Marine Pollution Bulletin 151 (2020) 110858

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Review

Quantitative overview of marine debris ingested by marine megafauna

Susanne Kühn*, Jan Andries van Franeker

Wageningen Marine Research, Ankerpark 27, 1781 AG Den Helder, the Netherlands

ARTICLE INFO

Keywords:
Plastic litter
Ingestion
Entanglement
Seabirds
Marine mammals
Turtles

ABSTRACT

This review quantifies plastic interaction in marine biota. Firstly, entanglement and ingestion records for all marine birds, mammals, turtles, fish, and invertebrate species, are summarized from 747 studies. Marine debris affected 914 species through entanglement and/or ingestion. Ingestion was recorded for 701 species, entanglement was documented for 354 species. Secondly, the frequency of occurrence of ingestion per species (Sp-%FO) was extracted for marine birds, mammals and turtles. Thirdly, for seabird species, average numbers of plastics ingested per individual were determined. Highest Sp-%FO and average number of plastics were found in tubenosed seabirds with 41% of all birds analysed having plastics, on average 9.9 particles per bird. The Sp-%FO and average number of ingested particles is lower for most other species. However, for certain species, ingestion rates of litter are reason for serious concern. Standardized methods are crucial for future studies, to generate datasets that allow higher level ecosystem analyses.

1. Introduction

Marine debris and especially plastic litter is a major concern for the general public as well as for scientists and policymakers worldwide. Social-economic costs caused by litter on coastlines and at sea are substantial (Mouat et al., 2010; Newman et al., 2015). But it is the ecological consequences that have created considerable and still growing awareness. Regularly new marine species are encountered to either ingest plastics or to become entangled in it. A first overview of affected species was provided by Laist (1997): the author noted records for either ingestion or entanglement for 267 marine species. In 2015 this list has been expanded to a total of 557 species (Kühn et al., 2015). An even higher number of 693 species was reported by Gall and Thompson (2015) including organisms that attach on plastics or get smothered by debris. These increases illustrate the research interest in this topic during the last decennia, but not necessarily the increase of affected individuals or species. Most publications have focused on plastic ingestion in seabirds, but recently the number of studies, especially those investigating fish is growing rapidly (Provencher et al., 2017; Markic et al., 2019). Since 2015, several review articles have shown the ever-growing body of literature (e.g. Battisti et al., 2019; Staffieri et al., 2019; Parton et al., 2019), but these were not very successful in extending the simple listing of species to a more in-depth quantitative analysis. Methods applied in studies vary greatly, making comparisons between studies extremely difficult. Nevertheless, an upgrade from a simple species list to a more detailed quantitative overview is crucial for the interpretation of the scale of the impacts of mainly plastic debris on marine wildlife.

This review firstly updates the Kühn et al. (2015) list on records of entanglement in, and ingestion of marine debris. Concerning entanglement records, the distinction between entanglement in active fishing gear and lost or discarded fishing equipment, so-called ghost nets (e.g. Ryan, 2018) remains a major problem. For other items such as strap bands, balloon ribbons, plastic bags etc. the classification of marine debris is less ambiguous. Especially for whales, entanglement rates are difficult to obtain, as they may free themselves or be released alive by fishermen when entangled in active gear, still carrying some fishing gear on their body (Baulch and Perry, 2014; Fossi et al., 2018). In seals, entanglement has often been observed in younger animals, potential caused by curiosity and lack of experience according to McIntosh et al. (2015). All seven marine turtle species have been documented with entanglement, in turtles and the amputation of limbs caused by entanglement has been recorded (Kühn et al., 2015). Harm (e.g. injuries or death) caused by entanglement is commonly reported for marine megafauna (Gall and Thompson, 2015). Data on entanglement in birds has recently been reviewed by Ryan (2018). Another type of potential risk, closely related to entanglement is the incorporation of plastics in seabird nests. An overview has been recently published by Jagiello et al. (2019) and a website has been launched in 2019 offering the general public the opportunity to record cases of seabird entanglement or plastic in nests (www.birdsanddebris.com). To study the incidence of entanglement, a systematic census in a specific area would

* Corresponding author.
E-mail address: susanne.kuehn@wur.nl (S. Kühn).

https://doi.org/10.1016/j.marpolbul.2019.110858
Received 29 October 2019; Received in revised form 21 December 2019; Accepted 21 December 2019
Available online 29 January 2020

be required in order to evaluate the incidence of entanglement in regard to the total sample size but is usually difficult to obtain. Therefore, the current study focuses on ingestion data but nevertheless provides a list of entangled marine species to allow comparison with earlier work (Laist, 1997; Kühn et al., 2015).

The basic information provided by many studies is data on the frequency of occurrence (%FO) of ingested plastic within a study population. In order to improve on the existing simple species lists, this new review has gathered information on all available data for the %FO within species of marine birds, mammals and turtles. This allows the creation of species-specific averages of %FO for plastic ingestion, and derived averages for higher taxa like genera, families or orders. Due to a lack of standardized methods, only a limited number of studies provides data that allows estimates of the average number of plastic particles ingested per individual within a species or in higher level taxonomic units. With some examples of methodological constraints, the need for more standardization is highlighted.

2. Methods

To be considered for this review, articles and reports had to fulfil certain requirements:

- Only cases of ingestion or entanglement were considered.
- Records have to provide the exact species name.
- Data on external fouling e.g. in fish gills (e.g. Collard et al., 2017; Abreo et al., 2019), on crustacean carapaces (Welden et al., 2018) etc. were excluded.
- Impacts on marine sedentary organisms (from entanglement or smothering; e.g. Kühn et al., 2015; de Carvalho-Souza et al., 2018) have not been included.
- Only studies on animals living in the wild have been included. Experiments where organisms are exposed to plastics were excluded.
- Extinct species and species occurring only in freshwater were excluded.
- Both dedicated plastic studies and studies where plastic was a sideline, e.g. in traditional diet studies, have been included. While being confident that all publications that dedicatedly reported plastics are included in this review, records of plastics in non-dedicated studies are not always easy to find.
- Different types of references (e.g. peer-reviewed articles, gray literature such as reports) were considered and all references are included in the Online Supplement.
- All marine debris, including plastics, metal, glass, rubber, natural ropes etc. reported in wildlife were used. According to the definition of marine debris described by Werner et al. (2016), this includes "*any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment.*" However, plastics are by far the most abundant items known to have impacts on marine wildlife and data presented are basically the figures for impact from plastic marine debris.
- All sizes of plastics were included (micro- (< 5 mm), meso- (5–20 mm) and macro- (> 20 mm) plastics; GESAMP, 2019).
- Concerning entanglement, we only used data where debris, and not active gear (bycatch) was involved. When evident that hooks were from active gear, records were not included.
- Calculations for ingested plastic include reports of ingested microfibres, because in many papers no clear distinction is made between small dust-like fibres (which may partly stem from secondary aerial contamination (Dris et al., 2016; Hermsen et al., 2017; Kühn et al., 2020)) and more solid plastic particles. Microfibres are defined as filaments with a diameter < 50 μm. Thicker filaments are considered as threads, originating from ropes and nets (Tanaka and Takada, 2016).
- Studies published until May 2019 were considered.

These restrictions in data were applied to create a clear focus on ingestion and entanglement records. A broader definition of impacts is used by Gall and Thompson (2015) who included smothering and other interaction of plastic and marine wildlife and a continuous update is provided in the online database 'Litterbase' (Bergmann et al., 2017). Starting point for the literature review was the data provided by Kühn et al. (2015). New literature was continuously collected using search engines such as Google Scholar and web of Science or alerts by ResearchGate and common journals for plastic research (search terms: 'species name' and plastic, litter, debris, ingest, entangle, diet, etc.). Each plastic ingestion or entanglement study was searched for references therein. Systematic standard search was conducted in English, but occasional records in German, Portuguese, Spanish, French and Dutch were also included.

2.1. Taxonomic %FO ingestion (Tax-%FO)

Firstly, this review provides data on the frequency of occurrence of plastic ingestion and entanglement within higher taxonomic units (Tax-%FO; e.g. for the number of species within a family). As in Kühn et al. (2015), the Online Supplement (Online Supplement Table 1) contains a detailed table with the underlying information for each species in the taxon. Updates include studies published since the review in 2015 and earlier accounts that had not been detected at that time. In addition two features have been added: dedicated plastic ingestion studies where zero plastics were found in a species, have been included and marked, as recommended by Provencher et al. (2017). Secondly, entanglement accounts were categorized according to their likelihood of being caused by discarded and lost fishing gear.

Current species classification and names for seabirds were derived from HBW and BirdLife International (2018). The group of marine ducks (Anseriformes) has been expanded in comparison with Kühn et al. (2015), as recommended by Ryan (2018). We've added four species of steamerducks (*Tachyeres* sp.), three marine mergansers and four other species that spend their time at least partly at sea: long-tailed duck (*Clangula hyemalis*), black-necked swan (*Cygnus melancoryphus*), kelp goose (*Chloephaga hybrida*) and crested duck (*Lophonetta specularioides*), leading to a total of 26 species of Anseriformes rather than the 13 species considered in Kühn et al. (2015). As the procellariiform and charadriiform orders include many different species, subfamilies were considered. The families of the procellariidae (petrels) and diomedeidae (albatrosses) have been split even further as this group belongs to the most affected family and required more detailed analyses. For marine mammals, names provided by the Society for Marine Mammalogy (2018) were used. All marine bird and mammal species that have been included, are listed in the Online Supplement Table 1. The species numbers for fish and invertebrates were taken from WoRMS (2019). Species numbers differ slightly from previous reviews mainly because of continuous changes in accepted taxonomy.

2.2. %FO ingestion per species (Sp-%FO)

Although many species have been recorded with ingested plastics, not all of them are affected to the same extent. One single record for an individual of a species is enough to be included in the Tax-%FO lists. However, it is the frequency of occurrence within a species that is relevant in terms of potential harm to populations or species. Within species, the frequency of occurrence of ingested plastic per species (Sp-%FO) could be assessed for marine birds, mammals and turtles. Therefore, all studies that reported the sample size and either the number or the percentage of affected animals are summarized. The studies used are marked with a superscript asterisk in the Online Supplement Reference section. It should be noted that figures may become biased towards the more frequently and better studied species. Fish and invertebrates have been excluded from this detailed overview, as data on %FO is often incomplete. For fish, available data was

Table 1
Overview plastic ingestion or entanglement or both in the main animal taxa. Shown are the total number of species within the taxon, the number of species known to be affected, and the derived percentage of affected species within the taxon (Tax-%FO). Species specific data underlying the taxon figures are given in Online Supplement Table 1.

