NMFS-SWFC-54: 344-386

Dell'Ariccia G, Phillips RA, van Franeker JA, Gaidet N, Catry P, Granadeiro JP, Ryan PG, Bonadonna F. 2017. Does DMS build-up really explain plastic ingestion by seabirds? A comment on Savoca et al. (2016). Sci. Adv. 3, e1700526.

Di M, Wang J. 2018. Microplastics in surface waters and sediments of the Three Gorges Reservoir, China. Sci. Total Environ. 616: 1620-1627.

Dickerman RW, Goelet RG. 1987. Northern Gannet starvation after swallowing styrofoam. Mar. Pollut. Bull. 18: 293.

Eerkes-Medrano D, Thompson RC, Aldridge DC. 2015. Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Research 75: 63-82.

Endo S, Yuyama M, Takada H. 2013. Desorption kinetics of hydrophobic organic contaminants from marine plastic pellets. Mar. Pollut. Bull. 74:125-131.

English MD, Robertson GJ, Avery-Gomm S, Pirie-Hay D, Roul S, Ryan PC, Wilhelm SI, Mallory ML. 2015. Plastic and metal ingestion in three species of coastal waterfowl wintering in Atlantic Canada. Mar. Pollut. Bull. 98: 349-353.

Eriksen M, Mason S, Wilson S, Box C, Zellers AF, Edwards W, Farley H, Amato, S. 2013. Microplastic pollution in the surface waters of the Laurentian Great Lakes. Mar. Pollut. Bull. 77: 177-182.

Faure F, Corbaz M, Baecher H, De Alencastro LF. 2012. Pollution due to plastics and microplastics in Lake Geneva and in the Mediterranean Sea. Arch. Sci. 65: 157-164.

Faure F, Demars C, Wieser O, Kunz M, de Alencastro LF. 2015. Plastic pollution in Swiss surface waters: nature and concentrations, interaction with pollutants. Environ. Chem. 12: 582-591.

Fife DT, Robertson GJ, Shutler D, Braune BM, Mallory ML. 2015. Trace elements and ingested plastic debris in wintering dovekies (*Alle alle*). Mar. Pollut. Bull. 91: 368-371.

Gall SC, Thompson RC. 2015. The impact of debris on marine life. Mar. Pollut. Bull. 92: 170-179.

Gauger Metz VH, Schreiber EA. 2002. Great Frigatebird *Fregata minor*, version 2.0. In: The Birds of North America (eds Poole AF, Gill FB). Cornell Lab of Ornithology, Ithaca, NY.

GESAMP. 2015. Sources, fate and effects of microplastics in the marine environment: a global assessment (ed. Kershaw PJ). IMO/FAO/UNESCO-IOC/UNIDO/WMO/ IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. Rep. Stud. GESAMP No. 90, 96 pp.

Geyer R, Jambeck JR, Law KL. 2017. Production, use, and fate of all plastics ever made Sci. Adv. 3: e1700782.

Gil-Delgado JA, Guijarro D, Gosálvez RU, López-Iborra GM, Ponz A, Velasco A. 2017. Presence of plastic particles in waterbirds faeces collected in Spanish lakes. Environ. Pollut. 220: 732-736.

Good TP, June JA, Etnier MA, Broadhurst G. 2009. Ghosts of the Salish Sea: threats to marine birds in Puget Sound and the Northwest Straits from derelict fishing gear. Mar. Ornithol. 37, 67-76.

Gregory MR. 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Phil. Trans. R. Soc. B 364: 2013-2025.

Hammer S, Nager RG, Johnson PCD, Furness RW, Provencher JF. 2016. Plastic debris in great skua (*Stercorarius skua*) pellets corresponds to seabird prey species. Mar. Pollut. Bull. 103: 206–210.

Hardesty BD, Holdsworth D, Revill AT, Wilcox C. 2014. A biochemical approach for identifying plastics exposure in live wildlife. Methods Ecol. Evol. 6: 92-98.

Harper PC. 1979. Colour vision in the Procellariiformes. Mauri Ora 7: 151-155.

Hartwig E, Clemens T, Heckroth M. 2007. Plastic debris as nesting material in a kittiwake (*Rissa tridactyla*) colony at the Jammerbugt, northwest Denmark. Mar. Pollut. Bull. 54: 595–597.

Hays H, Cormons G. 1974. Plastic particles found in tern pellets, on coastal beaches and at factory sites. Mar. Pollut. Bull. 5: 44-46.

Hermsen E, Pompe R, Besseling E, Koelmans AA. 2017. Detection of low numbers of microplastics in North Sea fish using strict quality assurance criteria. Mar. Pollut. Bull. 122: 253-258.

Holland ER, Mallory ML, Shutler D. 2016. Plastics and other anthropogenic debris in freshwater birds from Canada. Sci. Total Environ. 571: 251–258.

