**Literature Review:**

**PLASTIC MARINE LITTER IN THE ARCTIC**

The literature is grouped under the six following items:

* **Sources**: Literature on the origin of the plastic ending up in the Arctic Ocean (e.g. fisheries, shipping, industry, tourism/recreation…).
* **Transport**: Literature related to the transport and pathways used by plastics: (e.g. oceanic currents, river transport…).
* **Distribution**: Quantitative and qualitative studies on plastic presence in the different sinks in the Arctic: coastal areas, surface water, water column, seafloor and sea ice.
* **Impact**: Literature on the effects of plastic presence in the Arctic (impacts on economic activities, ecosystems, human health, ingestion, entanglement, pathogens or invasive species transport…)
* **Response**: Literature on the solutions and actions (…) aiming at mitigating plastic litter in the Arctic (e.g. governance, regulations, cleanups).
* **Crosscutting issues:** Literature providing a general review on the issue of plastic marine litter in the Arctic, and/or literature covering several of the five items previously described.

The literature covered in this review is mainly related to the Arctic. There is a vast amount of literature related to other parts of the world, which is not covered here. However, we added a few of the more general publications because, they either provide a good overview of the general challenges related to marine litter or they explain mechanisms elsewhere that might be relevant to the Arctic.

**Color Code:**

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| ***Macroplastics*** |  | ***Microplastics*** |  | ***Marine Litter general/undefined*** |

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# **1- SOURCES**

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| **Hess, N. A., et al. (1999). "Benthic marine debris, with an emphasis on fishery-related items, surrounding Kodiak Island, Alaska, 1994–1996." Marine Pollution Bulletin 38(10): 885-890.**  Composition and abundance of benthic marine debris were investigated during three bottom trawl surveys in inlet and offshore locations surrounding Kodiak Island, Alaska, 1994–1996. Debris items were primarily plastic and metal regardless of trawl location. Plastic bait jars, fishing line, and crab pots were the most common fishery-related debris items and were encountered in large amounts in inlets (20–25 items km−2), but were less abundant outside of inlets (4.5–11 items km−2). Overall density of debris was also significantly greater in inlets than outside of inlets. Plastic debris densities in inlets ranged 22–31.5 items km−2, 7.8–18.8 items km−2 outside of inlets. Trawls in inlets contained almost as much metal debris as plastic debris. Density of metal debris ranged from 21.2 to 23.7 items km−2 in inlets, a maximum of 2.7 items km−2 outside of inlets. Inlets around the town of Kodiak had the highest densities of fishery-related and total benthic debris. Differences in benthic debris density between inlets and outside of inlets and differences by area may be due to differences in fishing activity and water circulation patterns. At the current reduced levels of fishing activity, however, yearly monitoring of benthic debris appears unnecessary. |
| **King, B. (2009). Derelict fishing gear in Alaska: Accumulation rates and fishing net analysis. Marine debris in Alaska: Coordinating our efforts. . M. Williams and W. Ammann. University of Alaska Fairbanks, Alaska Sea Grant.**  *No Abstract Available* |
| **MARP (2017). Report on WP 1.2 "Sources of Marine Litter" Workshop Svalbard 4th-6th September 2016, MARine Plastic Pollution in the Arctic: origin status, costs and incentives for Prevention (MARP3).**  *No Abstract Available* |
| **Merrell, T. R. (1984). "A decade of change in nets and plastic litter from fisheries off Alaska." Marine Pollution Bulletin 15(10): 378-384.**  Ten 1 km beaches on Amchitka Island, Alaska, were surveyed once annually in 1972–1974 and in 1982 to determine weights and numbers of fish-net fragments and other plastic litter items. Most litter was from Japanese and Soviet fishing vessels. Litter rapidly increased during 1972–74 (from 122 to 345 kg km−1 of beach) but decreased 26% by 1982 to 255 kg km−1. There was a 37% reduction in weight of trawl web on Amchitka beaches, and the number of gill-net floats declined 47%. The decrease in litter between 1974 and 1982, attributed to fewer trawlers and gill-netters fishing off Alaska, shows that marine litter could be rapidly reduced if disposal of litter at sea were restricted. |

# **2- TRANSPORT**

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| **Cózar, A., et al. (2017). "The Arctic Ocean as a dead end for floating plastics in the North Atlantic branch of the Thermohaline Circulation." Science advances 3(4): e1600582.**  The subtropical ocean gyres are recognized as great marine accummulation zones of floating plastic debris; however, the possibility of plastic accumulation at polar latitudes has been overlooked because of the lack of nearby pollution sources. In the present study, the Arctic Ocean was extensively sampled for floating plastic debris from the Tara Oceans circumpolar expedition. Although plastic debris was scarce or absent in most of the Arctic waters, it reached high concentrations (hundreds of thousands of pieces per square kilometer) in the northernmost and easternmost areas of the Greenland and Barents seas. The fragmentation and typology of the plastic suggested an abundant presence of aged debris that originated from distant sources. This hypothesis was corroborated by the relatively high ratios of marine surface plastic to local pollution sources. Surface circulation models and field data showed that the poleward branch of the Thermohaline Circulation transfers floating debris from the North Atlantic to the Greenland and Barents seas, which would be a dead end for this plastic conveyor belt. Given the limited surface transport of the plastic that accumulated here and the mechanisms acting for the downward transport, the seafloor beneath this Arctic sector is hypothesized as an important sink of plastic debris. |
| **Obbard, R. W., et al. (2014). "Global warming releases microplastic legacy frozen in Arctic Sea ice." Earth's Future 2(6): 315-320.**  When sea ice forms it scavenges and concentrates particulates from the water column, which then become trapped until the ice melts. In recent years, melting has led to record lows in Arctic Sea ice extent, the most recent in September 2012. Global climate models, such as that of Gregory et al. (2002), suggest that the decline in Arctic Sea ice volume (3.4% per decade) will actually exceed the decline in sea ice extent, something that Laxon et al. (2013) have shown supported by satellite data. The extent to which melting ice could release anthropogenic particulates back to the open ocean has not yet been examined. Here we show that Arctic Sea ice from remote locations contains concentrations of microplastics are several orders of magnitude greater than those that have been previously reported in highly contaminated surface waters, such as those of the Pacific Gyre. Our findings indicate that microplastics have accumulated far from population centers and that polar sea ice represents a major historic global sink of man-made particulates. The potential for substantial quantities of legacy microplastic contamination to be released to the ocean as the ice melts therefore needs to be evaluated, as do the physical and toxicological effects of plastics on marine life. |
| **van Sebille, E., et al. (2012). "Origin, dynamics and evolution of ocean garbage patches from observed surface drifters." Environmental Research Letters 7(4): 044040.**  Much of the debris in the near-surface ocean collects in so-called garbage patches where, due to convergence of the surface ﬂow, the debris is trapped for decades to millennia. Until now, studies modelling the pathways of surface marine debris have not included release from coasts or factored in the possibilities that release concentrations vary with region or that pathways may include seasonal cycles. Here, we use observational data from the Global Drifter Program in a particle-trajectory tracer approach that includes the seasonal cycle to study the fate of marine debris in the open ocean from coastal regions around the world on interannual to centennial timescales. We ﬁnd that six major garbage patches emerge, one in each of the ﬁve subtropical basins and one previously unreported patch in the Barents Sea. The evolution of each of the six patches is markedly different. With the exception of the North Paciﬁc, all patches are much more dispersive than expected from linear ocean circulation theory, suggesting that on centennial timescales the different basins are much better connected than previously thought and that inter-ocean exchanges play a large role in the spreading of marine debris. This study suggests that, over multi-millennial timescales, a signiﬁcant amount of the debris released outside of the North Atlantic will eventually end up in the North Paciﬁc patch, the main attractor of global marine debris. |
