Marine Pollution Bulletin 150 (2020) 110772

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Baseline

No plastics detected in seal (Phocidae) stomachs harvested in the eastern Canadian Arctic

Madelaine P.T. Bourdages[a,*], Jennifer F. Provencher[b], Enooyaq Sudlovenick[c,1], Steven H. Ferguson[d], Brent G. Young[d], Nicolas Pelletier[a], Michael J.J. Murphy[a], Alexa D'Addario[a], Jesse C. Vermaire[a,e]

[a] Carleton University, Geography and Environmental Studies, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada
[b] Environment and Climate Change Canada, 200 Boulevard Sacré-Coeur, Gatineau, QC J8X 4C6, Canada
[c] University of Prince Edward Island, Canada
[d] Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, MB R3T 2N6, Canada
[e] Carleton University, Institute for Environmental and Interdisciplinary Sciences, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada

ARTICLE INFO

Keywords:
Plastic pollution
Arctic marine mammals
Plastic ingestion
Anthropocene

ABSTRACT

Through collaboration with Inuit hunters, we examined the stomach contents of 142 seals (ringed seals [*Phoca hispida*; n = 135], bearded seals [*Erignathus barbatus*; n = 6], and one harbour seal [*Phoca vitualina*; n = 1]) hunted between 2007 and 2019 from communities around Nunavut to assess whether seals in the eastern Canadian Arctic ingest and retain plastics in their stomachs. The seals in this study ranged from juveniles to adults of up to 30 years of age, and 55% of the seals were males. We found no evidence of plastic ingestion in any of the seals suggesting that seals in Nunavut are not accumulating plastics (> 425 μm) in their stomachs. These data provide important baseline information for future plastic pollution monitoring programs in the Arctic.

Plastic pollution has been found in virtually all oceanic and coastal regions (Kühn et al., 2015) and there is increasing recognition that some marine plastic pollution is moving as far as the Arctic and Antarctic poles (Thompson et al., 2009). It has even been suggested that portions of the Arctic Ocean act as a final accumulation point for plastic movement in the World's Oceans (Cózar et al., 2017). Therefore, it is critical that we gain a better understanding of the prevalence and concentration of plastic pollution in the Arctic and how this plastic debris may be impacting Arctic wildlife.

Few studies of plastic ingestion and retention rates in stomachs exist for marine mammals and this is particularly true for Arctic marine mammals. Seals (Phocidae) are an important component of marine Arctic ecosystems and also make up an important portion of the diets of Inuit, holding high cultural, social and economic value for many northern communities (Searles, 2019). In regions where subsistence hunting accounts for an important nutrient source, it is critical to examine plastic ingestion and accumulation in species that may result in negative effects on wildlife or its consumers.

In this study, we examined the stomach contents of 142 seals (ringed seals [*Phoca hispida*; n = 135], bearded seals [*Erignathus barbatus*; n = 6], and a single harbour seal [*Phoca vitulina*; n = 1]) to investigate if seals from the eastern Canadian Arctic are ingesting and retaining plastics. Given that some avian species in the region have been found to ingest and accumulate plastic debris (e.g. Provencher et al., 2010), and that contaminants potentially derived from plastics were found in Arctic seal tissues (Lu et al., 2019), we predicted that we would find plastic debris in the seal stomachs. These data are important as they provide the first assessment of plastic pollution in an ecologically and culturally important marine mammal in the eastern Canadian Arctic.

Stomachs were collected from 142 seals harvested by Inuit hunters for subsistence in 2007, 2008, 2018 and 2019 from Arviat (61.1078° N, 94.0624° W), Naujaat (66.5283° N, 86.2447° W), Sanikiluaq (56.5408° N, 79.2232° W), and Iqaluit (63.7467° N, 68.5170° W), Nunavut, Canada (Fig. 1). Tissues from the seals were harvested with permits from the Department of Fisheries and Oceans (DFO) (DFO LFSP S-17/18 1005-NU), approval from the Nunavut Wildlife Management Board (NWMB), and support from the Arviat, Arviq, Sanikiluaq, and Amaruq Hunter and Trapper Organizations. The species, sex, and body measurements of the seals were recorded by the hunters. The relative age of

* Corresponding author.
E-mail address: madelainebourdages@cmail.carleton.ca (M.P.T. Bourdages).
[1] Current address: University of Manitoba, 66 Chancellors Cir, Winnipeg, MB R3T 2N2, Canada.