Hong S, Lee J, Jang YC, Kim YJ, Kim HJ, Han D, Hong SH, Kang D, Shim, WJ. 2013. Impacts of marine debris on wild animals in the coastal area of Korea. Mar. Pollut. Bull. 66: 117-124.

Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady A, Narayan R, Law KL. 2015. Plastic waste inputs from land into the ocean Science 347: 768-771.

Koelmans AA, Besseling E, Foekema EM. 2014. Leaching of plastic additives to marine organisms. Environ. Pollut. 187: 49-54.

Kühn S, Rebolledo ELB, van Franeker JA. 2015. Deleterious effects of litter on marine life. Pp 75-116 in Marine Anthropogenic Litter (eds Bergmann M, Gutow L, Klages M). Springer Open, Cham.

Lavers, JL, Bond AL, Hutton I. 2014. Plastic ingestion by Flesh-footed Shearwaters (*Puffinus carneipes*): Implications for fledgling body condition and the accumulation of plastic-derived chemicals. Environ. Pollut. 187: 124-129.

Laist DW. 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. Pp. 99-139 in: Marine Debris: Sources, Impacts, and Solutions (eds Coe JM, Rogers DB). Springer-Verlag, New York.

Lavers JL, Hodgson JC, Clarke RH. 2013. Prevalence and composition of marine debris in brown booby (*Sula leucogaster*) nests at Ashmore Reef. Mar. Pollut. Bull. 77: 320-324.

Lavers, JL, Bond AL, Hutton I. 2014. Plastic ingestion by Flesh-footed Shearwaters (*Puffinus carneipes*): Implications for fledgling body condition and the accumulation of plastic-derived chemicals. Environ. Pollut. 187: 124-129.

Lebreton LCM, van der Zwet J, Damsteeg J-W, Slat B, Andrady A, Reisser J. 2017. River plastic emissions to the world's oceans. Nature Comm. 8:15611.

Lee K, Jang YC, Hong S, Lee J, Kwon IK. 2015. Plastic marine debris used as nesting materials of the endangered species Black-faced Spoonbill *Platalea minor* decreases by conservation activities. J. Korean Soc. Mar. Environ. Energy 18: 45-49.

Leighton GRM, Hugo PS, Roulin A, Amar A. 2016. Just Google it: assessing the use of Google Images to describe geographical variation in visible traits of organisms. Methods Ecol. Evol. 7: 1060-1070.

Lindborg VA, Ledbetter JF, Walat JM, Moffett C. 2012. Plastic consumption and diet of Glaucous-winged Gulls (*Larus glaucescens*). Mar. Pollut. Bull. 64: 2351-2356.

Lundqvist M, Stigler J, Elia G, Lynch I, Cedervall T, Dawson KA. 2008. Nanoparticle size and surface properties determine the protein corona with possible implications for biological impacts. Proc. Natl Acad. Sci. USA 105: 14265-14270.

Mato Y, Isobe T, Takada H, Kanehiro H, Ohtake C, Kaminuma T. 2000. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environ. Sci. Technol. 35: 318-324.

Mattsson K, Ekvall MT, Hansson L-A, Linse S, Malmendal A, Cedervall T. 2015. Altered behavior, physiology, and metabolism in fish exposed to polystyrene nanoparticles. Environ. Sci. Tech. 49: 553-561.

McCauley SJ, Bjorndal KA. 1999. Conservation implications of dietary dilution from debris ingestion: sublethal effects in post-hatchling Loggerhead Sea Turtles. Conserv. Biol. 13: 925-929.

Montevecchi WA. 1991. Incidence and types of plastic in gannets' nests in the Northwest Atlantic. Can. J. Zool. 69: 295-297.

Moore E, Lyday S, Roletto J, Litle K, Parrish JK, Nevins H, Harvey J, Mortenson J, Greig D, Piazza M, Hermance A, Lee D, Adams D, Allen S, Kell S. 2009. Entanglement of marine mammals and seabirds in central California and the north-west coast of the United States 2001-2005. Mar. Pollut. Bull. 58: 1045-1051.

Moser ML, Lee DS. 1992. A 14-year survey of plastic ingestion by western North Atlantic seabirds. Colonial Waterbirds 15: 83-94.

Murphy F, Russell M, Ewins C, Quinn B. 2017. The uptake of macroplastic & microplastic by demersal & pelagic fish in the Northeast Atlantic around Scotland. Mar. Pollut. Bull. 122: 353-359.

Nemtzov SC, Olsvig-Whittaker L. 2003. The use of netting over fishponds as a hazard to waterbirds. Waterbirds 26: 416-423.

Norman F, Menkhorst P, Hurley V. 1995. Plastics in nests of Australasian gannets *Morus serrator* in Victoria, Australia. Emu 95: 129-133.

O'Hanlon NJ, James NA, Masden EA, Bond AL. 2017. Seabirds and marine plastic debris in the northeastern Atlantic: A synthesis and recommendations for monitoring and research. Environ. Pollut. 231: 1291-1301.