| **Tubau, X., et al. (2015). "Marine litter on the floor of deep submarine canyons of the Northwestern Mediterranean Sea: the role of hydrodynamic processes." Progress in Oceanography 134: 379-403.**  Marine litter represents a widespread type of pollution in the World’s Oceans. This study is based on direct observation of the seafloor by means of Remotely Operated Vehicle (ROV) dives and reports litter abundance, type and distribution in three large submarine canyons of the NW Mediterranean Sea, namely Cap de Creus, La Fonera and Blanes canyons. Our ultimate objective is establishing the links between active hydrodynamic processes and litter distribution, thus going beyond previous, essentially descriptive studies.  Litter was monitored using the Liropus 2000 ROV. Litter items were identified in 24 of the 26 dives carried out in the study area, at depths ranging from 140 to 1731 m. Relative abundance of litter objects by type, size and apparent weight, and distribution of litter in relation to depth and canyon environments (i.e. floor and flanks) were analysed. Plastics are the dominant litter component (72%), followed by lost fishing gear, disregarding their composition (17%), and metal objects (8%). Most of the observed litter seems to be land-sourced. It reaches the ocean through wind transport, river discharge and after direct dumping along the coastline. While coastal towns and industrial areas represent a permanent source of litter, tourism and associated activities relevantly increase litter production during summer months ready to be transported to the deep sea by extreme events. After being lost, fishing gear such as nets and long-lines has the potential of being harmful for marine life (e.g. by ghost fishing), at least for some time, but also provides shelter and a substrate on which some species like cold-water corals are capable to settle and grow.  La Fonera and Cap de Creus canyons show the highest mean concentrations of litter ever seen on the deep-sea floor, with 15,057 and 8090 items km−2, respectively, and for a single dive litter observed reached 167,540 items km−2. While most of the largest concentrations were found on the canyon floors at water depths exceeding 1000 m, relatively little litter was identified on the canyon walls. The finding of litter ‘hotspots’ (i.e., large accumulations of litter) formed by mixtures of land- and marine-sourced litter items and natural debris such as sea urchin carcasses evidences an efficient transport to the floor of mid and lower canyon reaches at least.  High-energy, down canyon near-bottom flows are known to occur in the investigated canyons. These are associated to seasonal dense shelf water cascading and severe coastal storms, which are the most energetic hydrodynamic processes in the study area thus becoming the best candidates as main carriers of debris to the deep. The fact that the investigated canyons have their heads at short distance (<4 km) from the shoreline enhances their ability to trap littoral drift currents and also to convey the signal of the above-mentioned high-energy events to the deep, including their litter load. This study contributes to assess the origin and transport mechanisms of litter to the deep sea as well as its potential impact on deep-sea ecosystems. |

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# **3- DISTRIBUTION**

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| **Bergmann, M. and M. Klages (2012). "Increase of litter at the Arctic deep-sea observatory HAUSGARTEN." Marine Pollution Bulletin 64(12): 2734-2741.**  Although recent research has shown that marine litter has made it even to the remotest parts of our planet, little information is available about temporal trends on the deep ocean floor. To quantify litter on the deep seafloor over time, we analysed images from the HAUSGARTEN observatory (79°N) taken in 2002, 2004, 2007, 2008 and 2011 (2500 m depth). Our results indicate that litter increased from 3635 to 7710 items km−2 between 2002 and 2011 and reached densities similar to those reported from a canyon near the Portuguese capital Lisboa. Plastic constituted the majority of litter (59%) followed by a black fabric (11%) and cardboard/paper (7%). Sixty-seven percent of the litter was entangled or colonised by invertebrates such as sponges (41%) or sea anemones (15%). The changes in litter could be an indirect consequence of the receding sea ice, which opens the Arctic Ocean to the impacts of man’s activities. |
| **Bergmann, M., et al. (2016). "Observations of floating anthropogenic litter in the Barents Sea and Fram Strait, Arctic." Polar Biology 39(3): 553-560.**  Although recent reports indicate that anthropogenic waste has made it to the remotest parts of our oceans, there is still only limited information about its spread, especially in polar seas. Here, we present litter densities recorded during ship- and helicopter-based observer surveys in the Barents Sea and Fram Strait (Arctic). Thirty-one items were recorded in total, 23 from helicopter and eight from research vessel transects. Litter quantities ranged between 0 and 0.216 items km−1 with a mean of 0.001 (±SEM 0.005) items km−1. All of the floating objects observed were plastic items. Litter densities were slightly higher in the Fram Strait (0.006 items km−1) compared with the Barents Sea (0.004 items km−1). More litter was recorded during helicopter-based surveys than during ship-based surveys (0.006 and 0.004 items km−1, respectively). When comparing with the few available data with the same unit (items km−1 transect), the densities found herein are slightly higher than those from Antarctica but substantially lower than those from temperate waters. However, since anthropogenic activities in the Fram Strait are expanding because of sea ice shrinkage, and since currents from the North Atlantic carry a continuous supply of litter to the north, this problem is likely to worsen in years to come unless serious mitigating actions are taken to reduce the amounts of litter entering the oceans. |
| **Bergmann, M., et al. (2016). "Vast Quantities of Microplastics in Arctic Sea Ice—A Prime Temporary Sink for Plastic Litter and a Medium of Transport." MICRO 2016: Fate and Impact of Microplastics in Marine Ecosystems: From the Coastline to the Open Sea: 75.**  Although the Arctic covers 6% of our planet’s surface and plays a key role in the Earth’s climate it remains one of the least explored ecosystems. The global change induced decline of sea ice has led to increasing anthropogenic presence in the Arctic Ocean. Exploitation of its resources is already underway, and Arctic waters are likely important future shipping lanes as indicated by already increasing numbers of fishing vessels, cruise liners and hydrocarbon prospecting in the area over the past decade. Global estimates of plastic entering the oceans currently exceed results based on empirical evidence by up to three orders of magnitude highlighting that we have not yet identified some of the major sinks of plastic in our oceans. Fragmentation into microplastics could explain part of the discrepancy. Indeed, microplastics were identified from numerous marine ecosystems globally, including the Arctic. Here, we analysed horizons of ice cores from the western and eastern Fram Strait by focal plane array based micro-Fourier transform infrared spectroscopy to assess if sea ice is a sink of microplastic. Ice cores were taken from land-locked and drifting sea ice to distinguish between local entrainment of microplastics vs long-distance transport. Mean concentrations of 2 x 106 particles m-3 in pack ice and 6 x 105 particles m-3 in land-locked ice were detected (numbers of fibers will soon be added). Eleven different polymer types were identified; polyethylene (PE) was the most abundant one. Preliminary results from four further ice cores from the central Arctic range in a similar order but the microplastics composition was very different. Calculation of drift trajectories by back-tracking of the ice floes sampled indicates multiple source areas, which explains the differences in the microplastic composition. Preliminary analysis of snow samples taken from ice floes in the Fram Strait showed numerous fibers of yet unknown but most likely anthropogenic origin indicating atmospheric fallout as a possible pathway. Our results exceed concentrations from the North Pacific by several orders of magnitudes. This can be explained partly by the process of ice formation, during which (organic) particles tend to concentrate by 1-2 orders of magnitude compared with ambient seawater. However, the magnitude of the difference indicates that Arctic sea ice is a temporal sink for microplastics. Increasing quantities of small plastic litter items on the seafloor nearby, which is located in the marginal ice zone corroborate the notion that melting sea ice releases entrained plastic particles and that sea ice acts as a vector of transport both horizontally and vertically to underlying ecosystem compartments |
| **Bergmann, M., et al. (2017). "High quantities of microplastic in Arctic deep-sea sediments from the HAUSGARTEN observatory." Environmental science & technology.**  Although mounting evidence suggests the ubiquity of microplastic in aquatic ecosystems worldwide, our knowledge of its distribution in remote environments such as Polar Regions and the deep sea is scarce. Here, we analyzed nine sediment samples taken at the HAUSGARTEN observatory in the Arctic at 2,340 – 5,570 m depth. Density separation by MicroPlastic Sediment Separator and treatment with Fenton’s reagent enabled analysis via Attenuated Total Reflection FTIR and µFTIR spectroscopy. Our analyses indicate the wide spread of high numbers of microplastics (42 – 6,595 microplastics kg-1). The northernmost stations harbored the highest quantities, indicating sea ice as a transport vehicle. A positive correlation between microplastic abundance and chlorophyll a content suggests vertical export via incorporation in sinking (ice-) algal aggregates. Overall, 18 different polymers were detected. Chlorinated polyethylene accounted for the largest proportion (38 %), followed by polyamide (22 %) and polypropylene (16 %). Almost 80 % of the microplastics were ≤ 25 µm. The microplastic quantities are amongst the highest recorded from benthic sediments, which corroborates the deep sea as a major sink for microplastics and the presence of accumulation areas in this remote part of the world, fed by plastics transported to the North via the Thermohaline Circulation. |