https://doi.org/10.1016/j.marpolbul.2019.110772
Received 30 October 2019; Received in revised form 20 November 2019; Accepted 21 November 2019
Available online 29 November 2019

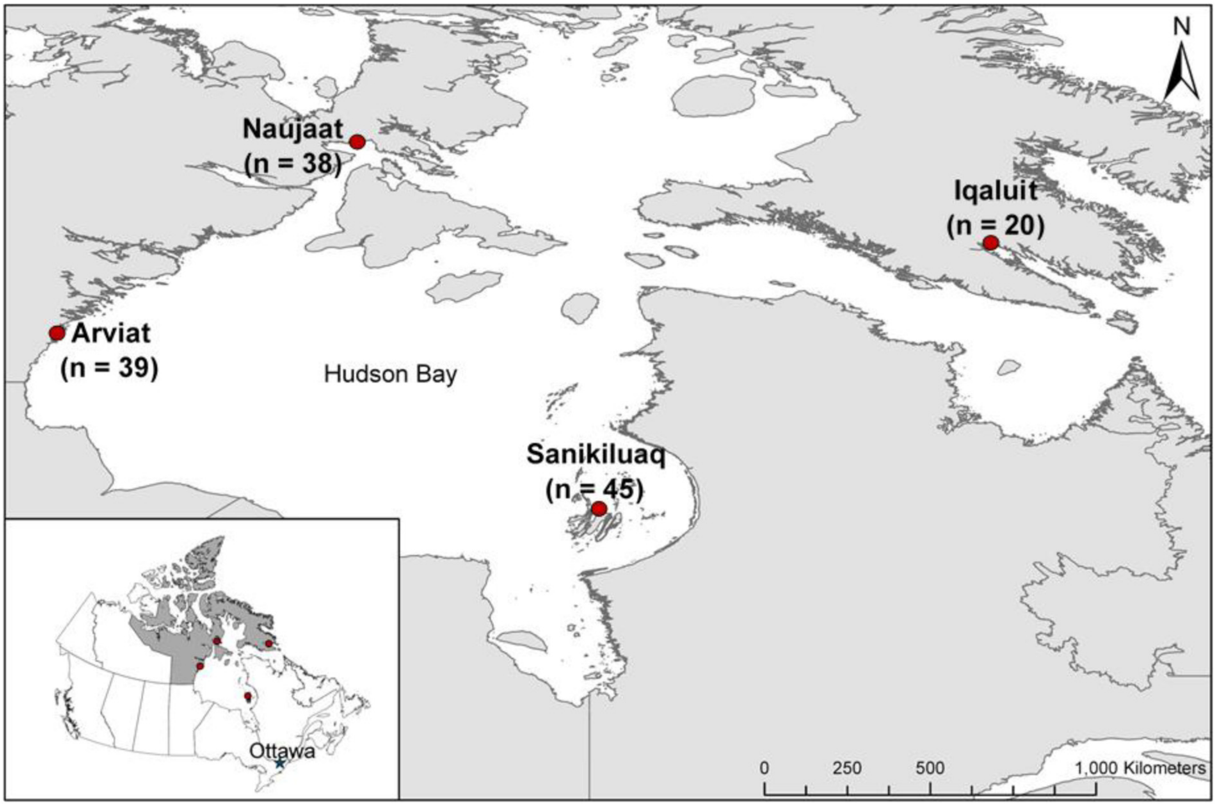

Fig. 1. Locations in Nunavut, Canada, where Inuit subsistence hunters collected seal stomachs for this study: Arviat (61.1078° N, 94.0624° W); Naujaat (66.5283° N, 86.2447° W); Sanikiluaq (56.5408° N, 79.2232° W); and Iqaluit (63.7467° N, 68.5170° W). The numbers of seals collected from each location are indicated on the map.

some seals were determined by the hunters, while for other seals the lower right canine teeth were sent to Matson's Laboratory (Montana, USA) to determine age via counting cementum annuli from a cross-sectioned portion of the tooth (Stewart et al., 1996). The seal stomachs were removed by the hunters, placed into low-density polyethylene bags and frozen to be analyzed at a later date. Other tissues were taken by the hunters for studies involving the health of the seals, including pathology and contaminants.