Onions C, Rees G. 1992. An assessment of the environmental impacts of carriers discarded in the marine environment and the benefits derived from those fabricated from a photodegradable plastic giving enhanced degradability. The Tidy Group, Wigan.

OSPAR. 2010. The OSPAR System of Ecological Quality Objectives for the North Sea: a contribution to OSPAR's Quality Status Report 2010. OSPAR Publication 404/ 2009. OSPAR Commission, London.

Paijmans D, Stewart M. 2016. African Black Oystercatcher fatality as a result of fishing line. Biodiv. Obs. 7.27: 1-3.

Perrins C, Martin P, Broughton B. 2002. The impact of lost and discarded fishing line and tackle on Mute Swans. R&D Technical Report W1-051/TR C.

Petersen ES, Krüger L, Dezevieski A, Petry M, Montone RC. 2016. Incidence of plastic debris in sooty tern nests: a preliminary study on Trindade Island, a remote area of Brazil. Mar. Pollut. Bull. 105: 373-376.

Pettit TN, Grant GS, Whittow GC. 1981. Ingestion of plastics by Laysan Albatross. Auk 98: 839-841.

Phillips RA, Ridley C, Reid K, Pugh PJA, Tuck GN, Harrison N. 2010. Ingestion of fishing gear and entanglements of seabirds: Monitoring and implications for management. Biol. Conserv. 143: 501-512.

Pierce KE, Harris RJ, Larned LS, Pokras MA. 2004. Obstruction and starvation associated with plastic ingestion in a Northern Gannet *Morus bassanus* and a Greater Shearwater *Puffinus gravis*. Mar. Orn. 32: 187-189.

Provencher JF, Bond AL, Hedd A, Montevecchi WA, Muzaffar SB, Courchesne SJ, Gilchrist HG, Jamieson SE, Merkel FR, Falk K, Durinck J, Mallory ML. 2014. Prevalence of marine debris in marine birds from the North Atlantic. Mar. Pollut. Bull. 84: 411-417.

Provencher JF, Vermaire JC, Avery-Gomm S, Braune BM, Mallory ML. in press. Garbage in guano: microplastics found in fecal precursors of seabirds known to ingest plastics. Sci. Total Environ.

Rapp DC, Youngren SM, Hartzell P, Hyrenbach KD. 2017. Community-wide patterns of plastic ingestion in seabirds breeding at French Frigate Shoals, Northwestern Hawaiian Islands. Mar. Pollut. Bull.123: 269-278.

Reynolds C, Ryan PG. 2018. Micro-plastic ingestion by waterbirds from contaminated wetlands in South Africa. Mar. Pollut. Bull. 126: 330-333.

Robards MD, Gould PJ, Piatt JF. 1997. The highest global concentrations and increased abundance of oceanic plastic debris in the North Pacific: evidence from seabirds. Pp. 71-80 in: Marine Debris: Sources, Impacts, and Solutions (eds Coe JM, Rogers DB). Springer-Verlag, New York.

Robinson KJ, Meyer C, Underhill LG, Calder J-L. 2012. Bank Cormorant chick entangled in fishing line dies after more than 88 hours. Biodiv. Obs. 3: 188-194.

Rochman CM, Hoh E, Kurobe T, Teh SJ. 2013a. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Sci. Rpts 3: 3263.

Rochman CM, Hoh E, Hentschel BT, Kaye S. 2013b. Long-term field measurement of sorption of organic contaminants to five types of plastic pellets: implications for plastic marine debris. Environ. Sci. Technol. 47: 1646-1654.

Rodríguez A, Rodríguez B, Carrasco MN. 2012. High prevalence of parental delivery of plastic debris in Cory's Shearwaters (*Calonectris diomedea*). Mar. Pollut. Bull. 64: 2219–2223.

Rodríguez B, Bécares J, Rodríguez A, Arcos JM. 2013. Incidence of entanglement with marine debris by northern gannets (*Morus bassanus*) in the non- breeding grounds. Mar. Pollut. Bull. 75: 259-263.

Robinson KJ, Meyer C, Underhill LG, Calder J 2012. Bank Cormorant chick entangled in fishing line dies after more than 88 hours. Ornith. Obs. 3: 188-194.

Rummel CD, Löder MGJ, Fricke NF, Lang T, Griebeler E-M, Janke M, Gerdts G. 2016. Plastic ingestion by pelagic and demersal fish from the North Sea and Baltic Sea. Mar. Pollut. Bull. 102: 134-141.

Ryan PG. 1987a. The incidence and characteristics of plastic particles ingested by seabirds. Mar. Environ. Res. 23: 175-206.

Ryan PG. 1987b. The effects of ingested plastic on seabirds: correlations between plastic load and body condition. Environ. Pollut. 46: 119-125.

Ryan PG. 1988a. Intraspecific variation in plastic ingestion by seabirds and the flux of plastic through seabird populations. Condor 90: 446-452.