| **Day, R. H. and D. G. Shaw (1987). "Patterns in the abundance of pelagic plastic and tar in the North Pacific Ocean, 1976–1985." Marine Pollution Bulletin 18(6): 311-316.**  We determined the distribution and abundance of pelagic plastic and tar in the subtropical and subarctic North Pacific and the Bering Sea in June–August 1985 and compared them with similar observations from the same areas in 1976 and 1984. Large (aproximately 2.5 cm diameter or larger) plastic objects were counted from the deck of a ship, and small plastic objects and tarballs were caught with a neuston net. Densities (number items m−2) of large plastic in subtropical waters averaged two times those in subarctic waters and eight times those in the Bering Sea. Concentrations (mg m−2) of small plastic in subtropical waters averaged 26 times those in subarctic waters and 400 times those in the Bering Sea. Concentrations of tar in subtropical waters averaged three times those in subarctic waters; no tar was found in the Bering Sea. Densities of large plastic along 155°W in the Subarctic North Pacific were not significantly different between 1984 and 1985. Concentrations of small plastic increased significantly between 1976 (along 158°W) and 1985 (along 155°W), probably because of escapement into and subsequent accumulation in the oceans. Concentrations of tar decreased, although not significantly, between 1976 and 1985, possibly because of decreased dumping of petroleum compounds at sea. Densities of large plastic were strongly correlated with both densities and concentrations of small plastic, but neither densities nor concentrations of large or small plastic were correlated with densities or concentrations of tar. |
| **Dippo, B. (2012). Microplastics in the coastal environment of West Iceland. Faculty of Business and Science, University of Akureyri: 66.**  Microplastic particles in the marine environment and the effects on wildlife, human and ecosystem health are just beginning to be understood in a global setting. The presence of microplastics particles in West Iceland are evaluated to determine if there is a detectable gradient of decreasing plastic concentrations with increasing distance from the urban centres around Reykjavik. The study region includes sample sites within urban, semi-rural and coastal settings, with 4 sites at each type of location being sa;pled. Microplasitc particles were found at 3 of the urban sites, 2 of teh semi-rural sites, and not detected in any of the rural locations. It is concludded that a decreasing concentration gradient that is based solely on distance travelled from the urbanized area of Reykjavik does not exist due to patchy distributions that could be the result of strong influcences from ocean currents and offshore activities. |
| **Feder, H. M., et al. (1978). "Man-made debris on the Bering Sea floor." Marine Pollution Bulletin 9(2): 52-53.**  Proposed oil development in the Bering Sea has led to intensive biological assessment surveys there. A benthic trawl, used to collect bottom invertebrates and fishes in these surveys also brings up any man-made debris in its path. A description of this debris, its distribution, and frequency of occurrence are given for the southeastern Bering Sea in 1975 and 1976. |
| **van Franeker, J. A. and K. L. Law (2015). "Seabirds, gyres and global trends in plastic pollution." Environmental Pollution 203: 89-96.**  Fulmars are effective biological indicators of the abundance of floating plastic marine debris. Long-term data reveal high plastic abundance in the southern North Sea, gradually decreasing to the north at increasing distance from population centres, with lowest levels in high-arctic waters. Since the 1980s, pre-production plastic pellets in North Sea fulmars have decreased by ∼75%, while user plastics varied without a strong overall change. Similar trends were found in net-collected floating plastic debris in the North Atlantic subtropical gyre, with a ∼75% decrease in plastic pellets and no obvious trend in user plastic. The decreases in pellets suggest that changes in litter input are rapidly visible in the environment not only close to presumed sources, but also far from land. Floating plastic debris is rapidly “lost” from the ocean surface to other as-yet undetermined sinks in the marine environment. |
| **Galgani, F. and F. Lecornu (2004). Debris on the seafloor at "Hausgarten" The expedition ARK XIX/3 of the Research Vessel POLARSTERN in 2003: Reports of legs 3a, 3b and 3c. M. Klages, J. Thiede and J.-P. Foucher, Reports on Polar and Marine Research 488: 260-262.**  *No Abstract Available* |
| **June, J. A. (1990). Type, source, and abundance of trawl-caught marine debris off Oregon, in the eastern Bering Sea, and in Norton Sound in 1988. Proceedings of the Second International Conference on Marine Debris, NOAA Technical Memo NMFS-SWF-SC-154.**  In 1988, National Marine Fisheries Service scientists collected information on type, source, and abundance of marine debris caught during annual bottom trawl surveys off Oregon, in the eastern Bering Sea, and in Norton Sound. Numbers of indi- vidual debris items caught were tallied by haul. When possible, the nationality of origin was determined. Animals entangled or associated with debris items were noted. Debris items were categorized by material (e.g., plastic, glass) and use (e.g., galley wastes, fishing equipment). Effort in square kilometers trawled was calculated for each haul from distance fished and average net width measurements. Average catch-per-unit-effort (CPUE) in numbers of items per square kilometer was calculated for individual debris items, major categories, and total debris by area and for combined areas.  Of the 696 hauls surveyed, 70 were off Oregon, 541 in the eastern Bering Sea, and 85 in Norton Sound. Marine debris was most abundant off Oregon, occurring in 70% of the hauls and averaging 149.6 items/km2. In the eastern Bering Sea, 23% of the hauls caught marine debris, for an average of 7.5 items/km2. Norton Sound had the least amount of debris. It occurred in 7% of the hauls and averaged 1.9 items/km2. Galley wastes dominated debris in Oregon (64% of the total CPUE) and in the eastern Bering Sea (40% of the total CPUE), followed by engineering/processing wastes. Fishing equipment debris was abundant in the eastern Bering Sea (1.86 items/km2) and off Oregon (1.69 items/km2), but was not found in Norton Sound. Plastic debris was found in all three areas, but was most abundant in the eastern Bering Sea. Debris of foreign origin accounted for 70% of the total CPUE of all debris found in the eastern Bering Sea; however, domestic debris dominated off Oregon (88% of the total CPUE) and in Norton Sound (100% of the total CPUE). |
| **Lusher, A. L., et al. (2015). "Microplastics in Arctic polar waters: the first reported values of particles in surface and sub-surface samples." Scientific reports 5.**  Plastic, as a form of marine litter, is found in varying quantities and sizes around the globe from surface waters to deep-sea sediments. Identifying patterns of microplastic distribution will benefit an understanding of the scale of their potential effect on the environment and organisms. As sea ice extent is reducing in the Arctic, heightened shipping and fishing activity may increase marine pollution in the area. Microplastics may enter the region following ocean transport and local input, although baseline contamination measurements are still required. Here we present the first study of microplastics in Arctic waters, south and southwest of Svalbard, Norway. Microplastics were found in surface (top 16 cm) and sub-surface (6 m depth) samples using two independent techniques. Origins and pathways bringing microplastic to the Arctic remain unclear. Particle composition (95% fibres) suggests they may either result from the breakdown of larger items (transported over large distances by prevailing currents, or derived from local vessel activity), or input in sewage and wastewater from coastal areas. Concurrent observations of high zooplankton abundance suggest a high probability for marine biota to encounter microplastics and a potential for trophic interactions. Further research is required to understand the effects of microplastic-biota interaction within this productive environment. |
| **Merrell, T. R. (1980). "Accumulation of plastic litter on beaches of Amchitka Island, Alaska." Marine environmental research 3(3): 171-184.**  Between 1972 and 1974 plastic marine litter on ten 1-km beaches at Amchitka Island increased from 2,221 to 5,367 items—a 2·4 x increase in a two-year period. Most litter originated from Japanese and Soviet fishing vessels, but some items were from the Asian coast, at least 1,150 km distant. In 1974 there were 345 kg of common items of plastic litter per kilometre of beach. In 1972, an estimated 1,664 metric tons of plastic litter was lost or dumped from fishing vessels in the Bering Sea and North Pacific Ocean. Stranded plastic litter persists indefinitely but rapidly becomes buried in beach material or is blown inland and covered with vegetation. The most serious environmental impact is probably entanglement of marine mammals and birds in some types of litter. The accelerating accumulation of litter could be reduced through unilateral action by countries that regulate coastal fishing privileges if these countries make litter control a condition for permission to fish. |