In April 2019, the seal stomachs were shipped frozen to Carleton University (Ottawa, Canada) to be dissected and inspected for accumulated plastics. In the laboratory the seal stomachs were thawed and weighed. The stomachs were then cut open with a pair of clean scissors and the stomach contents were visually inspected. The dominant diet items were noted, but not quantified. The stomach contents were then removed, weighed, and sieved through nested stainless-steel sieves (mesh size 850 μm and 425 μm) and rinsed using tap water. Material retained by the 850 μm sieves was visually inspected for any plastics. Visual inspection involved thoroughly picking through sections of the stomach contents using forceps and running tap water. Any material that was hard, floated, was sheet like, or was of bright colour was placed into a Petri dish to be inspected more closely under a microscope. The material retained by the 425 μm sieves were rinsed into Petri dishes and carefully inspected under a Leica stereo-microscope at 50 times magnification.

This study focused on the ingestion and retention of plastics > 425 μm in size, as the sampling methodology, specimen storage, and size of the stomachs would have made analysis of smaller plastic particles difficult given uncertainties around airborne contamination by microfibres (Torre et al., 2016) and the amount of organic material that would require digestion in order to isolate these smaller plastics (Lusher et al., 2017). Due to the uncertainties of atmospheric contamination by microfibres (both at the time of sampling and in the laboratory) we did not quantify microfibres in the stomach contents although a few were visible under the microscope. Although we are confident in the caution exerted in inspecting the sieves, we acknowledge that without conducting a digestion of the stomach contents, it is possible that small clear film-like plastics could have been overlooked amongst the organic prey items.

Of the 142 seal stomachs, the majority were from ringed seals (n = 135), along with some bearded seals (n = 6) and a single harbour seal (n = 1). The harvested seals ranged in age from juvenile to 30 years old and of the harvested seals there were 61 female, 78 male, and 3 unknown (Table 1 with full dataset in supplementary material). The standard length of the seals ranged from 77 cm to 252 cm (mean = 111 cm). The weight of the seal stomachs ranged from 123 g to 6210 g (mean = 494 g). The weight of stomach contents ranged from 0 g to 3446 g (mean 148 g). Approximately 21% (n = 31) of the seal stomachs were empty, which is similar to what has been reported in other seal diet studies (Gjertz and Lydersen, 1986; Holst et al., 2001; Labansen et al., 2007; Ogloff et al., 2019; Siegstad et al., 1998). The contents of the seal stomachs were fairly homogenous with either exclusively euphausiids (n = 60) or exclusively small fish (n = 19) making up the bulk of the stomach contents, however, a few stomachs had a mix of euphausiids and fish (n = 9) (Fig. 2A, Fig. 2B [I, II]). Less prevalent stomach contents included parasitic roundworms (n = 10), kelp (n = 2), and rocks (n = 1) (Fig. 2A, Fig. 2B [III, IV, V]). Four of the six bearded seal stomachs only contained large quantities of parasitic roundworms, while one contained fish and the other contained a large amount of sand, gravel and larger rocks, together weighing approximately 3.4 kg (Fig. 2B [V, VI]). The harbour seal stomach contained fish. The stomach contents of a few seals (n = 10) were not identifiable given the state of digestion.

We detected no accumulated plastic particles > 425 μm in the stomachs examined, which suggests that seals in the eastern Canadian