Ryan PG. 1988b. Effects of plastic ingestion on seabird feeding: evidence from chickens. Mar. Pollut. Bull. 19: 125-128.

Ryan PG. 1990a. The effects of ingested plastic and other marine debris on seabirds. Proc. Second Int. Conf. on Marine Debris, NOAA Tech. Mem., NMFS, SWFC 154: 623-634.

Ryan PG. 1990b. The marine plastic debris problem off southern Africa: types of debris, their environmental effects, and control measures. Proc. Second Int. Conf. on Marine Debris, NOAA Tech. Mem., NMFS, SWFC 154: 85-102.

Ryan PG. 2008. Seabirds indicate decreases in plastic pellet litter in the Atlantic and south-western Indian Ocean. Mar. Pollut. Bull. 56: 1406-1409.

Ryan PG. 2015a. A brief history of marine litter research. Pp. 1-25 in: *Marine Anthropogenic Litter* (eds Bergmann M, Gutow L, Klages M). Springer International Publishing, Cham.

Ryan PG. 2015b. How quickly do albatrosses and petrels digest plastic particles? Environ. Pollut. 207: 438-440.

Ryan PG. 2016. Ingestion of plastics by marine organisms. In: *Hazardous Chemicals Associated with Plastics in the Environment* (eds Takada H, Karapanagioti HK). Springer, Berlin (32 pp). http://dx.doi.org/10.1007/698_2016_21.

Ryan PG. 2018. Entanglement of birds in plastics and other synthetic materials. Mar. Pollut. Bull. 135: 159-164.

Ryan PG, Fraser MW. 1988. The use of Great Skua pellets as indicators of plastic pollution in seabirds. Emu 88: 16-19.

Ryan PG, Jackson S. 1987. The lifespan of ingested plastic particles in seabirds and their effect on digestive efficiency. Mar. Pollut. Bull. 18: 217-219.

Ryan PG, Connell AD, Gardner BD. 1988. Plastic ingestion and PCBs in seabirds: is there a relationship? Mar. Pollut. Bull. 19: 174-176.

Ryan PG, Moore CJ, van Franeker JA, Moloney CL. 2009. Monitoring the abundance of plastic debris in the marine environment. Phil. Trans. R. Soc. B 364: 1999-2012.

Sanchez W, Bender C, Porcher J-M. 2014. Wild gudgeons (*Gobio gobio*) from French rivers are contaminated by microplastics: preliminary study and first evidence. Environ. Res. 128, 98-100.

Savoca MS, Wohlfeil ME, Ebeler SE, Nevitt GA. 2016. Marine plastic debris emits a keystone infochemical for olfactory foraging seabirds. Sci. Adv. 2: e1600395.

Spear LB, Ainley DG, Ribic CA. 1995. Incidence of plastic in seabirds from the tropical Pacific, 1984-1991: relation with distribution of species, sex, age, season, year and body weight. Mar. Environ. Res. 40: 123-146.

Tanaka K, Takada H, Yamashita R, Mizukawa K, Fukuwaka M, Watanuki Y. 2013. Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics. Mar. Pollut. Bull. 69: 219-222.

Tanaka K, Takada H, Yamashita R, Mizukawa K, Fukuwaka M, Watanuki Y. 2015. Facilitated leaching of additive-derived PBDEs from plastic by seabirds' stomach oil and accumulation in tissues. Environ. Sci. Technol. 49: 11799-11807.

Taylor GA. 2004. Beach patrol scheme: Seabirds found dead on New Zealand beaches, 1997-1999. Notornis 51: 176-191.

Teuten EL, Saquing JM, Knappe DRU, Barlaz MA, Jonsson S, Björn A, Rowland SJ, Thompson RC, Galloway TS, Yamashita R, Ochi D, Watanuki Y, Moore C, Viet PH, Tana TS, Prudente M, Boonyatumanond R, Zakaria MP, Akkhavong K, Ogata Y, Hirai H, Iwasa S, Mizukawa K, Hagino Y, Imamura A, Saha M, Takada H. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Phil. Trans. R. Soc. Lond. B 364: 2027-2045.

Tirtaningtyas FN, Hennicke JC. 2015. Threats to the critically endangered Christmas Island Frigatebird *Fregata andrewsi* in Jakarta Bay, Indonesia, and implications for reconsidering conservation priorities. Mar. Ornithol. 43: 137-140

UNEP. 2014. UNEP Year Book 2014: emerging issues update. United Nations Environment Programme, Nairobi.

van Franeker JA, Law KL. 2015. Seabirds, gyres and global trends in plastic pollution. Environ. Pollut. 203: 89-96.

van Franeker JA, Blaize C, Danielsen J, Fairclough K, Gollan J, Guse N, Hansen PL, Heubeck M, Jensen J-K, Le Guillou G, Olsen B, Olsen KO, Pedersen J, Stienen EWM, Turner DM. 2011. Monitoring plastic ingestion by the Northern Fulmar *Fulmarus glacialis* in the North Sea. Environ. Pollut. 159, 2609-2615.