| **Pham, C. K., et al. (2014). "Marine litter distribution and density in European seas, from the shelves to deep basins." PloS one 9(4): e95839.**  Anthropogenic litter is present in all marine habitats, from beaches to the most remote points in the oceans. On the seafloor, marine litter, particularly plastic, can accumulate in high densities with deleterious consequences for its inhabitants. Yet, because of the high cost involved with sampling the seafloor, no large-scale assessment of distribution patterns was available to date. Here, we present data on litter distribution and density collected during 588 video and trawl surveys across 32 sites in European waters. We found litter to be present in the deepest areas and at locations as remote from land as the Charlie-Gibbs Fracture Zone across the Mid-Atlantic Ridge. The highest litter density occurs in submarine canyons, whilst the lowest density can be found on continental shelves and on ocean ridges. Plastic was the most prevalent litter item found on the seafloor. Litter from fishing activities (derelict fishing lines and nets) was particularly common on seamounts, banks, mounds and ocean ridges. Our results highlight the extent of the problem and the need for action to prevent increasing accumulation of litter in marine environments. |
| **Polasek, L., et al. (2017). "Marine debris in five national parks in Alaska." Marine Pollution Bulletin 117(1): 371-379.**  Marine debris is a management issue with ecological and recreational impacts for agencies, especially on remote beaches not accessible by road. This project was implemented to remove and document marine debris from five coastal National Park Service units in Alaska. Approximately 80 km of coastline were cleaned with over 10,000 kg of debris collected. Marine debris was found at all 28 beaches surveyed. Hard plastics were found on every beach and foam was found at every beach except one. Rope/netting was the next most commonly found category, present at 23 beaches. Overall, plastic contributed to 60% of the total weight of debris. Rope/netting (14.6%) was a greater proportion of the weight from all beaches than foam (13.3%). Non-ferrous metal contributed the smallest amount of debris by weight (1.7%). The work forms a reference condition dataset of debris surveyed in the Western Arctic and the Gulf of Alaska within one season. |
| **Shaw, D. G. and S. E. Ignell (1989). "The quantitative distribution and characteristics of neuston plastic in the North Pacific Ocean, 1985-88." In R. S. Shomura & M. L. Godfrey (Eds.) Proceedings of the Second International Conference on Marine Debris(pp. 2–7). Honolulu, Hawaii. U.S Dep. Commerce., NOAA Technical. Memorandum. NMFS, NOAATM- SWFSC-154, 2–7 April 1989.**  The distribution, abundance, and characteristics of neuston plastic in the North Pacific, Bering Sea, and Japan Sea were studied during the 4-year period 1985-88 at 203 neuston stations encompassing ca. 91,000 m2 of sampling. The highest total density of neuston plastic was 316,800 pieces/km2 at lat. 35"59'N, long. 152"OO'E in Transitional Water east of Japan. The highest total concentration of neuston plastic was 3,491.8 g/km2 at lat. 40"00'N, long. 171'30'E near the Subarctic Front in the central North Pacific. Main types of neuston plastic were miscellaneous line fragments (21.7% of all stations), Styrofoam (12.8%), polypropylene line fragments (7.4%), miscellaneous or unidentified plastic (7.4%), and raw pellets (5.9%). Plastic fragments were recorded at 52.2% of all stations and at 88.3% of those stations with plastic. The highest densities (number per square kilometer) and concentrations (gram per square kilometer) of neuston plastic occurred in Japan Sea/nearshore Japan Water, in Transitional Water, and in Subtropical Water. Densities of neuston plastic in Subarctic Water and Bering Sea Water were low. Heterogeneous geographic input and currents and winds are important in distributing and concentrating neuston plastic. Microscale convergences appear to be important mechanisms that locally concentrate neuston plastic, increasing the probability of its entering food chains. |
| **Tekman, M. B., et al. (2017). "Marine litter on deep Arctic seafloor continues to increase and spreads to the North at the HAUSGARTEN observatory." Deep Sea Research Part I: Oceanographic Research Papers 120: 88-99.**  The increased global production of plastics has been mirrored by greater accumulations of plastic litter in marine environments worldwide. Global plastic litter estimates based on field observations account only for 1% of the total volumes of plastic assumed to enter the marine ecosystem from land, raising again the question ‘Where is all the plastic? ’. Scant information exists on temporal trends on litter transport and litter accumulation on the deep seafloor. Here, we present the results of photographic time-series surveys indicating a strong increase in marine litter over the period of 2002–2014 at two stations of the HAUSGARTEN observatory in the Arctic (2500 m depth).  Plastic accounted for the highest proportion (47%) of litter recorded at HAUSGARTEN for the whole study period. When the most southern station was considered separately, the proportion of plastic items was even higher (65%). Increasing quantities of small plastics raise concerns about fragmentation and future microplastic contamination. Analysis of litter types and sizes indicate temporal and spatial differences in the transport pathways to the deep sea for different categories of litter. Litter densities were positively correlated with the counts of ship entering harbour at Longyearbyen, the number of active fishing vessels and extent of summer sea ice. Sea ice may act as a transport vehicle for entrained litter, being released during periods of melting. The receding sea ice coverage associated with global change has opened hitherto largely inaccessible environments to humans and the impacts of tourism, industrial activities including shipping and fisheries, all of which are potential sources of marine litter. |
| **Woodall, L. C., et al. (2014). "The deep sea is a major sink for microplastic debris." Royal Society Open Science 1(4): 140317.**  Marine debris, mostly consisting of plastic, is a global problem, negatively impacting wildlife, tourism and shipping. However, despite the durability of plastic, and the exponential increase in its production, monitoring data show limited evidence of concomitant increasing concentrations in marine habitats. There appears to be a considerable proportion of the manufactured plastic that is unaccounted for in surveys tracking the fate of environmental plastics. Even the discovery of widespread accumulation of microscopic fragments (microplastics) in oceanic gyres and shallow water sediments is unable to explain the missing fraction. Here, we show that deep-sea sediments are a likely sink for microplastics. Microplastic, in the form of fibres, was up to four orders of magnitude more abundant (per unit volume) in deep-sea sediments from the Atlantic Ocean, Mediterranean Sea and Indian Ocean than in contaminated sea-surface waters. Our results show evidence for a large and hitherto unknown repository of microplastics. The dominance of microfibres points to a previously underreported and unsampled plastic fraction. Given the vastness of the deep sea and the prevalence of microplastics at all sites we investigated, the deep-sea floor appears to provide an answer to the question—where is all the plastic? |

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# **4- IMPACT**

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| **Ardea Miljö (2001). Marine litter: Trash that kills, Swedish Environmental Protection Agency.**  Marine litter (marine debris) has become an increasingly serious environmental, economic, health and aesthetic problem around the world.  Marine litter items travel widely, over long distances, with ocean currents and winds, around sea areas and between oceas. It is found not only in waters, on the seabed or on the beaches of densily populated regions, but also in remote places far away from any obvious sources.  Marine litter is long-lived and active for decades, directly and indirectly. It consists to a very great extent of plastics, and of metal and glass - material that do not beark down easily or quickly.  Marine litter is a vicious killer of marine mammals, seabirds and many other life forms in the marine and coastal environment . It also entails subsantial economic costs and losses to, e.g. fishermen, boat owners in general, coastal communities, farmers, power stations and individuals. |