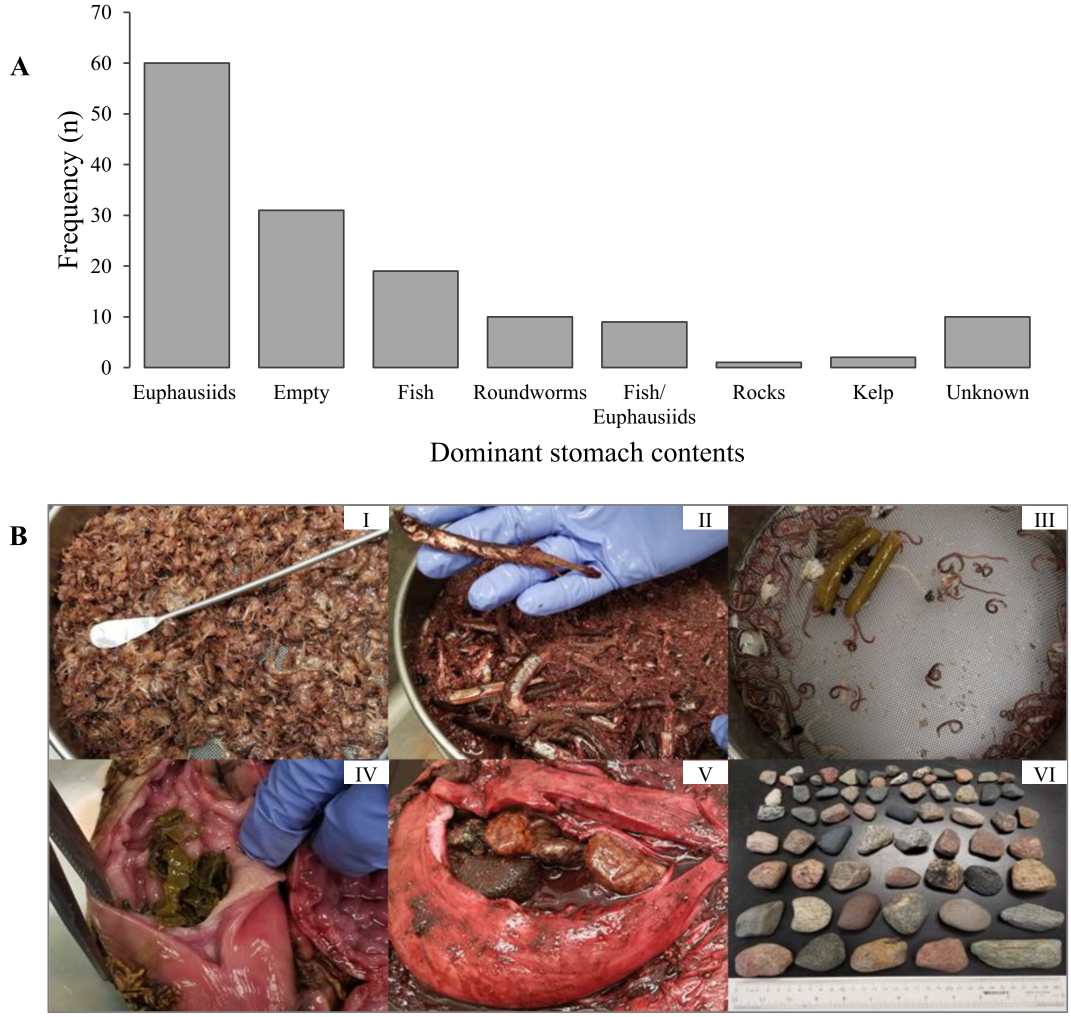

Fig. 2. Stomach contents from the 142 seals examined for this study. **A**: the frequency distribution of dominant stomach contents from the 142 seals. **B**: the dominant stomach contents observed during dissections, including euphausiids **(I)**, fish **(II)**, roundworms **(III)**, kelp **(IV)**, and rocks **(V)**. **(VI)** shows the large rocks removed from the same stomach shown in **(V)**.

Table 1
Distribution of species and sex of seals harvested from four communities in Nunavut, Canada between 2007 and 2019.

Community	Year	Species			Sex		
		Ringed	Bearded	Harbour	Male	Female	Unknown
Arviat	2008	32	5	1	18	19	1
	2018	1	0	0	0	0	1
Naujaat	2008	38	0	0	18	19	1
Sanikiluaq	2007	33	1	0	21	13	0
	2008	11	0	0	7	4	0
Iqaluit	2018	18	0	0	12	6	0
	2019	2	0	0	2	0	0

Arctic are not retaining plastics in their stomachs. Although our study does not rule out the possibility that seals may be ingesting plastics that are passing through their digestive system, our fairly large sample size (n = 142) and the absence of plastic in any of the samples suggests a low ingestion rate of larger plastics, if any. These results indicate that unlike Arctic seabirds collected from the same region, seals are 1) not as exposed to plastic pollution when feeding; 2) not ingesting plastics if they are exposed to plastic pollution when feeding; and/or 3) not retaining plastics in their gastrointestinal systems. Furthermore, these results provide important baseline data for plastic retention in seal stomachs that can be used to assess future rates of plastic ingestion/retention in seals as the concentration of plastic pollution in the Arctic increases.