Vliestra LS, Parga JA. 2002. Long-term changes in the type, but not amount, of ingested plastic particles in short-tailed shearwaters in the Southeastern Berin Sea. Mar. Pollut. Bull. 44: 945-955.

Votier SC, Archibald K, Morgan G, Morgan L. 2011. The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Mar. Pollut. Bull. 62: 168-172 .

Wagner M, Lambert S (eds). 2018. *Freshwater Microplastics: Emerging Environmental Contaminants?* Springer Open, Cham.

Watts AJR, Lewis C, Goodhead RM, Beckett SJ, Moger J, Tyler CR, Galloway TS. 2014. Uptake and retention of microplastics by the Shore Crab *Carcinus maenas*. Environ. Sci. Technol. 48: 8823-8830.

Witteveen M, Brown M, Ryan PG. 2017. Anthropogenic debris in the nests of Kelp Gulls in South Africa. Mar. Pollut. Bull. 114: 699-704.

Yamashita R, Takada H, Fukuwaka M, Watanuki Y. 2011. Physical and chemical effects of ingested plastic debris on Short-tailed Shearwaters, *Puffinus tenuirostris*, in the North Pacific Ocean. Mar. Pollut. Bull. 162: 2845-2849.

Young LC, Vanderlip C, Duffy DC, Afanasyev V, Shaffer SA. 2009. Bringing home the trash: do colony-based differences in foraging distribution lead to increased plastic ingestion in Laysan Albatrosses? PLoS ONE 4(10): e7623.

Appendix 1. List of AEWA species recorded to ingest (I) or be entangled (E) in plastic debris, or use plastic as nesting materials (N), based on references listed in Kühn et al. (2015), O'Hanlon et al. (2017) and Ryan (2018) unless otherwise indicated. Parentheses indicate records from outside the AEWA region. I* and E* indicates ingestion of fishing gear (hooks, lines, weights) or stranding in nets that could be considered accidental bycatch rather than plastic ingestion or entanglement.

Family ANATIDAE (ducks, geese, swans)					
Dendrocygna viduata	White-faced Whistling-duck		E		Paijmans & Stewart 2016
Dendrocygna bicolor	Fulvous Whistling-duck				
Thalassornis leuconotus	White-backed Duck				
Oxyura maccoa	Maccoa Duck				
Oxyura leucocephala	White-headed Duck		E		Google images
Cygnus olor	Mute Swan	I*	E	N	Faure et al. 2015, Google images
Cygnus cygnus	Whooper Swan	(I*)	E*		Hong et al. 2013, Google images
Cygnus columbianus	Tundra Swan				
Branta bernicla	Brent Goose		E		Google images
Branta leucopsis	Barnacle Goose				
Branta ruficollis	Red-breasted Goose				
Anser anser	Greylag Goose				
Anser fabalis	Bean Goose				
Anser brachyrhynchus	Pink-footed Goose				
Anser albifrons	Greater White-fronted Goose				
Anser erythropus	Lesser White-fronted Goose				
Clangula hyemalis	Long-tailed Duck		E*		Google images
Somateria spectabilis	King Eider				
Somateria mollissima	Common Eider	I	E		English et al. 2015, Holland et al. 2016
Polysticta stelleri	Steller's Eider		E		Google images
Melanitta fusca	Velvet Scoter				
Melanitta nigra	Common Scoter		E*		Camphuysen 1990b
Bucephala clangula	Common Goldeneye		E*		Camphuysen 1990b

Mergellus albellus	Smew			
Mergus merganser	Goosander		(E)	Moore et al. 2009
Mergus serrator	Red-breasted Merganser		E	Google images, Camphuysen 2008
Alopochen aegyptiaca	Egyptian Goose	I	E	Paijmans & Stewart 2016, Reynolds & Ryan 2018
Tadorna tadorna	Common Shelduck	I		Gil-Delgado et al. 2017
Tadorna ferruginea	Ruddy Shelduck			
Tadorna cana	South African Shelduck			
Plectropterus gambensis	Spur-winged Goose	I		Reynolds & Ryan 2018
Sarkidiornis melanotos	African Comb Duck			
Nettapus auritus	African Pygmy-goose			
Marmaronetta angustirostris	Marbled Teal			
Netta rufina	Red-crested Pochard			
Netta erythrophthalma	Southern Pochard		E	Paijmans & Stewart 2016
Aythya ferina	Common Pochard			
Aythya nyroca	Ferruginous Pochard			
Aythya fuligula	Tufted Duck		E	Camphuysen 1990b
Aythya marila	Greater Scaup		E	Camphuysen 1990b
Spatula querquedula	Garganey			
Spatula hottentota	Hottentot Teal			
Spatula clypeata	Northern Shoveler			
Mareca strepera	Gadwall			
Mareca penelope	Eurasian Wigeon			
Anas undulata	Yellow-billed Duck	I		Reynolds & Ryan 2018
Anas platyrhynchos	Mallard	I	E	Hong et al. 2013, Faure et al. 2015, Holland et al. 2016, Gil-Delgado et al. 2017, Google images
Anas capensis	Cape Teal	I		Reynolds & Ryan 2018
Anas erythrorhyncha	Red-billed Teal	I		Reynolds & Ryan 2018
Anas acuta	Northern Pintail	(I)		Holland et al. 2016
Anas crecca	Common Teal			
Family PODICIPEDIDAE (grebes)				