| **Ask, A., et al. (2016). Contaminants in northern fulmars (Fulmarus glacialis) exposed to plastic. Copenhagen K., Nordic Council of Ministers.**  Marine plastic pollution is a widespread and increasing problem. Due to the chemical and physical properties of plastic, it tends to persist in the marine environment over long periods of time where it has the potential to harm fauna and flora. Among the many threats posed by plastic, ingestion of plastic is frequently observed in a variety of species. Seabirds, and especially the Procellariiformes, are commonly found with high levels of ingested plastics. Apart from the physical dangers of ingested plastics (e.g. internal injuries and lodging in the digestive system), there is concern that the chemicals added to and adsorbed to the plastic could be absorbed by the bird and exert toxic effects. The aim of this study was to investigate this by expanding upon and comparing two datasets on northern fulmars (Fulmarus glacialis) in relation to the contaminant concentration in selected tissues and ingested plastics. Fulmars from the Faroe Islands were all bycatch victims from longline fisheries caught in 2011 and fulmars from Norway were predominantly bycatch from fisheries in 2012 and 2013, supplemented with a few individuals found beached. Upon dissection, plastic content in the stomach was quantified and tissues (liver for the Faroese fulmars and muscle and liver for the Norwegian fulmars) were frozen for subsequent chemical analyses. Tissues were analysed for a suite of persistent organic pollutants: polychlorinated biphenyls, polybrominated diphenyl ethers, perfluoroalkyl and polyfluoroalkyl substances, metabolites, organophosphate flame retardants, dichlorodiphenyltrichloroethane and other pesticides. The data were then analysed statistically to examine whether there were associations between the level of ingested plastic and contaminant concentration in the fulmars, in addition to comparing contaminant burdens between Faroese and Norwegian fulmars. After correcting for the multiple testing, there were no statistically significant differences in contaminant concentrations between the various plastic ingestion groups. The contaminant concentrations in liver in Faroese and Norwegian fulmars were not significantly different after correcting for the multiple testing. Thus, it appears that ingested plastic is not a significant route of exposure to the adsorbed contaminants analysed herein for the fulmar. |
| **Acampora, H., et al. (2017). "Opportunistic sampling to quantify plastics in the diet of unfledged Black Legged Kittiwakes (Rissa tridactyla), Northern Fulmars (Fulmarus glacialis) and Great Cormorants (Phalacrocorax carbo)." Marine Pollution Bulletin.**  Seabirds can interact with marine litter, mainly by entanglement or ingestion. The ingestion of plastics can lead to starvation or physical damage to the digestive tract. For chicks, it could additionally lead to reduced growth, affecting survival and fledging. This study quantified the ingestion of plastics by seabird chicks via an opportunistic sampling strategy. When ringing is carried out at colonies, birds may spontaneously regurgitate their stomach contents due to the stress or as a defence mechanism. Regurgitates were collected from nestlings of three different species: Black-legged Kittiwake (Rissa tridactyla, n = 38), Northern Fulmar (Fulmarus glacialis, n = 14) and Great Cormorant (Phalacrocorax carbo, n = 28). Plastic was present in all species, with the highest frequency of occurrence (FO) in Northern Fulmar chicks (28.6%), followed by Black-legged Kittiwakes (7.9%) and Great Cormorants (7.1%). The observed load of plastics on chicks, which have not yet left the nest, highlights the pervasive nature of plastic pollution. |
| **Amélineau, F., et al. (2016). "Microplastic pollution in the Greenland Sea: Background levels and selective contamination of planktivorous diving seabirds." Environ. Pollut 219: 1131-1139.**  Microplastics have been reported everywhere around the globe. With very limited human activities, the Arctic is distant from major sources of microplastics. However, microplastic ingestions have been found in several Arctic marine predators, confirming their presence in this region. Nonetheless, existing information for this area remains scarce, thus there is an urgent need to quantify the contamination of Arctic marine waters. In this context, we studied microplastic abundance and composition within the zooplankton community off East Greenland. For the same area, we concurrently evaluated microplastic contamination of little auks (Alle alle), an Arctic seabird feeding on zooplankton while diving between 0 and 50 m. The study took place off East Greenland in July 2005 and 2014, under strongly contrasted seaice conditions. Among all samples, 97.2% of the debris found were filaments. Despite the remoteness of our study area, microplastic abundances were comparable to those of other oceans, with 0.99 +/0.62 m(3) in the presence of seaice (2005), and 2.38 +/1.11 m(3) in the nearby absence of seaice (2014). Microplastic rise between 2005 and 2014 might be linked to an increase in plastic production worldwide or to lower sea ice extents in 2014, as seaice can represent a sink for microplastic particles, which are subsequently released to the water column upon melting. Crucially, all birds had eaten plastic filaments, and they collected high levels of microplastics compared to background levels with 9.99 and 8.99 pieces per chick meal in 2005 and 2014, respectively. Importantly, we also demonstrated that little auks took more often light colored microplastics, rather than darker ones, strongly suggesting an active contamination with birds mistaking microplastics for their natural prey. Overall, our study stresses the great vulnerability of Arctic marine species to microplastic pollution in a warming Arctic, where seaice melting is expected to release vast volumes of trapped debris. |
| **Anderson, J. C., et al. (2016). "Microplastics in aquatic environments: Implications for Canadian ecosystems." Environmental Pollution 218: 269-280.**  Microplastics have been increasingly detected and quantified in marine and freshwater environments, and there are growing concerns about potential effects in biota. A literature review was conducted to summarize the current state of knowledge of microplastics in Canadian aquatic environments; specifically, the sources, environmental fate, behaviour, abundance, and toxicological effects in aquatic organisms. While we found that research and publications on these topics have increased dramatically since 2010, relatively few studies have assessed the presence, fate, and effects of microplastics in Canadian water bodies. We suggest that efforts to determine aquatic receptors at greatest risk of detrimental effects due to microplastic exposure, and their associated contaminants, are particularly warranted. There is also a need to address the gaps identified, with a particular focus on the species and conditions found in Canadian aquatic systems. These gaps include characterization of the presence of microplastics in Canadian freshwater ecosystems, identifying key sources of microplastics to these systems, and evaluating the presence of microplastics in Arctic waters and biota. |
| **Avery-Gomm, S., et al. (2012). "Northern fulmars as biological monitors of trends of plastic pollution in the eastern North Pacific." Marine Pollution Bulletin 64(9): 1776-1781.**  Marine plastic debris is a global issue, which highlights the need for internationally standardized methods of monitoring plastic pollution. The stomach contents of beached northern fulmar (Fulmarus glacialis) have proven a cost-effective biomonitor in Europe. However, recent information on northern fulmar plastic ingestion is lacking in the North Pacific. We quantified the stomach contents of 67 fulmars from beaches in the eastern North Pacific in 2009–2010 and found that 92.5% of fulmars had ingested an average of 36.8 pieces, or 0.385 g of plastic. Plastic ingestion in these fulmars is among the highest recorded globally. Compared to earlier studies in the North Pacific, our findings indicate an increase in plastic ingestion over the past 40 years. This study substantiates the use of northern fulmar as biomonitors of plastic pollution in the North Pacific and suggests that the high levels of plastic pollution in this region warrant further monitoring. |
| **Barnes, D. K. (2002). "Biodiversity: invasions by marine life on plastic debris." Nature 416(6883): 808-809.**  Colonization by alien species poses one of the greatest threats to global biodiversity1. Here I investigate the colonization by marine organisms of drift debris deposited on the shores of 30 remote islands from the Arctic to the Antarctic (across all oceans) and find that human litter more than doubles the rafting opportunities for biota, particularly at high latitudes. Although the poles may be protected from invasion by freezing sea surface temperatures, these may be under threat as the fastest-warming areas anywhere2 are at these latitudes. |
| **Barnes, D. and P. Milner (2005). "Drifting plastic and its consequences for sessile organism dispersal in the Atlantic Ocean." Marine Biology 146(4): 815-825.**  Organisms have travelled the Atlantic Ocean as neuston and have rafted on natural marine debris for millions of years. Shipping increased opportunities for marine organism travel mere thousands of years ago but in just decades floating plastic debris is transforming marine rafting. Here we present a combined open-ocean and remote coasts marine debris survey of the Atlantic (from 68°S–78°N). Daily shipboard observations were made from the Southern Ocean to the high Arctic and the shores of 16 remote islands were surveyed. We report (1) anthropogenic debris from the most northerly and southerly latitudes to date, (2) the first record of marine biota colonising debris at latitudes >68°, and (3) the finding of exotic species (the barnacle Elminius modestus) on northern plastic debris. Plastic pieces dominated both open-ocean and stranding marine debris. The highest densities of oceanic debris were found around northwest Europe, whereas the highest stranding levels were equatorial. Our findings of high east-Arctic debris colonisation by fauna contrast with low values from west Arctic (though only two samples) and south Atlantic shores. Colonisation rates of debris differed between hemispheres, previously considered to be similar. Our two South Atlantic mega-debris shipboard surveys (10 years apart) found no changes in open-ocean debris densities but resurvey of a UK and an Arctic island both found increases. We put our findings in the context of the Atlantic literature to interpret spatial and temporal trends in marine debris accumulation and its organismal consequences. |