		Ingestion		Entanglement		Ingestion & entanglement	
Taxa	n species in taxon	n affected species	Tax-%FO	n affected species	Tax-%FO	n affected species	Tax-%FO
Seabirds							
Anseriformes (marine ducks)	*26*	2	7.7%	6	23.1%	6	23.1%
Podicipediformes (grebes)	*20*	0	0.0%	6	30.0%	6	30.0%
Phaetontiformes (tropicbirds)	*3*	2	66.7%	1	33.3%	3	100.0%
Gaviformes (loons)	*5*	4	80.0%	5	100.0%	5	100.0%
Sphenisciformes (penguins)	*18*	5	27.8%	6	33.3%	9	50.0%
Procellariiformes (tubenoses)	*144*	91	63.2%	18	12.5%	91	63.2%
Pelecaniformes (pelicans)	*8*	3	37.5%	4	50.0%	5	62.5%
Suliformes (gannets, cormorants)	*49*	15	30.6%	19	38.8%	24	49.0%
Charadriiformes (gulls, terns, skuas, auks)	*136*	58	42.6%	47	34.6%	77	56.6%
All seabirds	***409***	**180**	**44.0%**	**112**	**27.4%**	**226**	**55.3%**
Marine mammals							
Ursidae (polar bears)	*1*	0	0.0%	1	100.0%	1	100.0%
Mustelidae (marine otters)	*2*	0	0.0%	2	100.0%	2	100.0%
Pinnipedia (all seals)	*31*	15	48.4%	22	71.0%	22	71.0%
Otariidae (eared seals)	*14*	10	71.4%	12	85.7%	12	85.7%
Odobenidae (walruses)	*1*	0	0.0%	0	0.0%	0	0.0%
Phocidae (true seals)	*16*	5	31.3%	10	62.5%	10	62.5%
Cetartiodactyla (all whales)	*86*	52	60.5%	22	25.6%	59	68.6%
Mysticeti (baleen whales)	*14*	8	57.1%	10	71.4%	12	85.7%
Odontoceti (toothed whales)	*72*	44	61.1%	12	16.7%	47	65.3%
Sirenia (manatees, dugongs)	*3*	2	66.7%	2	66.7%	2	66.7%
All marine mammals	***123***	**69**	**56.1%**	**49**	**39.8%**	**86**	**69.9%**
Other taxa							
All turtles	***7***	**7**	**100.0%**	**7**	**100.0%**	**7**	**100.0%**
All sea snakes	***62***	**0**	**0.0%**	**2**	**3.2%**	**2**	**3.2%**
All fish	***31,243***	**363**		**101**		**430**	
All invertebrates	***159,000***	**82**		**83**		**163**	
All species		**701**		**354**		**914**	

recently reviewed by Markic et al. (2019).

Other than the general Tax-%FO for affected species within a group of species (as done above), the frequency of occurrence within a single species (Sp-%FO) was calculated. This was done by dividing the total number of individuals with ingested plastic, by the total number of individuals studied (from studies that report both numbers). Thus, the basis remains the frequency among individuals. In this paper, results are largely provided as combined data for higher level taxa. Full records for each species are provided in the Online Supplement Table 2. As for many species details of plastic ingestion have not been specified, the Sp-%FO could only be calculated for a limited number of species. Therefore, the percentage of species studied per taxon is provided. For a graphical impression, one species from each taxon was chosen on the basis of having the highest number of dedicated records. When two species had the same number of study records, the one with the higher sample size of individuals has been used.

2.3. Quantities of plastics ingested

Beside the Sp-%FO, it is the quantity of ingested plastic that is relevant when assessing potential harm to organisms. The interpretation of this data is complex, as there are two common types of reporting average number of plastics in biota:

- the *affected average* divides the number of items detected by the number of affected organisms.
- the *population average* is calculated by dividing the number of plastics by all the individuals in the complete sample, thus including the individuals with no plastics.

As already emphasized in Provencher et al. (2017) and Provencher et al. (2019) the population average should be used in order to provide a realistic and comparable overview of the pervasiveness of the plastic problem. For quantities of ingested plastic, this review only used studies where the population average was reported or could be recalculated from the underlying data provided in the papers. Thus, studies were excluded when it was unclear which type of average had been calculated by the authors. All references used for this quantitative part of this study are marked in the Online Supplement References with superscript 2. The quantitative data for individual species were combined into tables for higher taxa by dividing the total number of particles reported by the total number of individuals studied, again including zero records and species with the highest number of study records were depicted.

3. Results

A total of 747 studies which reported details on species that either got entangled in or ingested plastic are used for this review. All references are listed in the Online Supplement. The first study included was published in 1938 by Gudger (1938) describing an Atlantic cod (*Gadus morhua*), entangled in a metal can. There is an older account by the same author from 1931, where a shark has been found entangled in a rubber car tyre (Gudger and Hoffman, 1931), however, as the shark species was not specified, that account could not be included in the literature list. The first account of ingestion of litter by marine organisms comes again from Gudger (1949). In 1931, a tiger shark (*Galeocerdo cuvier*) was found to have ingested several items of human origin, such as horse shoes, metal cans and rope material. Despite earlier records of ingested marine litter, the first plastic item ingested was found in Leach's storm petrels (*Oceanodroma leucorhoa)* in 1962 (Rothstein, 1973). Since then there has been a continuously growing body of literature (Provencher et al., 2017).

3.1. Taxonomic frequency of occurrence (Tax-%FO)

The total number of species encountered either entangled in or with ingested litter has increased from 267 in 1997 (Laist, 1997) and 557 in 2015 (Kühn et al., 2015) to currently at least 914 species (Table 1). The number of all species and the number of species affected are presented together with the total percentage of affected species (Table 1). The total percentage may differ from the separate ones as some species may suffer from both, entanglement and ingestion. A detailed list of all species with ingestion or entanglement records for marine birds, mammals, turtles, sea snakes, fish and invertebrates is included in Online Supplement Table 1. Although seabirds belong to the species group most intensively studied (Provencher et al., 2017), affected species numbers still increased from 203 in 2015 to 226 in this study. The number of marine mammal species has increased slightly from 81 species in 2015 to 86 species in 2019. In turtles, seven out of seven species were already found to be entangled and to ingest plastics in 2015. The largest increase in studies and species records occurred in fish. In Kühn et al. (2015), 166 fish species had documented cases of plastic entanglement or ingestion. In the current review, this number increased to 430 species of marine fishes. For a full comparison between Kühn et al. (2015) and this study see Online Supplement Table 3.

3.2. Frequency of occurrence per species (Sp-%FO)

A total of 588 out of 747 studies reports ingestion of plastics by marine wildlife. Eligible for calculations on Sp-%FO, are 311 studies: 152 for marine birds, 75 for mammals and 84 for turtles. These studies report the sample size and the number or percentage of affected individuals.

Out of 409 known seabird species, 226 species were studied for plastic ingestion of which 180 species have been found with plastics. A total of 43,525 individual seabird samples has been studied of which more than a quarter (12,065 individuals, 27.7%) contain plastics. Procellariiformes are among the best studied taxon with 103 out of 144 species and 22,735 individuals analysed. This group exhibits the highest Sp-%FO with 41.5% of all individuals containing plastic (Table 2).

While 41.5% of the marine mammal species has currently been studied for plastic ingestion, only 860 out of 19,486 individuals (4%) contained plastics (Table 3). For both, baleen and toothed whales, around half of all species have been studied. Baleen whales showed a higher Sp-%FO (16.67%) than toothed whales (9.4%). However only 96 baleen but 5002 toothed whales have been autopsied. Plastic has been found in the digestive tracts of seals but not in polar bears or otters, the Sp-%FO for carnivores remains low at 0.95%.

There are only seven species of marine turtles and all of them, with exception of the flatback turtle (*Natator depressus),* have been repeatedly encountered with ingested plastics. Therefore, results are presented in a table for each species separately (Table 4). In contrast to the small number of species, plastic in turtles gained a lot of attention in scientific literature, with 140 study records. One third (32%) of 7879 turtles analysed contained plastic in their stomachs.

Fig. 1 provides the Sp-%FO for selected species having the highest number of dedicated study records within the higher level taxon. Thus, please note that also species-specific data are often derived from many different studies. The supplementary Table 2 provides data for all species studied. Low sample numbers can lead to unusual high Sp-%FO's of e.g. 100% (e.g. black-faced sheathbill *Chionis minor*, narwhal *Monodon monoceros* and flatback turtle). High Sp-%FO's with sufficient sample numbers are mainly reached in seabirds. Laysan albatross *Phoebastria immutabilis,* northern fulmar *Fulmarus glacialis*, sooty shearwater *Ardenna grisea* and red phalarope *Phalaropus fulicarius* are species with > 50% of the analysed individuals containing plastics. High Sp-%FO's in the other species groups were found in sperm whales (*Physeter macrocephalus;* 26%) and green turtles (*Chelonia mydas;* 47%).

Table 2
Frequency of occurrence per species (Sp-%FO) of plastic ingestion for seabirds per taxon. The total number of species in the taxon is given with the percentage of species within the taxon for which ingestion studies are available. For each taxon, the number of individuals studied, and the number of individuals with plastic is tabulated, with the derived Sp-%FO shown in the last column.

Taxon	n species	% species studied	Number of individuals studied	Number of individuals with plastic	Sp-FO%
Anseriformes	***26***	**38.5%**	**823**	**2**	**0.2%**
Podicipediformes	***20***	**15.0%**	**8**	**0**	**0.0%**
Phaetontiformes	***3***	**100.0%**	**221**	**31**	**14.0%**
Gaviformes	***5***	**80.0%**	**32**	**3**	**9.4%**
Sphenisciformes	***18***	**38.9%**	**1478**	**214**	**14.5%**
Procellariiformes					
Storm petrels	*27*	48.1%	1614	415	25.7%
Great albatrosses	*6*	83.3%	157	29	18.5%
N Pacific albatrosses	*4*	100.0%	1434	1205	84.0%
Sooty albatrosses	*2*	100.0%	83	2	2.4%
Mollymawks	*10*	100.0%	2301	114	5.0%
Fulmarine petrels	*7*	100.0%	4300	2725	63.4%
Whalebirds	*8*	75.0%	819	584	71.3%
Gadfly petrels	*35*	68.6%	1420	233	16.4%
Procellaria petrels	*5*	100.0%	875	92	10.5%
Shearwaters	*30*	60.0%	7258	4000	55.1%
Bulweria petrels	*6*	50.0%	289	5	1.7%
Diving petrels	*4*	75.0%	313	21	6.7%
All Procellariiformes	***144***	**71.5%**	**22,735**	**9426**	**41.5%**
Pelecaniformes	***8***	**37.5%**	**31**	**12**	**38.7%**
Suliformes					
Frigatebirds	*5*	60.0%	96	23	24.0%
Gannets	*10*	60.0%	984	262	26.6%
Cormorants	*34*	26.5%	580	51	8.8%
All Suliformes	***49***	**36.7%**	**1660**	**336**	**20.2%**
Charadriiformes					
Sheathbills	*2*	100.0%	5	3	60.0%
Phalaropes	*3*	66.7%	113	65	57.5%
Noddies	*5*	80.0%	258	15	5.8%
White terns	*2*	50.0%	54	1	1.9%
Skimmers	*3*	0.0%	0	0	0.0%
Gulls	*51*	49.0%	4840	788	16.3%
Terns	*39*	51.3%	1313	21	1.6%
Skuas	*7*	85.7%	2192	180	8.2%
Auks	*24*	79.2%	16,537	2041	12.3%
All Charadriiformes	***136***	**55.9%**	**16,537**	**2041**	**12.3%**
All seabirds	***409***	**55.3%**	**43,525**	**12,065**	**27.7%**

3.3. Average number of plastic items in seabirds

Less than a third of all study records of marine mammals and turtles report population averages for the number of rubbish or plastic items (27.9% of 218 and 31.2% of 189 study records, respectively). Consequently, we focus on seabirds, where almost half of the studies (48.9% of 841 study records, reported in 80 studies) provide population averages on numbers of plastics ingested.