Tachybaptus ruficollis	Little Grebe			
Podiceps grisegena	Red-necked Grebe		E*	
Podiceps cristatus	Great Crested Grebe		E	
Podiceps auritus	Horned Grebe			
Podiceps nigricollis	Black-necked Grebe			
Family PHOENICOPTERIDAE (flamingos)				
Phoenicopterus roseus	Greater Flamingo			
Phoeniconaias minor	Lesser Flamingo			
Family PHAETHONTIDAE (tropicbirds)				
Phaethon aetheras	Red-billed Tropicbird		E	Google images
Phaethon rubricauda	Red-tailed Tropicbird	I		
Phaethon lepturus	White-tailed Tropicbird	I		
Family RALLIDAE (rails, gallinules, coots)				
Sarothrura elegans	Buff-spotted Flufftail			
Sarothrura boehmi	Streaky-breasted Flufftail			
Sarothrura ayresi	White-winged Flufftail			
Rallus aquaticus	Western Water Rail			
Rallus caerulescens	African Rail			
Crex egregia	African Crake			
Crex crex *Porzana porzana*	Corncrake Spotted Crake			
Zapornia flavirostra	Black Crake			
Zapornia parva	Little Crake			
Zapornia pusilla	Baillon's Crake			
Amaurornis marginalis	Striped Crake			
Porphyrio alleni	Allen’s Gallinule			

Gallinula chloropus	Common Moorhen				
Gallinula angulata	Lesser Moorhen				
Fulica cristata *Fulica atra*	Red-knobbed Coot Common Coot	 I	E 		Paijmans & Stewart 2016 Gil-Delgado et al. 2017
Family GRUIDAE (cranes)					
Balearica regulorum	Grey Crowned-crane				
Balearica pavonina	Black Crowned-crane				
Leucogeranus leucogeranus	Siberian Crane				
Bugeranus carunculatus	Wattled Crane				
Anthropoides paradiseus	Blue Crane		E		Paijmans & Stewart 2016
Anthropoides virgo	Demoiselle Crane				
Grus grus	Common Crane				
Family GAVIIDAE (loons/divers)					
Gavia stellata	Red-throated Loon	I*	E		Google images
Gavia arctica	Black-throated Loon	I*	(E)		
Gavia immer	Common Loon		E		Google images
Gavia adamsii	Yellow-billed Loon	(I)			Holland et al. 2016
Family SPHENISCIDAE (penguins)					
Spheniscus demersus	African Penguin		E	N	DEA unpubl data
Family CICONIIDAE (storks)					
Leptoptilos crumenifer	Marabou			N	PGR unpubl. data
Mycteria ibis	Yellow-billed Stork				
Anastomus lamelligerus	African Openbill				
Ciconia nigra	Black Stork				
Ciconia abdimii	Abdim’s Stork				

Ciconia microscelis	African Woollyneck		E		Google images
Ciconia ciconia	White Stork		E	N	Paijmans & Stewart 2016, Google images
Family THRESKIORNITHIDAE (ibises, spoonbills)					
Platalea alba	African Spoonbill				
Platalea leucorodia	Eurasian Spoonbill				
Threskiornis aethiopicus	African Sacred Ibis		E	N	Paijmans & Stewart 2016, DEA unpubl data
Geronticus eremita	Northern Bald Ibis				
Plegadis falcinellus	Glossy Ibis				
Family ARDEIDAE (herons)					
Botaurus stellaris	Eurasian Bittern				
Ixobrychus minutus	Common Little Bittern				
Ixobrychus sturmii	Dwarf Bittern				
Nycticorax nycticorax	Black-crowned Night-heron	I	E		Hong et al. 2013, Google images
Ardeola ralloides	Squacco Heron				
Ardeola idae	Madagascar Pond-heron				
Ardeola rufiventris	Rufous-bellied Heron				
Bubulcus ibis	Cattle Egret		E		Paijmans & Stewart 2016
Ardea cinerea	Grey Heron	I		N	Faure et al. 2015, DEA unpubl data
Ardea melanocephala	Black-headed Heron			N	DEA unpubl data
Ardea purpurea	Purple Heron				
Ardea alba	Great White Egret		(E)		Hong et al. 2013
Ardea brachyrhyncha	Yellow-billed Egret				
Egretta ardesiaca	Black Heron				
Egretta vinaceigula	Slaty Egret				
Egretta garzetta	Little Egret		(E)		Hong et al. 2013
Egretta gularis	Western Reef-egret				