Previous studies have reported on plastic ingestion by fur seals (*Arctocephalus* ssp.) from the Southwestern Atlantic Ocean, the Eastern Pacific Ocean, and the Southwestern Pacific Ocean (Denuncio et al., 2017; Donohue et al., 2019; Eriksson and Burton, 2003), Hooker's sea lions (*Phocarctos hookeri*) from the Southwestern Pacific Ocean (McMahon et al., 1999), grey seals (*Halichoerus grypus*) from the Celtic and North seas (Hernandez-Milian et al., 2019; Nelms et al., 2019, 2018; Unger et al., 2017), harbour seals from the North Sea (Bravo Rebolledo et al., 2013; Nelms et al., 2019; Unger et al., 2017), and Mediterranean monk seals (*Monachus monachus*) from the Aegean Sea (Salman et al., 2001). Six of these studies found plastics in the stomachs and gastrointestinal tracts (GIT) of the sampled seals, and three studies found plastics in seal scat. Denuncio et al. (2017), Salman et al. (2001), and Unger et al. (2017) found macroplastics in the seal stomachs and GIT, which were predominately fishing-related debris, while Bravo Rebolledo et al. (2013), Hernandez-Milian et al. (2019), and Nelms et al. (2019) found microplastics in the stomachs and/or GIT of seals, of which the most common particles were fibres followed by fragments.

It has been suggested that the microplastics found in seal scat originated from secondary ingestion whereby the seals ingested prey already containing the plastic particles (Donohue et al., 2019; Eriksson and Burton, 2003; Nelms et al., 2018). McMahon et al. (1999) reported on microplastics in 11.5% of scats collected from Hooker's sea lions on Macquarie Island, also suggesting secondary ingestion of plastics after plastic fragments were found concurrently with otoliths from lanternfish (*Electrona subaspera*). Although the frequency of occurrence has been shown to be low, Kühn et al. (2018) and Morgana et al. (2018) both reported on plastics in polar cod (*Boreogadus saida*), a species commonly preyed upon by Arctic seals, highlighting the potential for Arctic seals to ingest microplastics through their prey. Similarly, low numbers of macro- and/or microplastics have been reported in the GIT of other marine mammals such as cetaceans (Lusher et al., 2018; Moore et al., 2019; Panti et al., 2019; Unger et al., 2017; van Franeker et al., 2018), suggesting fairly widespread exposure of marine mammals to plastics. Although plastics were found in all of the above studies, many of these authors noted the low occurrences of macro- and/or microplastics in stomachs and GIT, and suggested that plastics may not be retained for long periods of time in the GIT.

While seals are readily available in the region for monitoring chemical contaminants (Houde et al., 2017), the lack of plastic ingestion may indicate that seals may be less useful for tracking plastic pollution in the region. Importantly, most plastic debris either floats at the surface (e.g. polypropylene) or sinks to the bottom (e.g. polyvinyl chloride). The finding of mostly euphausiids in the diet suggests that the ringed seals are likely feeding in the middle of the water column, and thus are less likely to be exposed to plastic debris. In seabirds, similar trends have been found with surface feeders having the most plastic ingestion, whereas benthic and pelagic feeders have less accumulation of plastics (Poon et al., 2017; Provencher et al., 2014).

Although there was no evidence of plastic material in any of the stomachs dissected for this study, it is possible that there could have been microplastics < 425 μm that were not captured in the sieves, and which would have likely passed through the GIT of the seals. It is also possible that the prey within the seal stomachs (euphausiids and fish) could have contained microplastics, thus contributing to an indirect ingestion of microplastics by the seals. Although Arctic waters have been suggested as a final resting place for some plastic debris, the concentration of plastics in Canada's eastern Arctic waters are likely lower than in temperate or equatorial areas (Cózar et al., 2017), possibly resulting in marine mammals such as seals being less exposed to plastics. This study therefore provides important baseline data for plastic ingestion and concentrations in the eastern Canadian Arctic.