Table 5 provides data on the average number of plastic items per individual within seabird taxa. In 7572 procellariform birds, on average 9.88 pieces of plastics were encountered, almost ten times as many plastic pieces as in Charadriiformes. More than the half (53%) of all charadriiform species have records of average numbers and 9284 individuals have been analysed. Calculated for all these individuals, on average they have ingested 1.03 plastic pieces. Phalaropes and auks contain on average more than one piece of plastic (8 and 1.6 respectively), while terns have only 0.006 pieces of plastic on average, despite the relatively large sample size of 325 birds. In all other bird orders sample sizes were much smaller and these birds contained on average less than one particle per bird. The maximum average number reported in a species group concerns the smallest member of the procellariform seabird, the storm petrels. Youngren et al. (2018) report an average of

Table 3
Frequency of occurrence per species (Sp-%FO) of plastic ingestion for marine mammals per taxon. The total number of species in the taxon is given with the percentage of species within the taxon for which ingestion studies are available. For each taxon, the number of individuals studied, and the number of individuals with plastic is tabulated, with the derived Sp-%FO shown in the last column.

Taxon	n species	% species studied	Number of individuals studied	Number of individuals with plastic	Sp-FO%
Carnivores					
Ursidae	*1*	0.00%	0	0	0.00%
Mustelidae	*3*	0.00%	0	0	0.00%
Otariidae	*14*	28.57%	8593	58	0.67%
Odobenidae	*1*	0.00%	0	0	0.00%
Phocidae	*16*	25.00%	1191	34	2.85%
All carnivores	***34***	**23.53%**	**9784**	**93**	**0.95%**
Baleen whales					
Balaenidae	*4*	0.00%	0	0	0.00%
Neobalaenidae	*1*	0.00%	0	0	0.00%
Eschritiidae	*1*	0.00%	0	0	0.00%
Balaenopteridae	*8*	75.00%	96	16	16.67%
All baleen whales	***14***	**42.86%**	**96**	**16**	**16.67%**
Toothed whales					
Physteridae	*1*	100.00%	145	37	25.52%
Kogiidae	*2*	100.00%	39	10	25.64%
Ziphiidae	*22*	54.55%	266	66	24.81%
Pontoporiidae	*1*	100.00%	197	44	22.34%
Monodontidae	*2*	50.00%	1	1	100.00%
Delphinidae	*37*	45.95%	2495	205	8.22%
Phocoenidae	*7*	28.57%	1859	107	5.76%
All toothed whales	***72***	**50.00%**	**5002**	**470**	**9.40%**
All cetaceans	***86***	**48.84%**	**5098**	**486**	**9.53%**
Sirenia					
Trichechidae	*2*	50.00%	4604	281	6.10%
Dugongidae	*1*	0.00%	0	0	0.00%
All sirenia	***3***	**33.33%**	**4604**	**281**	**6.10%**
All marine mammals	***123***	**41.46%**	**19,486**	**860**	**4.41%**

203 plastic pieces in Tristram's storm petrels (*Oceanodroma tristrami)* on Hawaii with a maximum of 615 plastic pieces in a single bird. The second highest record was also found on Hawaii, in Laysan albatross fledglings. Lavers and Bond (2016) found an average number of 132.5 pieces and a maximum of 450 pieces in one bird. Other members of the procellariform order such as bulweria petrels, diving petrels and mollymawks contained < 0.017 plastic particles on average.

Again, as for Sp-%FO, a selection of species with the highest study record per taxon group was made to illustrate data on the average number of ingested plastic items. Laysan albatross, northern fulmar, white-chinned petrel (*Procellaria aequinoctialis)*, short-tailed shearwater (*Ardenna tenuirostris)*, northern gannet (*Morus bassanus)* and red phalarope exceed the average of more than one piece of ingested plastic per individual. To visualize this data, two graphs were made for species with either an average of < 1 or > 1 pieces respectively (Fig. 2).

4. Methodological constraints

Variation of methods represents the main issue that hampers analysis of data on a large scale. Some cases are highlighted, emphasizing the different outcomes of studies, depending on their study setup.

4.1. Seabirds – dissection and regurgitations

For many seabird studies samples are collected by dissecting dead individuals. However, to study the natural diet and plastic uptake in live birds, e.g. in breeding colonies, emetics or stomach lavages are regularly applied. Another method to obtain samples is the collection of regurgitates or boluses, some seabird species produce regularly. Provencher et al. (2017) found that 70% (n = 82) of the studies used dead birds from beaches, roads or colonies or being killed in hunting or bycatch. Stomach lavage or emetics were used in 9 studies and natural regurgitates were analysed in 23 studies. Beside potential harm to the individual when using invasive research methods, the full stomach content can often not be obtained in all seabird species. In some procellariform seabirds, the two stomachs are divided by a small constriction. As most plastic is retained in the latter stomach (the muscular gizzard), only a small fraction of plastics will be collected when

Table 4
Frequency of occurrence per species (Sp-%FO) of plastic ingestion for turtles. The species is given with the percentage of species within the taxon for which ingestion studies are available. For each taxon, the number of individual studied, and the number of individuals with plastic is tabulated, with the derived Sp-%FO shown in the last column.

Taxon	n species	% species studied	n individuals studied	n individuals with plastic	Sp-FO%
Loggerhead turtle	*1*	100%	3919	843	22%
Kemp's ridley turtle	*1*	100%	304	106	35%
Olive ridley turtle	*1*	100%	179	81	45%
Green turtle	*1*	100%	2720	1275	47%
Hawksbill turtle	*1*	100%	86	31	36%
Flatback turtle	*1*	100%	2	2	100%
Leatherback turtle	*1*	100%	669	198	30%
All turtles	***7***	**100%**	**7879**	**2536**	**32%**

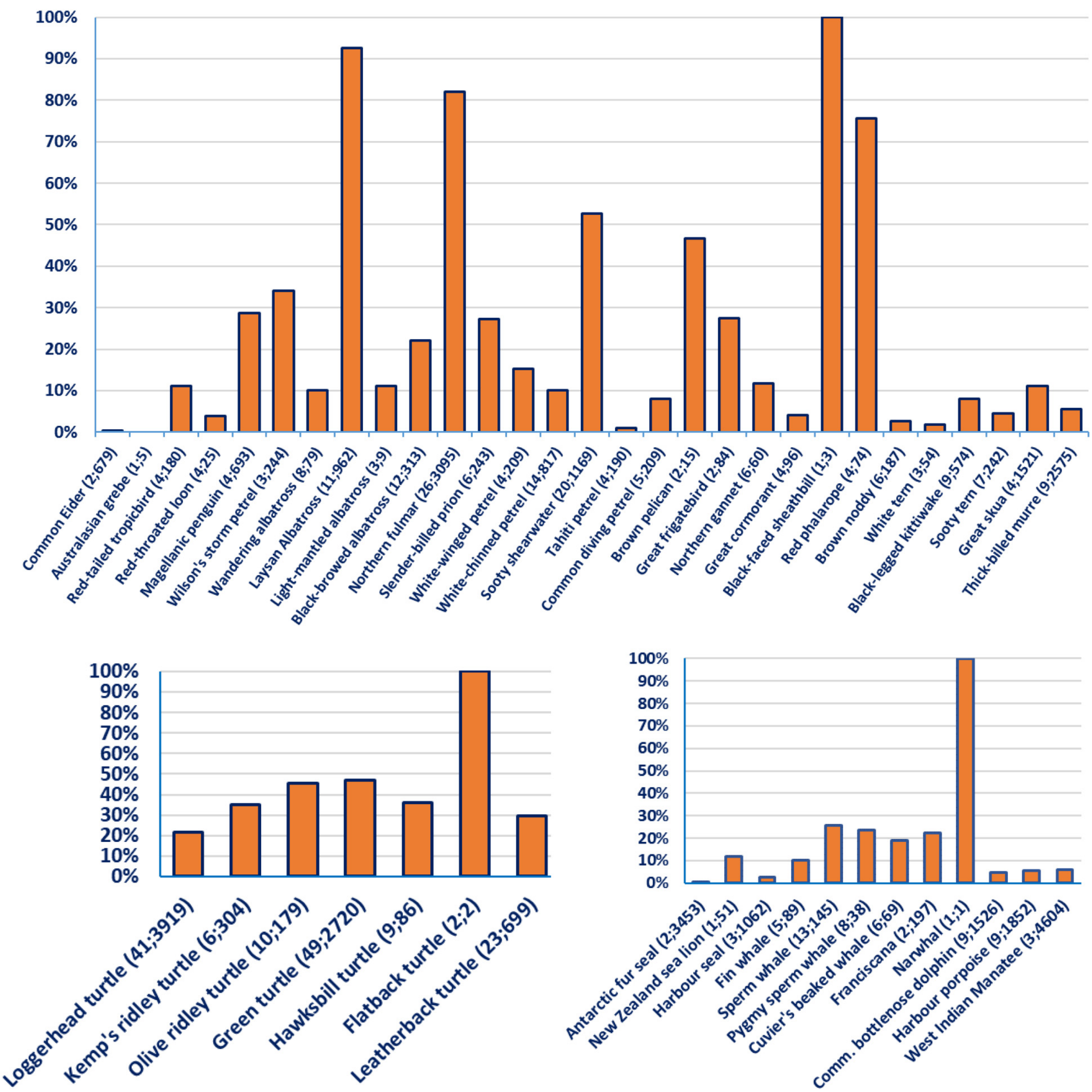

Fig. 1. Frequency of occurrence per species (Sp-%FO) of ingested plastics for a selection of best documented species of seabirds (top), turtles (bottom left) and marine mammals (bottom right). Species shown here were chosen from their taxonomic group as the species with the highest number of study records. With the species names, the number of studies on that species and the number of individuals used for the Sp-%FO calculations are shown in parenthesis.

regurgitations are obtained, making it difficult to compare results (Provencher et al., 2019). To emphasize the effect of method and gut morphology on Sp-%FO, gulls, skuas and cormorants, all known to regurgitate regularly, were compared with petrels (Procellariidae) and albatrosses (Diomedeidae), both accumulating plastics. Table 6 shows, that the outcome in gulls, skuas and cormorants are similar, irrespective the method, as probably in both cases the complete stomach content has been available. However, in petrels and albatrosses, more birds were encountered with plastics, when dissecting the birds and analysing both stomachs, indicating that regurgitates in these species do not reveal the full plastic load.

4.2. Seabirds – age variation

Sometimes it is not only the method used that can cause difference in numbers but it might for example be related to the ecology of species: young seabirds tend to have more plastics in their stomachs than adults, partly because they get fed by two plastic-ingesting parent but possibly also due to inexperience in searching for food (Kühn et al., 2015). For instance, in most studies of Laysan albatrosses, stomachs of young birds were analysed. When adding up all records of young birds from different studies (where Sp-%FO is available), 635 birds were analysed and 96% contained plastics (Auman et al., 1997; Lavers and Bond, 2016; Pettit et al., 1981; Rapp et al., 2017; Sileo et al., 1990). In contrast, among 222 adult Laysan albatrosses only 84% had ingested plastics (Gould et al., 1997; Gray et al., 2012; Rapp et al., 2017). The study bias towards younger birds may explain the high Sp-%FO in Laysan albatrosses. In beached northern fulmars found in the Netherlands, young birds consistently have a higher mass of ingested plastic in the stomach than adult birds (Van Franeker et al., 2011).

4.3. Seabirds – population and affected averages

For 10 dedicated seabird ingestion studies and 50 study records

Table 5
Average number of plastic pieces ingested per individual for the major seabird taxa. The total number of species in the taxon is given with the percentage of species within the taxon for which ingestion studies are available. For each taxon, the number of individual studied, and the population average of plastic items per bird is tabulated. The range of the average number of plastics per bird is shown for all studies considered for this calculation.