| **Bond, A. L., et al. (2010). "Auklet (Charadriiformes: Alcidae, Aethia spp.) chick meals from the Aleutian Islands, Alaska, have a very low incidence of plastic marine debris." Marine Pollution Bulletin 60(8): 1346-1349.**  The ingestion of plastic marine debris is a chronic problem for some of the world’s seabird species, contributing to reduced chick survival, population declines, and deposition of contaminants via absorption in birds’ gastrointestinal tract. We analysed the frequency of ingested plastic in chick meals delivered by adults in four species of auklet – Crested (Aethia cristatella), Least (A. pusilla), Parakeet (A. psittacula), and Whiskered (A. pygmaea) – from three breeding colonies in the Aleutian Islands, Alaska, USA over a 14-year period from 1993 to 2006. Among 2541 chick meals, we found plastic in only one – from a Whiskered Auklet on Buldir Island in 1993. While adult Parakeet Auklets have a high frequency of plastic ingestion (over 90%), no chick meals contained plastic. Unlike other seabirds, the planktivorous auklets do not appear to offload plastic to their chicks, and we conclude that auklet chicks are probably at a low risk of contamination from plastic debris. |
| **Bond, A. L., et al. (2014). "Plastic ingestion by fulmars and shearwaters at Sable Island, Nova Scotia, Canada." Marine Pollution Bulletin 87(1): 68-75.**  Plastic pollution is widespread in the marine environment, and plastic ingestion by seabirds is now widely reported for dozens of species. Beached Northern Fulmars, Great Shearwaters, Sooty Shearwaters and Cory’s Shearwaters are found on Sable Island, Nova Scotia, Canada regularly, and they can be used to assess plastic pollution. All species except Cory’s Shearwaters contained plastic debris in their gastrointestinal tracts. Northern Fulmars, Sooty Shearwaters and Great Shearwaters all showed high prevalence of plastic ingestion (>72%), with Northern Fulmars having the highest number and mass of plastics among the species examined. There was no difference in plastic ingestion between sexes or age classes. In all species user plastics made up the majority of the pieces found, with industrial pellets representing only a small proportion in the samples. Sable Island could be an important monitoring site for plastic pollution in Atlantic Canada. |
| **Bond, A. L., et al. (2013). "Ingestion of plastic marine debris by Common and Thick-billed Murres in the northwestern Atlantic from 1985 to 2012." Marine Pollution Bulletin 77(1): 192-195.**  Plastic ingestion by seabirds is a growing conservation issue, but there are few time series of plastic ingestion with large sample sizes for which one can assess temporal trends. Common and Thick-billed Murres (Uria aalge and U. lomvia) are pursuit-diving auks that are legally harvested in Newfoundland and Labrador, Canada. Here, we combined previously unpublished data on plastic ingestion (from the 1980s to the 1990s) with contemporary samples (2011–2012) to evaluate changes in murres’ plastic ingestion. Approximately 7% of murres had ingested plastic, with no significant change in the frequency of ingestion among species or periods. The number of pieces of plastic/bird, and mass of plastic/bird were highest in the 1980s, lowest in the late 1990s, and intermediate in contemporary samples. Studying plastic ingestion in harvested seabird populations links harvesters to conservation and health-related issues and is a useful source of large samples for diet and plastic ingestion studies. |
| **Day, R. H., et al. (1985). Ingestion of plastic pollutants by marine birds. Proceedings of the Workshop on the Fate and Impact of Marine Debris, US Dep. Commer. NOAA Tech Memo NMFS Honolulu, Hawaii.**  *No Abstract Available* |
| **Doyle, M. J., et al. (2011). "Plastic particles in coastal pelagic ecosystems of the Northeast Pacific ocean." Marine environmental research 71(1): 41-52.**  The purpose of this study was to examine the distribution, abundance and characteristics of plastic particles in plankton samples collected routinely in Northeast Pacific ecosystems, and to contribute to the development of ideas for future research into the occurrence and impact of small plastic debris in marine pelagic ecosystems. Plastic debris particles were assessed from zooplankton samples collected as part of the National Oceanic and Atmospheric Administration’s (NOAA) ongoing ecosystem surveys during two research cruises in the Southeast Bering Sea in the spring and fall of 2006 and four research cruises off the U.S. west coast (primarily off southern California) in spring, summer and fall of 2006, and in January of 2007. Nets with 0.505 mm mesh were used to collect surface samples during all cruises, and sub-surface samples during the four cruises off the west coast. The 595 plankton samples processed indicate that plastic particles are widely distributed in surface waters. The proportion of surface samples from each cruise that contained particles of plastic ranged from 8.75 to 84.0%, whereas particles were recorded in sub-surface samples from only one cruise (in 28.2% of the January 2007 samples). Spatial and temporal variability was apparent in the abundance and distribution of the plastic particles and mean standardized quantities varied among cruises with ranges of 0.004–0.19 particles/m3, and 0.014–0.209 mg dry mass/m3. Off southern California, quantities for the winter cruise were significantly higher, and for the spring cruise significantly lower than for the summer and fall surveys (surface data). Differences between surface particle concentrations and mass for the Bering Sea and California coast surveys were significant for pair-wise comparisons of the spring but not the fall cruises. The particles were assigned to three plastic product types: product fragments, fishing net and line fibers, and industrial pellets; and five size categories: <1 mm, 1–2.5 mm, >2.5–5 mm, >5–10 mm, and >10 mm. Product fragments accounted for the majority of the particles, and most were less than 2.5 mm in size. The ubiquity of such particles in the survey areas and predominance of sizes <2.5 mm implies persistence in these pelagic ecosystems as a result of continuous breakdown from larger plastic debris fragments, and widespread distribution by ocean currents. Detailed investigations of the trophic ecology of individual zooplankton species, and their encounter rates with various size ranges of plastic particles in the marine pelagic environment, are required in order to understand the potential for ingestion of such debris particles by these organisms. Ongoing plankton sampling programs by marine research institutes in large marine ecosystems are good potential sources of data for continued assessment of the abundance, distribution and potential impact of small plastic debris in productive coastal pelagic zones. |
| **Edwards, E. W., et al. (2016). "State‐space modelling of geolocation data reveals sex differences in the use of management areas by breeding northern fulmars." Journal of Applied Ecology 53(6): 1880-1889.**  Effective management and conservation of terrestrially breeding marine predators requires information on connectivity between specific breeding sites and at-sea foraging areas. In the north-east Atlantic, efforts to monitor and manage the impacts of bycatch or pollution events within different Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) management regions are currently constrained by uncertainty over the origins of seabirds occurring in each area.  Whilst Global Positioning System (GPS) loggers can now provide high resolution data on seabird foraging characteristics, their use is largely restricted to the chick-rearing period. Smaller light-based Global Location Sensors (geolocators) could provide valuable data during earlier phases of the breeding season, but additional information on their accuracy is required to assess this potential.  We used incubation trip tracking data from 11 double-tagged (GPS/geolocator) northern fulmars Fulmarus glacialis L. within a state-space modelling (SSM) framework to estimate errors around geolocator locations. The SSM was then fitted to a larger sample of geolocator data from the pre-laying exodus using the mean of these error estimates. Geolocator data were first used to compare the trip durations of males and females during this critical pre-laying period. Outputs from the SSM were then used to characterize their spatial distribution and assess the extent of within-colony variation in the use of different OSPAR management regions.  During the pre-laying exodus, fulmars from a single colony in the north-east of the United Kingdom foraged widely across several biogeographical regions, up to 2900 km from the colony. Most (60%) males remained within the North Sea region, whereas most (68%) females flew north, foraging within the Norwegian and Barents Sea. A small subset of birds (15%) travelled to the central North Atlantic. Foraging trips by males appeared to be shorter (x = 18 days, n = 20) than by females (x = 25 days, n = 19).  Policy implications. Our results of state-space modelling of geolocation data collected from northern fulmars show that within-colony variation in ranging behaviour during the breeding season results in sex differences in exposure to threats such as fisheries bycatch and marine plastics. Birds from a single colony dispersed over several north-east Atlantic management areas. These patterns have implications for interpreting trends in colony-based monitoring schemes, and European Union Marine Strategy Framework programmes using these seabirds as an indicator species for monitoring trends in marine litter and prioritizing efforts to mitigate its impact. |