Numerous studies have reported plastic ingestion by a variety of organisms, however, few studies have published results showing zero plastic ingestion rates. Liboiron et al. (2018) published findings of 0% plastic ingestion rates of silver hake (*Merluccius bilinearis*) from off the south coast of Newfoundland, Canada, while Ryan et al. (2016) published their findings of zero plastic particles in Antarctic fur seal scat from three islands in the Indian and South Atlantic Oceans. Both of these articles suggest that there is a general lack of reporting null results of plastic ingestion within the literature. In order to gain a complete understanding of the extent of plastic pollution and to mitigate the impacts on the environment, it is paramount that we identify the species and regions in which plastic ingestion is occurring.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2019.110772.

CRediT authorship contribution statement

M.P.T. Bourdages: Conceptualization, Data curation, Formal analysis, Investigation, Writing - original draft. **J.F. Provencher:** Conceptualization, Formal analysis, Funding acquisition, Supervision, Writing - review & editing. **E. Sudlovenick:** Conceptualization, Investigation, Writing - review & editing. **S.H. Ferguson:** Conceptualization, Funding acquisition, Writing - review & editing. **B.G. Young:** Conceptualization, Funding acquisition, Writing - review & editing. **N. Pelletier:** Investigation, Writing - review & editing. **M.J.J. Murphy:** Investigation, Writing - review & editing. **A. D'Addario:** Investigation, Writing - review & editing.

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.

Acknowledgements

We would like to thank all of the Inuit hunters that contributed samples to the different contaminant and health research programs over the years. In particular we would like to thank the Hunter and Trapper groups that supported the project; the Arviat Hunter and Trapper Organization, the Arviq Hunter and Trapper Organization, the Sanikiluaq Hunter and Trapper Association, and the Amaruq Hunter and Trapper Organization. Some of the samples were collected as part of work carried out with support from the Northern Contaminants Program under Crown and Indigenous Relations and Northern Affairs Canada. Support was also provided by the National Science and Engineering Research Council (NSERC), the Northern Scientific Training Program (NSTP), Fisheries & Oceans Canada, Nunavut Wildlife Management Board, Nunavut Research Institute in partnership with Irving Shipbuilding Inc., and Coastal Environmental Baseline Program. Special thanks to Pierre-Yves Daoust and Jan van Franeker for providing helpful comments on the manuscript.

References

Bravo Rebolledo, E.L., Van Franeker, J.A., Jansen, O.E., Brasseur, S.M.J.M., 2013. Plastic ingestion by harbour seals (Phoca vitulina) in The Netherlands. Mar. Pollut. Bull. 67, 200–202. https://doi.org/10.1016/j.marpolbul.2012.11.035.

Cózar, A., Martí, E., Duarte, C.M., García-de-Lomas, J., van Sebille, E., Ballatore, T.J., Eguíluz, V.M., Ignacio González-Gordillo, J., Pedrotti, M.L., Echevarría, F., Troublè, R., Irigoien, X., 2017. The Arctic Ocean as a dead end for floating plastics in the North Atlantic branch of the thermohaline circulation. Sci. Adv. 3, 1–8. https://doi.org/10.1126/sciadv.1600582.

Denuncio, P., Mandiola, M.A., Pérez Salles, S.B., Machado, R., Ott, P.H., De Oliveira, L.R., Rodriguez, D., 2017. Marine debris ingestion by the South American fur seal from the Southwest Atlantic Ocean. Mar. Pollut. Bull. 122, 420–425. https://doi.org/10.1016/j.marpolbul.2017.07.013.

Donohue, M.J., Masura, J., Gelatt, T., Ream, R., Baker, J.D., Faulhaber, K., Lerner, D.T., 2019. Evaluating exposure of northern fur seals, Callorhinus ursinus, to microplastic pollution through fecal analysis. Mar. Pollut. Bull. 138, 213–221. https://doi.org/10.1016/j.marpolbul.2018.11.036.

Eriksson, C., Burton, H., 2003. Origins and biological accumulation of small plastic particles in fur seals from Macquarie Island. AMBIO A J. Hum. Environ. 32, 380–384. https://doi.org/10.1579/0044-7447-32.6.380.

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 47, 387–397. https://doi.org/10.1007/s13280-017-1002-y.

Gjertz, I., Lydersen, C., 1986. The ringed seal (Phoca hispida) spring diet in northwestern Spitsbergen, Svalbard. Polar Res. 4, 53–56. https://doi.org/10.1111/j.1751-8369.1986.tb00518.x.