	Species	Species studied	Individuals studied	Plastics/bird	Reported range average in studies	
Taxon	*n*	%	n	n avg	Min	Max
Anseriformes	***26***	**38%**	**864**	**0.012**	**0**	**0.175**
Podicipediformes	***20***	**0%**	**8**	**0**	**0**	**0**
Phaetontiformes	***3***	**100%**	**15**	**0.067**	**0**	**0.3**
Gaviformes	***5***	**80%**	**14**	**0.071**	**0**	**0.333**
Sphenisciformes	***18***	**22%**	**143**	**0.014**	**0**	**0.222**
Procellariiformes						
Storm petrels	*27*	41%	939	13.122	0	203.2
Great albatrosses	*6*	67%	88	0.42	0	1
N. Pac. albatrosses	*4*	75%	154	36.935	0	132.46
Sooty albatrosses	*2*	0%	3	0	0	0
Mollymawks	*10*	60%	765	0.012	0	1.5
Fulmarine petrels	*7*	86%	2437	17.795	0	65.4
Whalebirds	*8*	50%	84	1.048	0	5.5
Gadfly petrels	*35*	43%	529	0.476	0	4.109
Procellaria petrels	*5*	40%	126	8.127	0	8.947
Shearwaters	*30*	53%	2207	5.454	0	43
Bulweria petrels	*6*	33%	182	0.005	0	0.008
Diving petrels	*4*	25%	58	0.017	0	0.02
All Procellariiformes	***144***	**49%**	**7572**	**9.882**	**0**	**203.2**
Pelecaniformes	***8***	**13%**	**15**	**0.53**	**0.53**	**0.53**
Suliformes						
Frigatebirds	*5*	40%	12	0	0	0
Gannets	*10*	50%	92	1.457	0	5.81
Cormorants	*34*	24%	207	0.415	0	2
All Suliformes	***49***	**31%**	**311**	**0.704**	**0**	**5.81**
Charadriiformes						
Sheathbills	*2*	50%	2	0	0	0
Phalaropes	*3*	67%	22	8	1	12.3
Noddies	*5*	80%	22	0	0	0
White terns	*2*	50%	54	0.093	0	0.625
Skimmers	*3*	0%	0	na	na	na
Gulls	*51*	43%	2827	0.736	0	9.8
Terns	*39*	46%	328	0.006	0	0.031
Skuas	*7*	71%	1465	0.145	0	30
Auks	*24*	79%	4564	1.559	0	47
All Charadriiformes	***136***	**53%**	**9284**	**1.033**	**0**	**47**
All seabirds	***409***	**44%**	**25,798**	**3.282**	**0**	**203**

therein, the affected average of the number of ingested plastic particles was reported. However, the true population average could be derived from underlying data (Ainley et al., 1990b; Bond et al., 2010; Donnelly-Greenan et al., 2018; Floren and Shugart, 2017; Lavers and Bond, 2016; Mallory, 2008; Mallory et al., 2006; Rodríguez et al., 2012; Spear et al., 1995; Verlis et al., 2013). The species (n = 43) belong mainly to the Procellariiformes and Charadriiformes. From these species, 2447 individuals were analysed, 385 birds contained plastics, 7244 items in total. The affected average, excluding birds without plastics is 18.82 plastic pieces. When including all birds sampled, the population average is much lower, 2.96 plastic pieces (Fig. 3).

A significant difference ($p < 0.0001$) was indicated (Wilcoxon signed rank test for non-parametric paired data https://epitools.ausvet.io/paired), with affected averages being higher than population averages, emphasizing the importance to present results including the complete study sample to avoid overestimation of numbers and second to report which type of average has been used to allow comparisons between studies. Reporting different or unclear metrics in plastic ingestion studies impede the structural analysis of results.

4.4. Marine mammals – sampling method

How much influence a specific sampling method can have on the results has been shown in one study of plastic ingestion in harbour porpoises by Van Franeker et al. (2018). Between 2003 and 2013, 654 porpoises were studied. Using a simple overflow method (to retain hard natural prey items), 6% of the porpoises contained plastics. However, after adapting the method towards a plastic-dedicated protocol using an additional sieve, that caught all overflowing material, the actual %FO increased to 15%.

4.5. Turtles – plastic distribution in the gastrointestinal tract

Most studies on plastics in turtles include the complete gastrointestinal tract (GIT), others analyse the stomach content only. The complete GIT of turtles was considered in 42 studies, only the stomach in 8 studies. The remaining studies do either give no details or consider faeces, parts of the GIT or stomach flushing. Sp-%FO was calculated for all individuals of each group. These two groups were tested for a significant difference, using 2-sample z test to compare proportions http://epitools.ausvet.com.au/content.php?page=z-test-2 as recommended by Provencher et al. (2017).

For a total of 3639 turtles the method was specified. In 218 turtles only the stomach was analysed while 3421 turtles were analysed for plastics in the complete GIT. Out of the stomach-only turtles, 19.27% were found to contain plastics and when the whole GIT was analysed, 51.45% contained plastics (Fig. 4), indicating that a substantial amount of plastic may be missed out when only analysing the stomach. Therefore, the parts of GIT analysed should always be specified as for example was done by Camedda et al. (2014).

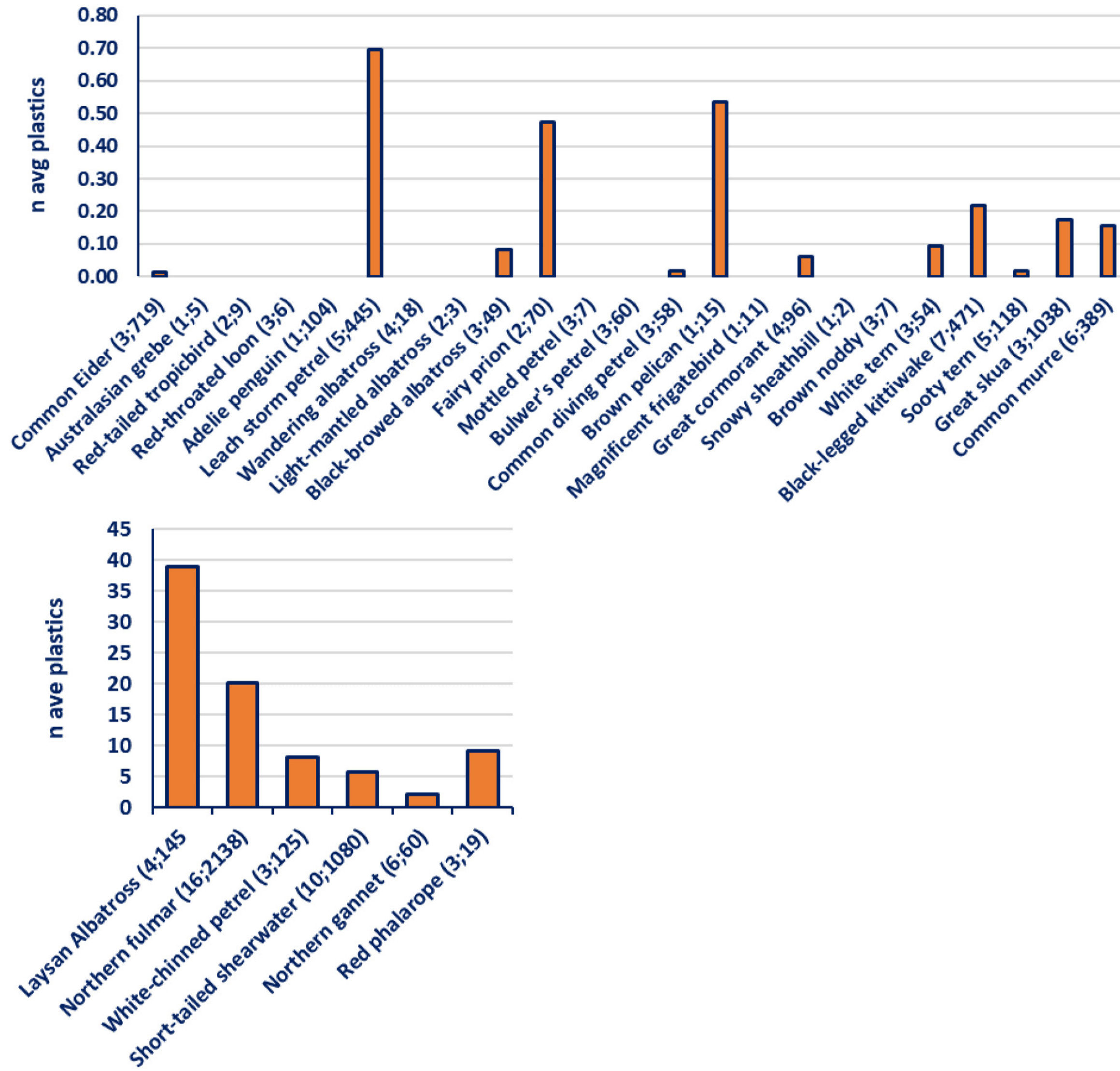

Fig. 2. Population average number of ingested plastic particles in seabirds. Species shown here were chosen from their taxonomic group as the species with the highest number of study records with the species names. The number of studies on that species and the number of individuals used are shown in parenthesis. The graph on the Top shows seabird species with on average < 1 piece of plastic per bird. On the Bottom, seabird species with an average of > 1 plastic items are depicted.

Table 6
Comparison of two different groups of species, with different gut morphology and foraging habits. Both groups have been studied by either dissecting the birds or using regurgitates (pellets, boluses, emetics). Sample size of birds analysed are shown together with the number of individuals with plastic and their according percentage.

Taxon	Dissection			Regurgitates		
	Sample size	Individuals with plastic	%	*Sample size*	Individuals with plastic	%
Gulls	*1386*	210	15.15	*3404*	572	16.8
Skuas	*110*	9	8.18	*2082*	171	8.21
Cormorants	*84*	10	11.9	*496*	41	8.27
Procellariidae	*14,661*	6916	47.17	*1653*	455	27.53
Albatrosses	*2878*	1066	37.1	*238*	14	5.88

5. Discussion

This review presents the most recent updated information on documented cases of plastic ingestion and entanglement in marine species. In recent years many reviews have been published focusing on either entanglement or ingestion and different taxon groups such as seabirds (Ryan, 2018; Battisti et al., 2019; Jagiello et al., 2019), marine mammals (Fossi et al., 2018; Stelfox and Hudgins, 2015), turtles (Duncan et al., 2017; Staffieri et al., 2019), fish (Azevedo-Santos et al., 2019; Markic et al., 2019; Parton et al., 2019) and zooplankton (Botterell et al., 2019). The numbers of affected species in these studies vary, as different criteria for species selection were applied. Battisti et al. (2019) and Azevedo-Santos et al. (2019) for example, included terrestrial bird species, but Battisti et al. (2019) also included many

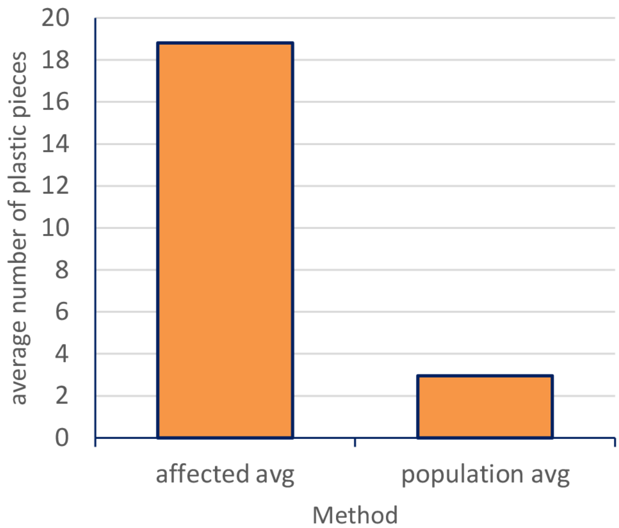

Fig. 3. Comparison of two methods. Affected average number of pieces excludes all seabirds without plastic (n = 385). The population average includes all birds sampled (n = 2447). In total, 7244 plastic items were detected in ten studies, where the affected average has been reported but the population average could be calculated.