| **Fife, D. T., et al. (2015). "Trace elements and ingested plastic debris in wintering dovekies (Alle alle)." Marine Pollution Bulletin 91(1): 368-371.**  We provide the first report on winter concentrations of 32 trace metals from dovekies (Alle alle), a small, Arctic seabird that has a seasonal shift in diet from small zooplankton in the breeding season to larger zooplankton and small fish in the non-breeding season. Concentrations of selected trace elements, as well as stable carbon (δ13C) and nitrogen (δ15N) isotope concentrations for a sample of 25 dovekies, were similar between adult males and females, and there was evidence that dovekies feeding at higher trophic levels had higher hepatic Hg. We also found plastic debris in nine of 65 (14%) gizzards examined. Our study helps provide a more complete picture of the foraging ecology and contaminant profile of dovekies, an important species in Arctic marine food webs. |
| **Fowler, C. W. (1987). "Marine debris and northern fur seals: a case study." Marine Pollution Bulletin 18(6): 326-335.**  Since the early 1930s small numbers of northern fur seals (Callorhinus ursinus) have been observed with various objects caught around their necks, shoulders and, less frequently, their flippers. The incidence of such entanglement increased following the mid-1960s when fishing effort in the North Pacific and Bering Sea increased and when plastic materials began to be used extensively in making trawl netting and packing bands. The current incidence of entanglement observed among subadult males on St. Paul Island (of the Pribilof Islands) is about 0.4%, a level at least two orders of magnitude greater than observed in the 1940s. Almost all entangling materials observed on subadult males ashore weigh less than 0.4 kg and are predominantly fragments of trawl netting and plastic packing bands. Most of the trawl netting debris found at sea or on beaches in the Bering Sea area consists of fragments larger than those found on the seals that return to the Pribilof Islands. During pelagic surveys, trawl netting debris is sighted at the rate of 0.2–3.1 fragments per 1,000 km. Between 10 and 17% of these fragments have been observed to contain entangled seals. Seals appear to become entangled after approaching and investigating debris. Entanglement involves both sexes and appears predominantly to involve young animals, which are occasionally observed entangled as groups in large debris. Entanglement in debris results in increased energy expenditures, especially while dragging large fragments of net at sea. Compared to non-entangled seals, entangled seals spend more time at sea, whether foraging, travelling, or both. Changes in pup numbers born and unexpected mortality in the first several years of life exhibit a relationship with entanglement to provide a correlative explanation for recent population dynamics. These factors collectively suggest that mortality of fur seals due to entanglement in marine debris contributes significantly to declining trends of the population on the Pribilof Islands. |
| **Fowler, C. W., et al. (1990). Studies of the population level effects of entanglement on Northen Fur Seals. Proceedings of the Second International Conference on Marine Debris, NOAA Technical Memorandum, NMFS SWFC, 154.**  Recent studies have focused on entanglement among the juvenile male northern fur seal, Callorhinus ursinus, as a means of evaluating the effects of entanglement at the population level. Most entanglement-related field studies were conducted on St. Paul Island, Alaska, in the 1980's but the analyses include relevant data from the late 1970's. Reported here are the results of recent studies on monitoring of entanglement, estimates of entanglement-caused mortality, and the effects entanglement may have on the chances an animal is observed on the breeding islands.  The observed proportions of seals entangled in 1985 and 1986 were consistent with those observed during the last few years of the commercial harvest (about 0.4%). The proportion observed in 1988 was 0.29%, the lowest observed since 1970. The change reflects a drop in the numbers of animals entangled in fragments of trawl webbing. The frequency of occurrence of trawl webbing among the entangling debris was about half the former levels whereas the proportion of seals entangled in other types of debris did not change.  These studies confirm earlier estimates indicating that, after 1 year, the survival of seals entangled in debris light enough to permit the animals to return once to land is about half of the survival of nonentangled seals. Data indicate that the main factor contributing to the success of entangled animals that do survive is escapement from the debris.  Rates at which entangled animals are resighted indicate that the proportion of animals resighted drops with an increase in the size (weight) of debris.  Data from radio-tagged seals confirm that entangled seals go to sea for longer periods of time than do controls. |
| **Fowler, C. W. (2000). Ecological effects of marine debris: the example of northern fur seals. Proceedings of the International Marine Debris Conference: Derelict Fishing Gear and the Ocean Environment held in Honolulu Hawaii.**  *No Abstract Available* |
| **Hammer, S., et al. (2016). "Plastic debris in great skua (Stercorarius skua) pellets corresponds to seabird prey species." Marine Pollution Bulletin 103(1): 206-210.**  Plastic is a common item in marine environments. Studies assessing seabird ingestion of plastics have focused on species that ingest plastics mistaken for prey items. Few studies have examined a scavenger and predatory species that are likely to ingest plastics indirectly through their prey items, such as the great skua (Stercorarius skua). We examined 1034 regurgitated pellets from a great skua colony in the Faroe Islands for plastics and found approximately 6% contained plastics. Pellets containing remains of Northern fulmars (Fulmarus glacialis) had the highest prevalence of plastic. Our findings support previous work showing that Northern fulmars have higher loads of plastics than other sympatric species. This study demonstrates that marine plastic debris is transferred from surface feeding seabird species to predatory great skuas. Examination of plastic ingestion in species that do not ingest plastics directly can provide insights into how plastic particles transfer vertically within the food web. |
| **Herzke, D., et al. (2016). "Negligible impact of ingested microplastics on tissue concentrations of persistent organic pollutants in northern fulmars off coastal Norway." Environmental science & technology 50(4): 1924-1933.**  The northern fulmar (Fulmarus glacialis) is defined as an indicator species of plastic pollution by the Oslo-Paris Convention for the North-East Atlantic, but few data exist for fulmars from Norway. Moreover, the relationship between uptake of plastic and pollutants in seabirds is poorly understood. We analyzed samples of fulmars from Norwegian waters and compared the POP concentrations in their liver and muscle tissue with the corresponding concentrations in the loads of ingested plastic in their stomachs, grouped as “no”, “medium” (0.01–0.21 g; 1–14 pieces of plastic), or “high” (0.11–0.59 g; 15–106 pieces of plastic). POP concentrations in the plastic did not differ significantly between the high and medium plastic ingestion group for sumPCBs, sumDDTs, and sumPBDEs. By combining correlations among POP concentrations, differences in tissue concentrations of POPs between plastic ingestion subgroups, fugacity calculations, and bioaccumulation modeling, we showed that plastic is more likely to act as a passive sampler than as a vector of POPs, thus reflecting the POP profiles of simultaneously ingested prey. |
| **Kühn, S. and J. A. van Franeker (2012). "Plastic ingestion by the northern fulmar (Fulmarus glacialis) in Iceland." Marine Pollution Bulletin 64(6): 1252-1254.**  In 2011, northern fulmars (Fulmarus glacialis) from Iceland were used to test the hypothesis that plastic debris decreases at northern latitudes in the Atlantic when moving away from major human centres of coastal and marine activities. Stomach analyses of Icelandic fulmars confirm that plastic pollution levels in the North Atlantic tend to decrease towards higher latitudes. Levels of pollution thus appear to link to regions of intense human coastal and marine activities, suggesting substantial current inputs in those areas. |
| **Mallory, M. L., et al. (2006). "Marine plastic debris in northern fulmars from Davis Strait, Nunavut, Canada." Marine Pollution Bulletin 52(7): 813-815.**  *No Abstract Available* |
| **Mallory, M. L. (2006). "The northern fulmar (Fulmarus glacialis) in Arctic Canada: ecology, threats, and what it tells us about marine environmental conditions." Environmental Reviews 14(3): 187-216.**  The northern fulmar Fulmarus glacialis is a ubiquitous seabird found across the North Atlantic Ocean and into the Canadian Arctic. However, we know little of its ecology in the Arctic, which is unfortunate, because it possesses many traits that make it an excellent biomonitor of the condition of Arctic marine environments. Presently, Arctic fulmars face threats from harvest, bycatch in fisheries, and fouling in oil spills while the birds are in their winter range (the North Atlantic). However, during breeding, migration, and overwintering, they may also experience stress from ecotourism, contaminants, particulate garbage, and climate change. In this paper I review the effects of all of these threats on fulmars and I describe how the ecology of these birds makes them particularly suitable for tracking contaminants, garbage, and the effects of climate change in the Arctic marine ecosystem. I also highlight our key existing knowledge gaps on this species and how additional research will strengthen the utility of fulmars as biomonitors. |