Family BALAENICIPITIDAE (shoebill)					
Balaeniceps rex	Shoebill				
Family PELECANIDAE (pelicans)					
Pelecanus crispus	Dalmatian Pelican				
Pelecanus rufescens	Pink-backed Pelican				
Pelecanus onocrotalus	Great White Pelican	I	E	N	Paijmans & Stewart 2016, DEA unpubl data
Family FREGATIDAE (frigatebirds)					
Fregata ariel	Lesser Frigatebird				
Fregata minor	Great Frigatebird	I	(E)		Gauger Metz & Schreiber 2002, Rapp et al. 2017
Family SULIDAE (gannets, boobies)					
Morus bassanus	Northern Gannet	I	E	N	
Morus capensis	Cape Gannet		E	N	Paijmans & Stewart 2016, DEA unpubl data
Sula dactylatra	Masked Booby	I	(E)		
Family PHALACROCORACIDAE (cormorants)					
Microcarbo coronatus	Crowned Cormorant	I	E	N	Paijmans & Stewart 2016, Two Oceans Aquarium, DEA unpubl data
Microcarbo pygmaeus	Pygmy Cormorant				
Phalacrocorax carbo	Great Cormorant	I	E	N	DEA unpubl data
Phalacrocorax capensis	Cape Cormorant		E	N	Paijmans & Stewart 2016, DEA unpubl data, PGR unpubl. data
Phalacrocorax nigrogularis	Socotra Cormorant				
Phalacrocorax neglectus	Bank Cormorant	I	E	N	Robinson et al. 2012, DEA unpubl data
Family BURHINIDAE (thick-knees)					
Burhinus senegalensis	Senegal Thick-knee				
Family PLUVIANIDAE (Egyptian Plover)					

Pluvianus aegyptius	Egyptian Plover		
Family HAEMATOPODIDAE (oystercatchers)			
Haematopus moquini	African Oystercatcher	E	Paijmans & Stewart 2016
Haematopus ostralegus	Eurasian Oystercatcher		
Family RECURVIROSTRIDAE (avocets, stilts)			
Recurvirostra avosetta	Pied Avocet		
Himantopus himantopus	Black-winged Stilt		
Family CHARADRIIDAE (plovers)			
Pluvialis squatarola	Grey Plover	E	Camphuysen 1990b
Pluvialis apricaria	Eurasian Golden Plover		
Pluvialis fulva	Pacific Golden Plover		
Eudromias morinellus	Eurasian Dotterel		
Charadrius hiaticula	Common Ringed Plover		
Charadrius dubius	Little Ringed Plover		
Charadrius pecuarius	Kittlitz's Plover		
Charadrius tricollaris	African Three-banded Plover		
Charadrius forbesi	Forbes's Plover		
Charadrius marginatus	White-fronted Plover	E	Paijmans & Stewart 2016, Google images
Charadrius alexandrinus	Kentish Plover		
Charadrius pallidus	Chestnut-banded Plover		
Charadrius mongolus	Lesser Sandplover		
Charadrius leschenaultii	Greater Sandplover		
Charadrius asiaticus	Caspian Plover		
Vanellus vanellus	Northern Lapwing		
Vanellus spinosus	Spur-winged Lapwing		
Vanellus albiceps	White-headed Lapwing		

Vanellus lugubris	Senegal Lapwing			
Vanellus melanopterus	Black-winged Lapwing			
Vanellus coronatus	Crowned Lapwing			
Vanellus senegallus	Wattled Lapwing		E	Paijmans & Stewart 2016
Vanellus superciliosus	Brown-chested Lapwing			
Vanellus gregarius	Sociable Lapwing			
Vanellus leucurus	White-tailed Lapwing			
Family SCOLOPACIDAE (sandpipers, snipes, phalaropes)				
Numenius phaeopus	Whimbrel		E	Camphuysen 1990b
Numenius tenuirostris	Slender-billed Curlew			
Numenius arquata	Eurasian Curlew			
Limosa lapponica	Bar-tailed Godwit	I		Robards et al. 1997
Limosa limosa	Black-tailed Godwit			
Arenaria interpres	Ruddy Turnstone		E	Paijmans & Stewart 2016, Google images
Calidris tenuirostris	Great Knot			
Calidris canutus	Red Knot			
Calidris pugnax	Ruff			
Calidris falcinellus	Broad-billed Sandpiper			
Calidris ferruginea	Curlew Sandpiper			
Calidris temminckii	Temminck's Stint			
Calidris alba	Sanderling			
Calidris alpina	Dunlin		E	Google images
Calidris maritima	Purple Sandpiper		E	Google images
Calidris minuta	Little Stint			
Scolopax rusticola	Eurasian Woodcock			
Gallinago stenura	Pintail Snipe			
Gallinago media	Great Snipe			
Gallinago gallinago	Common Snipe			