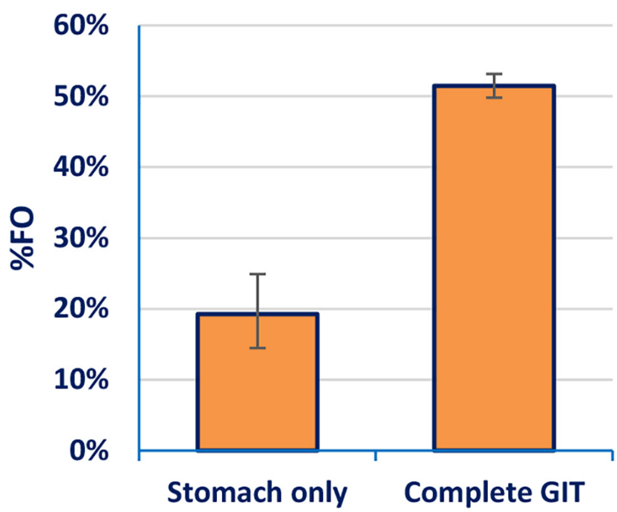

Fig. 4. Frequency of occurrence (%FO) of plastic ingestion of turtles (all species combined). Two methods analysing either the stomach only or the complete gastrointestinal tract (GIT) were compared. Error bars indicate the 95% confidence limits.

seabird species clearly caught in active fishing gear, confounding two very relevant but distinctive threats to seabirds.

The current study combines data on all marine taxa and presents a comprehensive list of all marine species recorded with plastic entanglement or ingestion. This list should serve as a useful tool for e.g. scientists to quickly gain insights in what is known about plastic ingestion or entanglement in a specific species, updating the list by Kühn et al. (2015). Beside this tool, this study provides insight in the number of affected individuals within species of marine megafauna and an overview of quantities of plastics found in seabirds. Unfortunately, it was not possible to provide an overview of data on average plastic mass, not even in the well-studied seabird group. Beside many zero-accounts, only 38 studies report population averages of plastic mass in seabirds, insufficient to compile a reliable overview for different species groups. Long-term studies in northern fulmars in the Netherlands show that the average mass of plastic particles decreased since the 1980s, indicating a trend towards more, but smaller plastics (Van Franeker et al., 2011; Van Franeker and Law, 2015). Plastic mass or volume would be a better indicator of impact on animals ingesting plastic than the number of plastic particles. Therefore, for long-term data collection, plastic mass should be considered the most reliable unit and should be provided as population average when studying plastics in marine organisms (Provencher et al., 2019).

Our numbers show, that plastics occur in many species, living in different marine habitats around the world, feeding and digesting in different ways. Interaction with plastic has been reported in tiny barnacles (Goldstein and Goodwin, 2013) and in blue whales (Baxter, 2009). It has been reported in different species from remote places such as polar regions (Nielsen et al., 2013; Poon et al., 2016; Ainley et al., 1990a; Van Franeker and Bell, 1988) and the deep sea (Carreras-Colom et al., 2018; Courtene-Jones et al., 2019; Courtene-Jones et al., 2017). With almost 1000 species affected, there is no doubt that plastic pollution is pervasive and available to any kind of marine organism. Plastic pollution has been considered as one of the most urgent environmental issues by UNEP (2011), but the extent of negative effects on marine wildlife is hard to assess and sometimes might be exaggerated (Völker et al., 2019). In well-studied turtles, where all species have been found to ingest plastics, only one third (32%) of the individuals contained plastic, although plastic abundances may be much higher (%FO > 90%) in some areas (González Carman et al., 2014; Clukey et al., 2017; Tourinho et al., 2010). Seabirds and specifically tubenosed seabirds also belong to a well-studied species group. The individual %FO in procellariforms is high with almost half of the birds (41.5%) containing plastics. However, when looking into the species groups within the tubenose order there is still a large variability in the occurrence of plastics. For instance, the mollymawks and the gadfly petrels, (10 and 35 species respectively), with sample sizes > 100, had low Sp-%FOs of 5% (mollymawks) and 16.4% (gadfly petrels). Other orders, such as Suliformes (gannets and cormorants) and Charadriiformes (gulls, terns, auks, etc.) have even lower Sp-%FOs of plastics in their stomachs (respectively 20.2% and 12.3%). Although known for regular visits at landfills and snack bars (e.g. Lenzi et al., 2016), only 16.3% of all studied gulls contained plastics at the moment of analysis. This may be explained by their feeding habits of regurgitating indigestible prey items (including plastics) on a regular basis (Barrett et al., 2007). Marine mammals and especially seal species seem to suffer more severely from entanglement (71% of all seal species) than from ingestion (48.4% of all seal species) of plastics. The Sp-%FO of ingestion of plastics in marine mammals is generally low (4.4%). Although some impressive cases of sperm whales ingesting many large plastic items exist (Jacobsen et al., 2010; De Stephanis et al., 2013; Unger et al., 2016), only baleen whales show a higher Sp-%FO (16.7%), all other species groups within the marine mammals remain well under 10%. These low numbers, however, are not irrelevant and do not provide evidence for a lack of harm for the individual or for populations and species. Some species exhibit an ongoing high intake of plastics throughout their distribution range, exceeding the Sp-%FO of 80%, such as Laysan albatrosses (sample size n = 962), Tristram's storm petrels (n = 150), northern fulmars (n = 3095) and parakeet auklets (*Aethia psittacula*; n = 325). This constant uptake should be of concern as reduced fitness and plastic-associated chemicals may negatively influence the health of the population when most individuals within a population are affected. On individual level, even small amounts of plastics can be fatal (Bjorndal et al., 1994; Domènech et al., 2019; Mate, 1985; Bogomolni et al., 2010; Brandão et al., 2011). Roman et al. (2019) and Wilcox et al. (2018) predict a strongly increased chance of mortality for tubenosed birds in the southern hemisphere and turtles when ingesting plastics.

An ongoing discussion is, how to deal with fibre contamination in samples. Fibres originate from e.g. clothing and due to their small weight easily become airborne. They are omnipresent in the environment (e.g. Dris et al., 2016; Bergmann et al., 2019) and available for marine organisms. Unfortunately, it is impossible to distinguish between fibres ingested by organisms and fibres as secondary contamination. Exposure time to air plays an important role (Kühn et al., 2018; Kühn et al., 2020) and should therefore be avoided, e.g. by the use of laminar flow cabinets (Hermsen et al., 2017; Wesch et al., 2017). In recent literature it is mainly fish where fibres are presented in high numbers, often strongly dominating the plastic particle abundance in samples (Mizraji et al., 2017; Nadal et al., 2016; McGoran et al., 2017), and often without a clear description of mitigation measures to prevent airborne fibre contamination. These numbers should therefore be treated with care, as overestimation is likely. Separate recording and reporting of fibres from other particles is recommended for any future publication.

Variation in plastic abundance in the environment is reflected by the amount of plastics found in marine organisms. These patterns are linked to input areas of plastic and currents distributing plastics (Jambeck et al., 2015; Van Sebille et al., 2012). The high concentration of plastics in Tristram's storm petrels and Laysan albatrosses are caused by high concentrations of plastics in the central north Pacific gyre (Moore et al., 2001; Eriksen et al., 2014). Linking the pollution in areas directly to plastic ingestion in species is complicated in most cases, as information is often scattered and incomplete for many regions. Species with a large distribution range are more likely investigated in several studies, as can be seen in e.g. turtles. For entanglement, Ryan (2018) calculated that most species records occurred in temperate regions and explained this by a lower number of seabird species towards the equatorial regions. Some regions appear underrepresented in plastic studies. Although plastic-accumulating gyres occur both in the North and South Pacific (van Sebille et al., 2015), 111 ingestion studies report data from the North Pacific and only 79 ingestion studies origin from the South Pacific (including unspecified Australian coasts). The same pattern occurs in the Atlantic Ocean, in the North Atlantic 193 studies report plastic ingestion and 89 ingestion studies are published from the South Atlantic (including unspecified South African coasts). Studies from the Arctic ($n = 17$) and Antarctic ($n = 7$) regions are scarce, most likely due to the inaccessibility of these regions. In temperate or tropic regions high temperatures could accelerate the decomposition process in beached animals, impeding collection efforts.

As long as data are scattered and not standardized, fine-scaling of regional differences remains futile. The only species with sufficient data allowing spatial comparisons of plastic uptake, is the northern fulmar. Fulmars are used as a monitoring species to assess plastic pollution in the North Sea (Van Franeker et al., 2011; OSPAR, 2017) and the same methods regarding sampling, analysis and data reporting have been applied elsewhere in the North Atlantic (Van Franeker, 1985; Van Franeker et al., 2011; Acampora et al., 2016; Kühn and Van Franeker, 2012), in the North Pacific (Avery-Gomm et al., 2012; Terepocki et al., 2017; Donnelly-Greenan et al., 2014) and in the Arctic Ocean (Trevail et al., 2015; Mallory, 2008; Provencher et al., 2009; Poon et al., 2016), allowing wide-scaled comparisons between regions. When studying fulmars throughout their distribution range, spatial patterns in the abundance of plastics appear, according to the grade of pollution in certain areas. Plastic in fulmars gradually decreases towards northern latitudes (Trevail et al., 2015). Long-term monitoring, as established in the North Sea, could be expanded to other regions were fulmars occur (Avery-Gomm et al., 2012; Avery-Gomm et al., 2018; Acampora et al., 2016). Based on the positive experience with northern fulmars, the European MSFD decided to also monitor plastic ingestion by loggerhead turtles in the Atlantic and the Mediterranean Sea (Darmon et al., 2017; Domènech et al., 2019; Matiddi et al., 2017). The results of this review may be helpful in identifying potential other species that are suitable as biological indicators for marine plastic pollution. To be assigned as suitable for monitoring, species should ingest plastics regularly, should be available in sufficient numbers (e.g. dead on beaches or fisheries bycatch) and should forage exclusively at sea (Van Franeker and Meijboom, 2002; Provencher et al., 2017; Matiddi et al., 2017; Claro et al., 2019; Bray et al., 2019).

6. Conclusion

Despite the fact that plastics are found in all regions of the ocean and are ingested by a great variety of marine organisms, the frequency and abundance of ingested plastic appears lower than sometimes suggested. Often the increasing proportion of seabird species that have at least one documented case of plastic ingestion (our Tax-%FO), is erroneously worded as the proportion of seabird individuals having plastic in the stomach (Sp-%FO). From historic data, Wilcox et al. (2015) modelled that by 2015, 90% of individuals of the worldwide seabird species would have plastic in the stomach. The model indicated that by 2050, records for ingestion would exist for 99% of seabird species. Like Wilcox et al. (2015), we do believe that with increased studies ultimately any species is likely to show individual examples of direct or indirect ingestion of plastic (see for example the increases in Tax-%FO in the few years between 2015 and 2019 in Online Supplement Table 3). But our data do not support the idea that already now nearly every individual seabird has plastics in the stomach. Many of the data considered in this review have a relatively recent origin, but nevertheless, overall, $< 30\%$ of individual seabirds, 4.4% of mammals and 32% of turtles have plastic in their stomachs. Some species, like several tubenoses, seem very prone to ingest plastic debris and a large proportion of their individuals may have a substantial amount of plastic in their stomach. Fortunately, these species do not represent the average current situation. This, however, gives no guarantee for the future, and should also not hide the fact, that already now some populations or species of marine wildlife may suffer from plastics in their stomachs or in their surroundings.