Hernandez-Milian, G., Lusher, A., MacGabban, S., Rogan, E., 2019. Microplastics in grey seal (Halichoerus grypus) intestines: are they associated with parasite aggregations? Mar. Pollut. Bull. 146, 349–354. https://doi.org/10.1016/j.marpolbul.2019.06.014.

Holst, M., Stirling, I., Hobson, K.A., 2001. Diet of ringed seals (Phoca hispida) on the east and west sides of the North Water Polynya, northern Baffin Bay. Mar. Mammal Sci. 17, 888–908. https://doi.org/10.1111/j.1748-7692.2001.tb01304.x.

Houde, M., Wang, X., Ferguson, S.H., Gagnon, P., Brown, T.M., Tanabe, S., Kunito, T., Kwan, M., Muir, D.C.G., 2017. Spatial and temporal trends of alternative flame retardants and polybrominated diphenyl ethers in ringed seals (Phoca hispida) across the Canadian Arctic. Environ. Pollut. 223, 266–276. https://doi.org/10.1016/j.envpol.2017.01.023.

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 International Publishing, Cham, pp. 75–116. https://doi.org/10.1007/978-3-319-16510-3_4.

Kühn, S., Schaafsma, F.L., Werven, B.V., 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.

Labansen, A.L., Lydersen, C., Haug, T., Kovacs, K.M., 2007. Spring diet of ringed seals (Phoca hispida) from northwestern Spitsbergen, Norway. ICES J. Mar. Sci. 64, 1246–1256. https://doi.org/10.1093/icesjms/fsm090.

Liboiron, F., Ammendolia, J., Saturno, J., Melvin, J., Zahara, A., Richárd, N., Liboiron, M., 2018. A zero percent plastic ingestion rate by silver hake (Merluccius bilinearis) from the south coast of Newfoundland, Canada. Mar. Pollut. Bull. 131, 267–275. https://doi.org/10.1016/j.marpolbul.2018.04.007.

Lu, Z., De Silva, A.O., Provencher, J.F., Mallory, M.L., Kirk, J.L., Houde, M., Stewart, C., Braune, B.M., Avery-Gomm, S., Muir, D.C.G., 2019. Occurrence of substituted diphenylamine antioxidants and benzotriazole UV stabilizers in Arctic seabirds and seals. Sci. Total Environ. 663, 950–957. https://doi.org/10.1016/j.scitotenv.2019.01.354.

Lusher, A.L., Welden, N.A., Sobral, P., Cole, M., 2017. Sampling, isolating and identifying microplastics ingested by fish and invertebrates. Anal. Methods 9, 1346–1360. https://doi.org/10.1039/C6AY02415G.

Lusher, A.L., Hernandez-Milian, G., Berrow, S., Rogan, E., O'Connor, I., 2018. Incidence of marine debris in cetaceans stranded and bycaught in Ireland: recent findings and a review of historical knowledge. Environ. Pollut. 232, 467–476. https://doi.org/10.1016/j.envpol.2017.09.070.

McMahon, C.R., Holley, D., Robinson, S., 1999. The diet of itinerant male Hooker's sea lions, Phocarctos hookeri, at sub-Antarctic Macquarie Island. Wildl. Res. 26, 839–846. https://doi.org/10.1071/WR98079.

Moore, R.C., Loseto, L., Noel, M., Etemadifar, A., Brewster, J.D., MacPhee, S., Bendell, L., Ross, P.S., 2019. Microplastics in beluga whales (Delphinapterus leucas) from the eastern Beaufort Sea. Mar. Pollut. Bull. 1–7. https://doi.org/10.1016/j.marpolbul.2019.110723.

Morgana, S., Ghigliotti, L., Estévez-Calvar, N., Stifanese, R., Wieckzorek, A., Doyle, T., Christiansen, J.S., Faimali, M., Garaventa, F., 2018. Microplastics in the Arctic: a case study with sub-surface water and fish samples off Northeast Greenland. Environ. Pollut. 242, 1078–1086. https://doi.org/10.1016/j.envpol.2018.08.001.

Nelms, S.E., Galloway, T.S., Godley, B.J., Jarvis, D.S., Lindeque, P.K., 2018. Investigating microplastic trophic transfer in marine top predators. Environ. Pollut. 238, 999–1007. https://doi.org/10.1016/j.envpol.2018.02.016.