Lymnocryptes minimus	Jack Snipe				
Phalaropus lobatus	Red-necked Phalarope	(I)			
Phalaropus fulicarius	Red Phalarope	I			
Xenus cinereus	Terek Sandpiper				
Actitis hypoleucos	Common Sandpiper		E		Paijmans & Stewart 2016
Tringa ochropus	Green Sandpiper				
Tringa erythropus	Spotted Redshank				
Tringa nebularia	Common Greenshank				
Tringa totanus	Common Redshank				
Tringa glareola	Wood Sandpiper				
Tringa stagnatilis	Marsh Sandpiper				
Family DROMADIDAE (Crab-plover)					
Dromas ardeola	Crab-plover				
Family GLAREOLIDAE (coursers, pratincoles)					
Glareola pratincola	Collared Pratincole				
Glareola nordmanni	Black-winged Pratincole				
Glareola ocularis	Madagascar Pratincole				
Glareola nuchalis	Rock Pratincole				
Glareola cinerea	Grey Pratincole				
Family LARIDAE (gulls, terns, skimmers)					
Anous stolidus *Anous tenuirostris*	Brown Noddy Lesser Noddy	(I)		N	PGR unpubl. data
Rynchops flavirostris	African Skimmer				
Hydrocoloeus minutus	Little Gull				
Xema sabini *Rissa tridactyla*	Sabine’s Gull Black-legged Kittiwake	(I) I	 E	 N	 Camphuysen 1990b, 2008, Hartwig et al. 2007

Larus genei	Slender-billed Gull				
Larus ridibundus	Black-headed Gull	I	E		
Larus hartlaubii	Hartlaub's Gull	I	E	N	DEA unpubl data
Larus cirrocephalus	Grey-headed Gull		E		Paijmans & Stewart 2016
Larus ichthyaetus	Pallas's Gull				
Larus melanocephalus	Mediterranean Gull	I			
Larus hemprichii	Sooty Gull				
Larus leucophthalmus	White-eyed Gull				
Larus audouinii	Audouin's Gull	I			
Larus canus	Mew Gull	I	E		Camphuysen 1990b, 2008
Larus dominicanus	Kelp Gull	I	E	N	Witteveen et al. 2017, DEA unpubl data
Larus fuscus	Lesser Black-backed Gull	I	E		
Larus argentatus	European Herring Gull	I	E		
Larus armenicus	Armenian Gull				
Larus michahellis	Yellow-legged Gull	I	E		Google images
Larus cachinnans	Caspian Gull				
Larus glaucoides	Iceland Gull	I			
Larus hyperboreus	Glaucous Gull	(I)			
Larus marinus	Great Black-backed Gull	I	E		
Onychoprion fuscatus	Sooty Tern	(I)	(E)	(N)	Petersen et al. 2016
Onychoprion anaethetus	Bridled Tern	(I)			
Sternula albifrons	Little Tern	(I)	(E)		
Sternula saundersi	Saunders's Tern				
Sternula balaenarum	Damara Tern				
Gelochelidon nilotica	Common Gull-billed Tern				
Hydroprogne caspia	Caspian Tern		E*		Moore et al. 2009, Paijmans & Stewart 2016
Chlidonias hybrida	Whiskered Tern		(E)		Google images
Chlidonias leucopterus	White-winged Tern				
Chlidonias niger	Black Tern	(I)	E		Paijmans & Stewart 2016
Sterna dougallii	Roseate Tern				
Sterna hirundo	Common Tern	(I)	E		Onions & Rees 1992, Paijmans & Stewart 2016

Sterna repressa *Sterna paradisaea*	White-cheeked Tern Arctic Tern		E		Paijmans & Stewart 2016, Google images
Sterna vittata	Antarctic Tern				
Thalasseus bengalensis	Lesser Crested Tern				
Thalasseus sandvicensis	Sandwich Tern		E		Paijmans & Stewart 2016
Thalasseus maximus	Royal Tern		(E)		Google images
Thalasseus bergii	Greater Crested Tern		E	N	Paijmans & Stewart 2016, DEA unpubl data
Family STERCORARIIDAE (skuas)					
Stercorarius longicaudus	Long-tailed Jaeger	(I)			
Catharacta skua	Great Skua	I			Hammer et al. 2016
Family ALCIDAE (auks)					
Fratercula arctica	Atlantic Puffin	I	E		Camphuysen 2000
Cepphus grylle	Black Guillemot	I	E		
Alca torda	Razorbill	I	E		
Alle alle	Little Auk	I	E		Camphuysen 2000, Fife et al. 2015
Uria lomvia	Thick-billed Murre	I	E		Camphuysen 2000
Uria aalge	Common Murre	I	E		
Total number of species		57	79	20	