In this, it must be emphasized that the data on plastic ingestion discussed in this review refer to visibly detectable plastic particles in digestive tracks of marine wildlife. Although some of these plastics are certainly in the range of microplastics, this review cannot tell anything about the potential abundance of, and inflicted harm from the smallest types of plastics that may be present in the marine environment and its food chains. Large plastics, as discussed in this review, continuously degrade to smaller sized plastics and are the precursor of risks from smaller plastics. The smallest particles are potentially able to pass through tissue walls or cell membranes. Although experimental evidence indicates a serious risk of harm to organisms from such small particles, the actual impact on marine wildlife and food chains remains uncertain (e.g. GESAMP, 2016; SAPEA, 2019). If consistent robust methods are applied, studying patterns and trends in the frequency and abundance of visible plastic sizes ingested by marine wildlife is probably the best indicator for the risks taken with our marine environments.

Declaration of competing interest

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

Acknowledgement

S. Kühn was funded by the Dutch Science Foundation (project ALW-NWO 856.15.001) under EU Joint Program Initiative (JPI) 'Oceans' within the PLASTOX project (Direct and indirect ecotoxicological impacts of microplastics on marine organisms). Marine litter monitoring by Wageningen Marine Research is supported by the Netherlands Ministry of Infrastructure and Waterways. We want to thank the anonymous reviewers for their comments and advise.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2019.110858.

References

Abreo, N.A.S., Blatchley, D., Superio, M.D., 2019. Stranded whale shark (*Rhincodon typus*) reveals vulnerability of filter-feeding elasmobranchs to marine litter in the Philippines. Mar. Pollut. Bull. 141, 79–83. https://doi.org/10.1016/j.marpolbul.2019.02.030.

Acampora, H., Lyashevska, O., Van Franeker, J.A., O'Connor, I., 2016. The use of beached bird surveys for marine plastic litter monitoring in Ireland. Mar. Environ. Res. 120, 122–129. https://doi.org/10.1016/j.marenvres.2016.08.002.

Ainley, D.G., Fraser, W.R., Spear, L.B., 1990a. The incidence of plastic in the diets of Antarctic seabirds. In: Shomura, R.S., Godfrey, M.L. (Eds.), Proceedings of the Workshop on the Fate and Impact of Marine Debris, Honolulu, Hawaii, pp. 682–691.

Ainley, D.G., Spear, L.B., Ribic, C.A., 1990b. The incidence of plastic in the diets of pelagic seabirds in the eastern equatorial Pacific region. In: Shomura, R.S., Godfrey, M.L. (Eds.), Proceedings of the Workshop on the Fate and Impact of Marine Debris, Honolulu, Hawaii, pp. 653–665.

Auman, H.J., Ludwig, J.P., Giesy, J.P., Colborn, T., 1997. Plastic ingestion by Laysan albatross chicks on Sand Island, midway atoll, in 1994 and 1995. In: Robinson, G., Gales, R. (Eds.), Albatross Biology and Conservation. Surrey Beatty and Sons, Chipping Norton.

Avery-Gomm, S., O'Hara, P.D., Kleine, L., Bowes, V., Wilson, L.K., Barry, K.L., 2012. Northern fulmars as biological monitors of trends of plastic pollution in the eastern North Pacific. Mar. Pollut. Bull. 64, 1776–1781. https://doi.org/10.1016/j.marpolbul.2012.04.017.

Avery-Gomm, S., Provencher, J.F., Liboiron, M., Poon, F.E., Smith, P.A., 2018. Plastic pollution in the Labrador Sea: an assessment using the seabird northern fulmar *Fulmarus glacialis* as a biological monitoring species. Mar. Pollut. Bull. 127, 817–822. https://doi.org/10.1016/j.marpolbul.2017.10.001.

Azevedo-Santos, V.M., Gonçalves, G.R.L., Manoel, P.S., Andrade, M.C., Lima, F.P., Pelicice, F.M., 2019. Plastic ingestion by fish: a global assessment. Environ. Pollut. 112994. https://doi.org/10.1016/j.envpol.2019.112994.

Barrett, R.T., Camphuysen, K., Anker-Nilssen, T., Chardine, J.W., Furness, R.W., Garthe, S., Hüppop, O., Leopold, M.F., Montevecchi, W.A., Veit, R.R., 2007. Diet studies of seabirds: a review and recommendations. ICES J. Mar. Sci. 64, 1675–1691. https://doi.org/10.1093/icesjms/fsm152.

Battisti, C., Staffieri, E., Poeta, G., Sorace, A., Luiselli, L., Amori, G., 2019. Interactions between anthropogenic litter and birds: a global review with a 'black-list' of species. Mar. Pollut. Bull. 138, 93–114. https://doi.org/10.1016/j.marpolbul.2018.11.017.

Baulch, S., Perry, C., 2014. Evaluating the impacts of marine debris on cetaceans. Mar. Pollut. Bull. 80, 210–221. https://doi.org/10.1016/j.marpolbul.2013.12.050.

Baxter, A., 2009. Report on the Blue Whale Stranding Northwest Coast of the South Island, New Zealand, May 2009. Department of Conservation, Nelson, New Zealand, pp. 4.

Bergmann, M., Tekman, M.B., Gutow, L., 2017. Marine litter: sea change for plastic pollution. Nature 544, 297. https://doi.org/10.1038/544297a.

Bergmann, M., Mützel, S., Primpke, S., Tekman, M.B., Trachsel, J., Gerdts, G., 2019. White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. Sci. Adv. 5, eaax 1157. https://doi.org/10.1126/sciadv.aax1157.

Bjorndal, K.A., Bolten, A.B., Lagueux, C.J., 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. Mar. Pollut. Bull. 28, 154–158. https://doi.org/10.1016/0025-326X(94)90391-3.

Bogomolni, A.L., Pugliares, K.R., Sharp, S.M., Patchett, K., Harry, C.T., LaRocque, J.M., Touhey, K.M., Moore, M.J., 2010. Mortality trends of stranded marine mammals on Cape Cod and southeastern Massachusetts, USA, 2000 to 2006. Dis. Aquat. Org. 88, 143–155. https://doi.org/10.3354/dao02146.

Bond, A.L., Jones, I.L., Williams, J.C., Byrd, G.V., 2010. Auklet (Charadriiformes: Alcidae, Aethia spp.) chick meals from the Aleutian Islands, Alaska, have a very low incidence of plastic marine debris. Mar. Pollut. Bull. 60, 1346–1349. https://doi.org/10.1016/j.marpolbul.2010.05.001.

Botterell, Z.L.R., Beaumont, N., Dorrington, T., Steinke, M., Thompson, R.C., Lindeque, P.K., 2019. Bioavailability and effects of microplastics on marine zooplankton: a review. Environ. Pollut. 245, 98–110. https://doi.org/10.1016/j.envpol.2018.10.065.

Brandão, M.L., Braga, K.M., Luque, J.L., 2011. Marine debris ingestion by Magellanic penguins, *Spheniscus magellanicus* (Aves: Sphenisciformes), from the Brazilian coastal zone. Mar. Pollut. Bull. 62, 2246–2249. https://doi.org/10.1016/j.marpolbul.2011.07.016.

Bray, L., Digka, N., Tsangaris, C., Camedda, A., Gambaiani, D., de Lucia, G.A., Matiddi, M., Miaud, C., Palazzo, L., Pérez-del-Olmo, A., Raga, J.A., Silvestri, C., Kaberi, H., 2019. Determining suitable fish to monitor plastic ingestion trends in the Mediterranean Sea. Environ. Pollut. 247, 1071–1077. https://doi.org/10.1016/j.envpol.2019.01.100.

Camedda, A., Marra, S., Matiddi, M., Massaro, G., Coppa, S., Perilli, A., Ruiu, A., Briguglio, P., de Lucia, G.A., 2014. Interaction between loggerhead sea turtles (*Caretta caretta*) and marine litter in Sardinia (Western Mediterranean Sea). Mar. Environ. Res. 100, 25–32. https://doi.org/10.1016/j.marenvres.2013.12.004.

Carreras-Colom, E., Constenla, M., Soler-Membrives, A., Cartes, J.E., Baeza, M., Padrós, F., Carrassón, M., 2018. Spatial occurrence and effects of microplastic ingestion on the deep-water shrimp *Aristeus antennatus*. Mar. Pollut. Bull. 133, 44–52. https://doi.org/10.1016/j.marpolbul.2018.05.012.

Claro, F., Fossi, M.C., Ioakeimidis, C., Baini, M., Lusher, A.L., Mc Fee, W., McIntosh, R.R., Pelamatti, T., Sorce, M., Galgani, F., Hardesty, B.D., 2019. Tools and constraints in monitoring interactions between marine litter and megafauna: insights from case studies around the world. Mar. Pollut. Bull. 141, 147–160. https://doi.org/10.1016/j.marpolbul.2019.01.018.

Clukey, K.E., Lepczyk, C.A., Balazs, G.H., Work, T.M., Lynch, J.M., 2017. Investigation of plastic debris ingestion by four species of sea turtles collected as bycatch in pelagic Pacific longline fisheries. Mar. Pollut. Bull. 120, 117–125. https://doi.org/10.1016/j.marpolbul.2017.04.064.

Collard, F., Gilbert, B., Eppe, G., Roos, L., Compère, P., Das, K., Parmentier, E., 2017. Morphology of the filtration apparatus of three planktivorous fishes and relation with ingested anthropogenic particles. Mar. Pollut. Bull. 116, 182–191. https://doi.org/10.1016/j.marpolbul.2016.12.067.

Courtene-Jones, W., Quinn, B., Gary, S.F., Mogg, A.O., Narayanaswamy, B.E., 2017. Microplastic pollution identified in deep-sea water and ingested by benthic invertebrates in the Rockall trough, North Atlantic Ocean. Environ. Pollut. 231, 271–280. https://doi.org/10.1016/j.envpol.2017.08.026.

Courtene-Jones, W., Quinn, B., Ewins, C., Gary, S.F., Narayanaswamy, B.E., 2019. Consistent microplastic ingestion by deep-sea invertebrates over the last four decades (1976–2015), a study from the north east Atlantic. Environ. Pollut. 244, 503–512. https://doi.org/10.1016/j.envpol.2018.10.090.

Darmon, G., Miaud, C., Claro, F., Doremus, G., Galgani, F., 2017. Risk assessment reveals high exposure of sea turtles to marine debris in French Mediterranean and metropolitan Atlantic waters. Deep-Sea Res. II Top. Stud. Oceanogr. 141, 319–328. https://doi.org/10.1016/j.dsr2.2016.07.005.

de Carvalho-Souza, G.F., Llope, M., Tinôco, M.S., Medeiros, D.V., Maia-Nogueira, R., Sampaio, C.L.S., 2018. Marine litter disrupts ecological processes in reef systems. Mar. Pollut. Bull. 133, 464–471. https://doi.org/10.1016/j.marpolbul.2018.05.049.

De Stephanis, R., Gimenez, J., Carpinelli, E., Gutierrez-Exposito, C., Canadas, A., 2013. As main meal for sperm whales: plastics debris. Mar. Pollut. Bull. 69, 206–214. https://doi.org/10.1016/j.marpolbul.2013.01.033.