Nelms, S.E., Barnett, J., Brownlow, A., Davison, N.J., Deaville, R., Galloway, T.S., Lindeque, P.K., Santillo, D., Godley, B.J., 2019. Microplastics in marine mammals stranded around the British coast: ubiquitous but transitory? Sci. Rep. 9, 1–8. https://doi.org/10.1038/s41598-018-37428-3.

Ogloff, W.R., Yurkowski, D.J., Davoren, G.K., Ferguson, S.H., 2019. Diet and isotopic niche overlap elucidate competition potential between seasonally sympatric phocids in the Canadian Arctic. Mar. Biol. 166, 1–12. https://doi.org/10.1007/s00227-019-3549-6.

Panti, C., Baini, M., Lusher, A., Hernandez-Milan, G., Bravo Rebolledo, E.L., Unger, B., Syberg, K., Simmonds, M.P., Fossi, M.C., 2019. Marine litter: one of the major threats for marine mammals. Outcomes from the European Cetacean Society workshop. Environ. Pollut. 247, 72–79. https://doi.org/10.1016/j.envpol.2019.01.029.

Poon, F.E., Provencher, J.F., Mallory, M.L., Braune, B.M., Smith, P.A., 2017. 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.L., O'hara, P.D., Gilchrist, H.G., 2010. Ingested plastic in a diving seabird, the thick-billed murre (Uria lomvia), in the eastern Canadian Arctic. Mar. Pollut. Bull. 60, 1406–1411. https://doi.org/10.1016/j.marpolbul.2010.05.017.

Provencher, J.F., Bond, A.L., Hedd, A., Montevecchi, W.A., Muzaffar, S. Bin, Courchesne, S.J., Gilchrist, H.G., Jamieson, S.E., Merkel, F.R., Falk, K., Durinck, J., Mallory, M.L., 2014. Prevalence of marine debris in marine birds from the North Atlantic. Mar. Pollut. Bull. 84, 411–417. https://doi.org/10.1016/j.marpolbul.2014.04.044.

Ryan, P.G., de Bruyn, P.J.N., Bester, M.N., 2016. Regional differences in plastic ingestion among Southern Ocean fur seals and albatrosses. Mar. Pollut. Bull. 104, 207–210. https://doi.org/10.1016/j.marpolbul.2016.01.032.

Salman, A., Bilecenoglu, M., Güçlüsoy, H., 2001. Stomach contents of two Mediterranean monk seals (Monachus monachus) from the Aegean Sea, Turkey. J. Mar. Biol. Assoc. United Kingdom 81, 719–720. https://doi.org/10.1017/S0025315401004519.

Searles, E.Q., 2019. 'Fresh seal blood looks like beauty and life' #Sealfies and subsistence in Nunavut. Hunt. Gatherer Res. 3, 677–696. https://doi.org/10.3828/hgr.2017.34.

Siegstad, H., Neve, P.B., Heide-Jørgensen, M.P., Härkönen, T., 1998. Diet of the ringed seal (Phoca hispida) in Greenland. NAMMCO Sci. Publ. 1, 229–241. https://doi.org/10.7557/3.2991.

Stewart, R.E.A., Stewart, B.E., Stirling, I., Street, E., 1996. Counts of growth layer groups in cementum and dentine in ringed seals (Phoca hispida). Mar. Mammal Sci. 12, 383–401. https://doi.org/10.1111/j.1748-7692.1996.tb00591.x.

Thompson, R.C., Moore, C.J., vom Saal, F.S., Swan, S.H., 2009. Plastics, the environment and human health: current consensus and future trends. Philos. Trans. Biol. Sci. 364, 2153–2166. https://doi.org/10.1098/rstb.2009.0053.

Torre, M., Digka, N., Anastasopoulou, A., Tsangaris, C., Mytilineou, C., 2016. Anthropogenic microfibres pollution in marine biota. A new and simple methodology to minimize airborne contamination. Mar. Pollut. Bull. 113, 55–61. https://doi.org/10.1016/j.marpolbul.2016.07.050.

Unger, B., Herr, H., Benke, H., Böhmert, M., Burkhardt-Holm, P., Dähne, M., Hillmann, M., Wolff-Schmidt, K., Wohlsein, P., Siebert, U., 2017. Marine debris in harbour porpoises and seals from German waters. Mar. Environ. Res. 130, 77–84. https://doi.org/10.1016/j.marenvres.2017.07.009.