Domènech, F., Aznar, F., Raga, J., Tomás, J., 2019. Two decades of monitoring in marine debris ingestion in loggerhead sea turtle, *Caretta caretta*, from the western Mediterranean. Environ. Pollut. 244, 367–378. https://doi.org/10.1016/j.envpol.2018.10.047.

Donnelly-Greenan, E., Hyrenbach, D., Beck, J., Fitzgerald, S., Nevins, H., Hester, M., 2018. First quantification of plastic ingestion by short-tailed albatross *Phoebastria albatrus*. Mar. Ornithol. 46, 79–84.

Donnelly-Greenan, E.L., Harvey, J.T., Nevins, H.M., Hester, M.M., Walker, W.A., 2014. Prey and plastic ingestion of Pacific northern fulmars (*Fulmarus glacialis rogersii*) from Monterey Bay, California. Mar. Pollut. Bull. 85, 214–224. https://doi.org/10.1016/j.marpolbul.2014.05.046.

Dris, R., Gasperi, J., Saad, M., Mirande, C., Tassin, B., 2016. Synthetic fibers in atmospheric fallout: a source of microplastics in the environment? Mar. Pollut. Bull. 104, 290–293. https://doi.org/10.1016/j.marpolbul.2016.01.006.

Duncan, E.M., Botterell, Z.L., Broderick, A.C., Galloway, T.S., Lindeque, P.K., Nuno, A., Godley, B.J., 2017. A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endanger. Species Res. 34, 431–448. https://doi.org/10.3354/esr00865.

Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G., Reisser, J., 2014. Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. PLoS One 9, e111913. https://doi.org/10.1371/journal.pone.0111913.

Floren, H.P., Shugart, G.W., 2017. Plastic in Cassin's auklets (*Ptychoramphus aleuticus*) from the 2014 stranding on the Northeast Pacific coast. Mar. Pollut. Bull. 117, 496–498. https://doi.org/10.1016/j.marpolbul.2017.01.076.

Fossi, M.C., Baini, M., Panti, C., Baulch, S., Fossi, M.C., Panti, C., 2018. Impacts of marine litter on cetaceans: a focus on plastic pollution. In: Marine Mammal Ecotoxicology. Academic Press, pp. 147–184. https://doi.org/10.1016/B978-0-12-812144-3.00006-1.

Gall, S.C., Thompson, R.C., 2015. The impact of debris on marine life. Mar. Pollut. Bull. 92, 170–179. https://doi.org/10.1016/j.marpolbul.2014.12.041.

GESAMP, 2016. Sources, fate and effects of microplastics in the marine environment: part two of a global assessment. In: Kershaw, P.J., Rochman, C.M. (Eds.), GESAMP Reports and Studies, pp. 220. http://www.gesamp.org/data/gesamp/files/file_element/220c250c023936f023937ffd016506be023330b023943c023956/rs023993e.pdf.

GESAMP, 2019. Guidelines for the monitoring and assessment of plastic litter and microplastics in the ocean. In: Kershaw, P., Turra, A., Galgani, F. (Eds.), IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. vols. 1020-4873. pp. 130.

Goldstein, M.C., Goodwin, D.S., 2013. Gooseneck barnacles (*Lepas* spp.) ingest microplastic debris in the North Pacific subtropical gyre. Peer J 1, e184. https://doi.org/10.7717/peerj.184.

González Carman, V., Acha, E.M., Maxwell, S.M., Albareda, D., Campagna, C., Mianzan, H., 2014. Young green turtles, *Chelonia mydas*, exposed to plastic in a frontal area of the SW Atlantic. Mar. Pollut. Bull. 78, 56–62. https://doi.org/10.1016/j.marpolbul.2013.11.012.

Gould, P., Ostrom, P., Walker, W., 1997. Trophic relationships of albatrosses associated with squid and large-mesh drift-net fisheries in the North Pacific Ocean. Can. J. Zool. 75, 549–562. https://doi.org/10.1139/z97-068.

Gray, H., Lattin, G.L., Moore, C.J., 2012. Incidence, mass and variety of plastics ingested by Laysan (*Phoebastria immutabilis*) and black-footed albatrosses (*P. nigripes*) recovered as by-catch in the North Pacific Ocean. Mar. Pollut. Bull. 64, 2190–2192. https://doi.org/10.1016/j.marpolbul.2012.07.053.

Gudger, E.W., 1938. The fish in the iron mask. Sci. Mon. 46, 281–285. www.jstor.org/stable/16337.

Gudger, E.W., 1949. Natural history notes on tiger sharks, *Galeocerdo tigrinus*, caught at Key West, Florida, with emphasis on food and feeding habits. Copeia 1949, 39–47. http://www.jstor.org/stable/1437661.

Gudger, E.W., Hoffman, W.H., 1931. A shark encircled with a rubber automobile tire. Sci. Mon. 33, 275–277. http://sharkmans-world.eu/research/Tyre%20Shark.pdf.

HBW and Bird Life International, 2018. Handbook of the birds of the world and bird life international digital checklist of the birds of the world. Version 3. Available at. http://datazone.birdlife.org/userfiles/file/Species/Taxonomy/HBW-BirdLife_Checklist_v3_Nov18.zip.

Hermsen, E., Pompe, R., Besseling, E., Koelmans, A.A., 2017. Detection of low numbers of microplastics in North Sea fish using strict quality assurance criteria. Mar. Pollut. Bull. 122, 253–258. https://doi.org/10.1016/j.marpolbul.2017.06.051.

Jacobsen, J.K., Massey, L., Gulland, F., 2010. Fatal ingestion of floating net debris by two sperm whales (*Physeter macrocephalus*). Mar. Pollut. Bull. 60, 765–767. https://doi.org/10.1016/j.marpolbul.2010.03.008.

Jagiello, Z., Dylewski, Ł., Tobolka, M., Aguirre, J.I., 2019. Life in a polluted world: a global review of anthropogenic materials in bird nests. Environ. Pollut. 251, 717–722. https://doi.org/10.1016/j.envpol.2019.05.028.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347, 768–771. https://doi.org/10.1126/science.1260352.

Kühn, S., Van Franeker, J.A., 2012. Plastic ingestion by the northern fulmar (*Fulmarus glacialis*) in Iceland. Mar. Pollut. Bull. 64, 1252–1254. https://doi.org/10.1016/j.marpolbul.2012.02.027.

Kühn, S., Bravo Rebolledo, E.L., van Franeker, J.A., 2015. Deleterious effects of litter on marine life. In: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter. Springer, pp. 75–116 (http://edepot.wur.nl/344861).

Kühn, S., Schaafsma, F.L., van Werven, B., Flores, H., Bergmann, M., Egelkraut-Holtus, M., Tekman, M.B., van Franeker, J.A., 2018. Plastic ingestion by juvenile polar cod (*Boreogadus saida*) in the Arctic Ocean. Polar Biol. 41, 1269–1278. https://doi.org/10.1007/s00300-018-2283-8.

Kühn, S., van Franeker, J.A., O'Donoghue, A.M., Swiers, A., Starkenburg, M., van Werven, B., Foekema, E., Hermsen, E., Egelkraut-Holtus, M., Lindeboom, H., 2020. Details of plastic ingestion and fibre contamination in North Sea fishes. Environ. Pollut. 113569. https://doi.org/10.1016/j.envpol.2019.113569.

Laist, D.W., 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: Coe, J.M., Rogers, D.B. (Eds.), Marine Debris Sources, Impacts and Solutions. Springer Series on Environmental Management, New Yorkpp. 99–132.

Lavers, J.L., Bond, A.L., 2016. Ingested plastic as a route for trace metals in Laysan albatross (*Phoebastria immutabilis*) and Bonin petrel (*Pterodroma hypoleuca*) from midway atoll. Mar. Pollut. Bull. 110, 493–500. https://doi.org/10.1016/j.marpolbul.2016.06.001.

Lenzi, J., Burgues, M.F., Carrizo, D., Machin, E., Teixeira-de Mello, F., 2016. Plastic ingestion by a generalist seabird on the coast of Uruguay. Mar. Pollut. Bull. 107, 71–76. https://doi.org/10.1016/j.marpolbul.2016.04.016.

Mallory, M.L., 2008. Marine plastic debris in northern fulmars from the Canadian high Arctic. Mar. Pollut. Bull. 56, 1501–1504. https://doi.org/10.1016/j.marpolbul.2008.04.017.

Mallory, M.L., Roberston, G.J., Moenting, A., 2006. Marine plastic debris in northern fulmars from Davis Strait, Nunavut, Canada. Mar. Pollut. Bull. 52, 813–815. https://doi.org/10.1016/j.marpolbul.2006.04.005.

Markic, A., Gaertner, J.-C., Gaertner-Mazouni, N., Koelmans, A.A., 2019. Plastic ingestion by marine fish in the wild. Crit. Rev. Environ. Sci. Technol. 1–41. https://doi.org/10.1080/10643389.2019.1631990.

Mate, B.R., 1985. Incidents of marine mammal encounters with debris in active fishing gear. In: Shomura, R.S., Yoshida, H.O. (Eds.), Proceedings of the Workshop on the Fate and Impact of Marine Debris, Honolulu, Hawaii, pp. 453–457.

Matiddi, M., Hochsheid, S., Camedda, A., Baini, M., Cocumelli, C., Serena, F., Tomassetti, P., Travaglini, A., Marra, S., Campani, T., Scholl, F., Mancusi, C., Amato, E., Briguglio, P., Maffucci, F., Fossi, M.C., Bentivegna, F., de Lucia, G.A., 2017. Loggerhead Sea turtles (*Caretta caretta*): a target species for monitoring litter ingested by marine organisms in the Mediterranean Sea. Environ. Pollut. 230, 199–209. https://doi.org/10.1016/j.envpol.2017.06.054.

McGoran, A., Clark, P., Morritt, D., 2017. Presence of microplastic in the digestive tracts of European flounder, *Platichthys flesus,* and European smelt, *Osmerus eperlanus*, from the river Thames. Environ. Pollut. 220, 744–751. https://doi.org/10.1016/j.envpol.2016.09.078.

McIntosh, R.R., Kirkwood, R., Sutherland, D.R., Dann, P., 2015. Drivers and annual estimates of marine wildlife entanglement rates: a long-term case study with Australian fur seals. Mar. Pollut. Bull. 101, 716–725. https://doi.org/10.1016/j.marpolbul.2015.10.007.

Mizraji, R., Ahrendt, C., Perez-Venegas, D., Vargas, J., Pulgar, J., Aldana, M., Ojeda, F.P., Duarte, C., Galbán-Malagón, C., 2017. Is the feeding type related with the content of microplastics in intertidal fish gut? Mar. Pollut. Bull. 116, 498–500. https://doi.org/10.1016/j.marpolbul.2017.01.008.

Moore, C.J., Moore, S.L., Leecaster, M.K., Weisberg, S.B., 2001. A comparison of plastic and plankton in the North Pacific central gyre. Mar. Pollut. Bull. 42, 1297–1300. https://doi.org/10.1016/S0025-326X(01)00114-X.

Mouat, J., Lozano, R.L., Bateson, H., 2010. Economic Impacts of Marine Litter. KIMO International, pp. 105.

Nadal, M., Alomar, C., Deudero, S., 2016. High levels of microplastic ingestion by the semipelagic fish bogue *Boops boops* (L.) around the Balearic Islands. Environ. Pollut. 214, 517–523. https://doi.org/10.1016/j.envpol.2016.04.054.

Newman S, Watkins E, Farmer A, ten Brink P, Schweitzer J-P (2015) The economics of marine litter. In: Bergmann M, Gutow L, Klages M (eds) Marine Anthropogenic Litter. Springer, pp 367–394.

Nielsen, J., Hedeholm, R.B., Simon, M., Steffensen, J.F., 2013. Distribution and feeding ecology of the Greenland shark (*Somniosus microcephalus*) in Greenland waters. Polar Biol. 37, 37–46. https://doi.org/10.1007/s00300-013-1408-3.

OSPAR, 2017. OSPAR intermediate assessment 2017. Plastic particles in fulmar stomachs in the North Sea, OSPAR assessment portal OAP online document. https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/marine-litter/plastic-particles-fulmar-stomachs-north-sea/.

Parton, K.J., Galloway, T.S., Godley, B.J., 2019. Global review of shark and ray entanglement in anthropogenic marine debris. Endanger. Species Res. 39, 173–190. https://doi.org/10.3354/esr00964.

Pettit, T.N., Grant, G.S., Whittow, G.C., 1981. Ingestion of plastics by Laysan albatross. Auk 98, 839–841. https://www.jstor.org/stable/4085908.

Poon, F.E., Provencher, J.F., Mallory, M.L., Braune, B.M., Smith, P.A., 2016. Levels of ingested debris vary across species in Canadian Arctic seabirds. Mar. Pollut. Bull. 116, 517–520. https://doi.org/10.1016/j.marpolbul.2016.11.051.

Provencher, J.F., Gaston, A.J., Mallory, M., 2009. Evidence for increased ingestion of plastics by northern fulmars (*Fulmarus glacialis*) in the Canadian Arctic. Mar. Pollut. Bull. 58, 1078–1096. https://doi.org/10.1016/j.marpolbul.2009.04.002.

Provencher, J.F., Bond, A.L., Avery-Gomm, S., Borrelle, S.B., Bravo Rebolledo, E.L., Hammer, S., Kühn, S., Lavers, J.L., Mallory, M.L., Trevail, A., van Franeker, J.A., 2017. Quantifying ingested debris in marine megafauna: a review and recommendations for standardization. Anal. Methods 9, 1454–1469. https://doi.org/10.1039/c6ay02419j.

Provencher, J.F., Borrelle, S.B., Bond, A.L., Lavers, J.L., Van Franeker, J.A., Kühn, S., Hammer, S., Avery-Gomm, S., Mallory, M.L., 2019. Recommended best practices for plastic and litter ingestion studies in marine birds: collection, processing, and reporting. Facets 4, 111–130. https://doi.org/10.1139/facets-2018-0043.

Rapp, D.C., Youngren, S.M., Hartzell, P., Hyrenbach, K.D., 2017. Community-wide patterns of plastic ingestion in seabirds breeding at French frigate shoals, northwestern Hawaiian islands. Mar. Pollut. Bull. https://doi.org/10.1016/j.marpolbul.2017.08.047.

Rodríguez, A., Rodríguez, B., Nazaret Carrasco, M., 2012. High prevalence of parental delivery of plastic debris in Cory's shearwaters (*Calonectris diomedea*). Mar. Pollut. Bull. 64, 2219–2223. https://doi.org/10.1016/j.marpolbul.2012.06.011.

Roman, L., Hardesty, B.D., Hindell, M.A., Wilcox, C., 2019. A quantitative analysis linking seabird mortality and marine debris ingestion. Sci. Rep. 9, 3202. https://doi.org/10.1038/s41598-018-36585-9.

Rothstein, S.I., 1973. Plastic particle pollution of the surface of the Atlantic Ocean: evidence from a seabird. Condor 75, 344–345. https://doi.org/10.2307/1366176.

Ryan, P.G., 2018. Entanglement of birds in plastics and other synthetic materials. Mar. Pollut. Bull. 135, 159–164. https://doi.org/10.1016/j.marpolbul.2018.06.057.

SAPEA, 2019. A Scientific Perspective on Microplastics in Nature and Society. Academies SAfPbE, Berlin, Germany, pp. 176. https://doi.org/10.26356/microplastics.

Sileo, L., Sievert, P.R., Samuel, M.D., Fefer, S.I., 1990. Prevalence and characteristics of plastic ingested by Hawaiian seabirds. In: Shomura, R.S., Godfrey, M.L. (Eds.), Proceedings of the Second International Conference on Marine Debris, 2–7 April 1989, Honolulu, Hawaii, pp. 665–681.

Society for Marine Mammalogy, 2018. List of Marine Mammal Species and Subspecies Committee on Taxonomy. www.marinemammalscience.org.

Spear, L.B., Ainley, D.G., Ribic, C.A., 1995. Incidence of plastic in seabirds from the tropical pacific 1984–91: relation with distribution of species, sex, age, season, year and body weight. Mar. Environ. Res. 40, 123–146. https://doi.org/10.1016/0141-1136(94)00140-K.

Staffieri, E., de Lucia, G.A., Camedda, A., Poeta, G., Battisti, C., 2019. Pressure and impact of anthropogenic litter on marine and estuarine reptiles: an updated “blacklist” highlighting gaps of evidence. Environ. Sci. Pollut. Res. 26, 1238–1249. https://doi.org/10.1007/s11356-018-3616-4.

Stelfox, M., Hudgins, J., 2015. A two year summary of turtle entanglements in ghost gear in the Maldives. Indian Ocean Turt Newsl (IOTN) 22, 1–7.

Tanaka, K., Takada, H., 2016. Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters. Sci. Rep. 6, 34351. https://doi.org/10.1038/srep34351.

Terepocki, A.K., Brush, A.T., Kleine, L.U., Shugart, G.W., Hodum, P., 2017. Size and dynamics of microplastic in gastrointestinal tracts of northern fulmars (*Fulmarus glacialis*) and sooty shearwaters (*Ardenna grisea*). Mar. Pollut. Bull. 116, 143–150. https://doi.org/10.1016/j.marpolbul.2016.12.064.

Tourinho, P.S., Ivar do Sul, J.A., Fillmann, G., 2010. Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil? Mar. Pollut. Bull. 60, 396–401. https://doi.org/10.1016/j.marpolbul.2009.10.013.

Trevail, A.M., Gabrielsen, G.W., Kühn, S., Van Franeker, J.A., 2015. Elevated levels of ingested plastic in a high Arctic seabird, the northern fulmar (*Fulmarus glacialis*). Polar Biol. 38, 975–981. https://doi.org/10.1007/s00300-015-1657-4.

UNEP, 2011. UNEP Year Book, 2011: Emerging Issues in our Global Environment. United Nations Environmental programme, Nairobi (79pp).

Unger, B., Bravo Rebolledo, E.L., Deaville, R., Gröne, A., IJsseldijk, L.L., Leopold, M.F., Siebert, U., Spitz, J., Wohlsein, P., Herr, H., 2016. Large amounts of marine debris found in sperm whales stranded along the North Sea coast in early 2016. Mar. Pollut. Bull. 112, 134–141. https://doi.org/10.1016/j.marpolbul.2016.08.027.

Van Franeker, J.A., 1985. Plastic ingestion in the North Atlantic fulmar. Mar. Pollut. Bull. 16, 367–369. https://doi.org/10.1016/0025-326x(85)90090-6.

Van Franeker, J.A., Bell, P.J., 1988. Plastic ingestion by petrels breeding in Antarctica. Mar. Pollut. Bull. 19, 672–674. https://doi.org/10.1016/0025-326X(88)90388-8.

Van Franeker, J.A., Law, K.L., 2015. Seabirds, gyres and global trends in plastic pollution. Environ. Pollut. 203, 89–96. https://doi.org/10.1016/j.envpol.2015.02.034.

Van Franeker, J.A., Meijboom, A., 2002. Litter NSV-Marine Litter Monitoring by Northern Fulmars. A Pilot Study. Alterra, Alterra-Rapport 401, Wageningen. pp. 72.

Van Franeker, J.A., Blaize, C., Danielsen, J., Fairclough, K., Gollan, J., Guse, N., Hansen, P.L., Heubeck, M., Jensen, J.K., Le Guillou, G., Olsen, B., Olsen, K.O., Pedersen, J., Stienen, E.W., Turner, D.M., 2011. Monitoring plastic ingestion by the northern fulmar *Fulmarus glacialis* in the North Sea. Environ. Pollut. 159, 2609–2615. https://

doi.org/10.1016/j.envpol.2011.06.008.
Van Franeker, J.A., Bravo Rebolledo, E.L., Hesse, E., IJsseldijk, L.L., Kühn, S., Leopold, M., Mielke, L., 2018. Plastic ingestion by harbour porpoises *Phocoena phocoena* in the Netherlands: establishing a standardised method. AMBIO J. Hum. Environ. 1–11. https://doi.org/10.1007/s13280-017-1002-y.
Van Sebille, E., England, M.H., Froyland, G., 2012. Origin, dynamics and evolution of ocean garbage patches from observed surface drifters. Environ. Res. Lett. 7, 044040. https://doi.org/10.1088/1748-9326/7/4/044040.
van Sebille, E., Wilcox, C., Lebreton, L.C.M., Maximenko, N., Hardesty, B.D., van Franeker, J.A., Eriksen, M., Siegel, D., Galgani, F., Law, K.L., 2015. A global inventory of small floating plastic debris. Environ. Res. Lett. 10, 124006. https://doi.org/10.1088/1748-9326/10/12/124006.
Verlis, K.M., Campbell, M.L., Wilson, S.P., 2013. Ingestion of marine debris plastic by the wedge-tailed shearwater *Ardenna pacifica* in the Great Barrier Reef, Australia. Mar. Pollut. Bull. 72, 244–249. https://doi.org/10.1016/j.marpolbul.2013.03.017.
Völker, C., Kramm, J., Wagner, M., 2019. On the creation of risk: framing of microplastics risks in science and media. Global Chall. 1900010. https://doi.org/10.1002/gch2.201900010.
Welden, N.A., Abylkhani, B., Howarth, L.M., 2018. The effects of trophic transfer and environmental factors on microplastic uptake by plaice, *Pleuronectes plastessa*, and spider crab, *Maja squinado*. Environ. Pollut. 239, 351–358. https://doi.org/10.1016/j.envpol.2018.03.110.
Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technical Report EUR 28317 EN. MSFDGES TG Marine Litter-Thematic Reportpp. 91. https://doi.org/10.2788/690366.
Wesch, C., Elert, A.M., Wörner, M., Braun, U., Klein, R., Paulus, M., 2017. Assuring quality in microplastic monitoring: about the value of clean-air devices as essentials for verified data. Sci. Rep. 7, 5424 doi. https://doi.org/10.1038/s41598-017-05838-4.
Wilcox, C., Van Sebille, E., Hardesty, B.D., 2015. Threat of plastic pollution to seabirds is global, pervasive, and increasing. Proc. Natl. Acad. Sci. 112, 11899–11904. https://doi.org/10.1073/pnas.1502108112.
Wilcox, C., Puckridge, M., Schuyler, Q.A., Townsend, K., Hardesty, B.D., 2018. A quantitative analysis linking sea turtle mortality and plastic debris ingestion. Sci. Rep. 8, 12536. https://doi.org/10.1038/s41598-018-30038-z.
WoRMS, 2019. World register of marine species. Available from. http://www.marinespecies.org, Accessed date: 30 June 2019.
Youngren, S.M., Rapp, D.C., Hyrenbach, K.D., 2018. Plastic ingestion by Tristram's storm-petrel (*Oceanodroma tristrami*) chicks from French frigate shoals, northwestern Hawaiian islands. Mar. Pollut. Bull. 128, 369–378. https://doi.org/10.1016/j.marpolbul.2018.01.053.