| **Mallory, M. L. (2008). "Marine plastic debris in northern fulmars from the Canadian high Arctic." Marine Pollution Bulletin 56(8): 1501-1504.**  *No Abstract Available* |
| **Poon, F. E., et al. (2017). "Levels of ingested debris vary across species in Canadian Arctic seabirds." Marine Pollution Bulletin 116(1): 517-520.**  Plastic debris has become a major pollutant in the world's oceans and is found in many seabird species from low to high latitudes. Here we compare levels of plastic ingestion from two surface feeders, northern fulmars (Fulmarus glacialis) and black-legged kittiwakes (Rissa tridactyla), and two pursuit diving species, thick-billed murres (Uria lomvia) and black guillemots (Cepphus grylle) in the Canadian high Arctic. This is the first report quantifying plastic ingestion in kittiwakes in this region, and as predicted, kittiwakes and fulmars had higher frequency of plastic ingestion than guillemots and murres. Despite this, amounts of plastic ingested by birds remain lower than regions farther south. |
| **Provencher, J. F., et al. (2009). "Evidence for increased ingestion of plastics by northern fulmars (Fulmarus glacialis) in the Canadian Arctic." Marine Pollution Bulletin 58(7): 1092-1095.**  *No Abstract Available* |
| **Provencher, J. F., et al. (2010). "Ingested plastic in a diving seabird, the thick-billed murre (Uria lomvia), in the eastern Canadian Arctic." Marine Pollution Bulletin 60(9): 1406-1411.**  Plastic debris has become ubiquitous in the marine environment and seabirds may ingest debris which can have deleterious effects on their health. In the North Atlantic Ocean, surface feeding seabirds typically ingest high levels of plastic, while the diving auks which feed in the water column typically have much lower levels. We examined 186 thick-billed murres from five colonies in the eastern Canadian Arctic for ingested plastic debris. Approximately 11% of the birds had at least one piece of plastic debris in their gastrointestinal tracts, with debris dominated by user plastics. This is the first report of ingested plastics in an auk species in Canada’s Arctic, and the highest incidence of plastic ingestion to date for thick-billed murres (Uria lomvia). |
| **Provencher, J. F., et al. (2014). "Marine birds and plastic debris in Canada: a national synthesis and a way forward." Environmental Reviews 23(1): 1-13.**  Marine plastic ingestion by seabirds was first documented in the 1960s, but over 50 years later our understanding about the prevalence, intensity, and subsequent effect of plastic pollution in the oceans is still developing. In Canada, systematic assessments using recognized standard protocols began only in the mid-2000s. With marine plastic pollution identified by the United Nations Environmental Program (UNEP) as one of the most critical challenges for the environment, a greater understanding of how plastics affect marine birds in Canada, along with a national strategy, is timely and necessary. To better understand which and how many marine birds are affected by marine debris, we reviewed reports of plastic ingestion and nest incorporation in Canada. Of the 91 marine bird species found in Canadian waters, detailed plastic ingestion data from multiple years and locations are available for only six species. Another 33 species have incidental reports, and we lack any data on dozens more. Future efforts should focus on characterizing the risk of plastic ingestion among understudied species and on continued monitoring of species that are known indicators of plastic pollution internationally and found in multiple regions of Canada to facilitate comparisons at the national and international levels. |
| **Provencher, J. F., et al. (2014). "Prevalence of marine debris in marine birds from the North Atlantic." Marine Pollution Bulletin 84(1): 411-417.**  Marine birds have been found to ingest plastic debris in many of the world’s oceans. Plastic accumulation data from necropsies findings and regurgitation studies are presented on 13 species of marine birds in the North Atlantic, from Georgia, USA to Nunavut, Canada and east to southwest Greenland and the Norwegian Sea. Of the species examined, the two surface plungers (great shearwaters Puffinus gravis; northern fulmars Fulmarus glacialis) had the highest prevalence of ingested plastic (71% and 51%, respectively). Great shearwaters also had the most pieces of plastics in their stomachs, with some individuals containing as many of 36 items. Seven species contained no evidence of plastic debris. Reporting of baseline data as done here is needed to ensure that data are available for marine birds over time and space scales in which we see changes in historical debris patterns in marine environments (i.e. decades) and among oceanographic regions. |
| **Robards, M. D., et al. (1995). "Increasing frequency of plastic particles ingested by seabirds in the subarctic North Pacific." Marine Pollution Bulletin 30(2): 151-157.**  We examined gut contents of 1799 seabirds comprising 24 species collected in 1988–1990 to assess the types and quantities of plastic particles ingested by seabirds in the subarctic waters of Alaska. Of the 15 species found to ingest plastic, most were surface-feeders (shearwaters, petrels, gulls) or plankton-feeding divers (auklets, puffins). Of 4417 plastic particles examined, 76% were industrial pellets and 21% were fragments of ‘user’ plastic. Ingestion rates varied geographically, but no trends were evident and rates of plastic ingestion varied far more among species within areas than within species among areas. Comparison with similar data from 1968 seabirds comprising 37 species collected in 1969–1977 revealed that plastic ingestion by seabirds has increased significantly during the 10–15-year interval between studies. This was demonstrated by: (i) an increase in the total number of species ingesting plastic; (ii) an increase in the frequency of occurrence of plastic particles within species that ingested plastic; and, (iii) an increase in the mean number of plastic particles ingested by individuals of those species. |
| **Stelfox, M., et al. (2016). "A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs." Marine Pollution Bulletin 111(1-2): 6-17.**  This review focuses on the effect that ghost gear entanglement has on marine megafauna, namely mammals, reptiles and elasmobranchs. A total of 76 publications and other sources of grey literature were assessed, and these highlighted that over 5400 individuals from 40 different species were recorded as entangled in, or associated with, ghost gear. Interestingly, there appeared to be a deficit of research in the Indian, Southern, and Arctic Oceans; and so, we recommend that future studies focus efforts on these areas. Furthermore, studies assessing the effects of ghost gear on elasmobranchs, manatees, and dugongs should also be prioritised, as these groups were underrepresented in the current literature. The development of regional databases, capable of recording entanglement incidences following a minimum global set of criteria, would be a logical next step in order to analyse the effect that ghost gear has on megafauna populations worldwide. |
| **Trevail, A. M., et al. (2014). Plastic Ingestion by Northern Fulmars, Fulmarus glacialis, in Svalbard and Iceland, and Relationships between Plastic Ingestion and Contaminant Uptake, Norsk Polarinstitutt.**  Plastic pollution is of worldwide concern. However, international commercial advances into the Arctic are occurring without knowledge of the existing threat posed to the local marine environment by plastic litter.  Here, we quantify plastic ingestion by northern fulmars, Fulmarus glacialis, from Svalbard, at the gateway to future shipping routes in the high Arctic. Plastic ingestion by Svalbard fulmars does not follow the established decreasing trend away from human marine impact. Of 40 individuals, 87.5% had ingested plastic, averaging at 0.08g or 15.3 pieces per individual. Plastic ingestion levels in Svalbard exceed the ecological quality objective defined by OSPAR for European seas, highlighting an urgent need for mitigation of plastic pollution in the Arctic, and international regulation of future commercial activity.  Preliminary analises of new data for plastic ingestion by fulmars in Iceland support the arguments above, and reveal that annual variation in plastic may be significant: an area warranting further study. The updated monitoring average shows that 84% of northern fulmars in Iceland have ingested plastic. Levels in Iceland still exceed OSPAR monitoring targets.  In addition, this report presents an increase in variability of tissue contaminant load with plastic ingestion, although differences are not significant. This is the case for multiple classes of contaminants, including PCBs, PBDEs, DDTs, chlordanes and other pesticides, that could either be adsorbing to the surface of plastic pieces whilst in sea water or leaching from within the plastic (e.g. flame retardants). This further emphasises the need for mitigation of plastic pollution and strict enforcement of legislation in the future.  This report highlights future research needs, as well as policy needs to regulate and mitigate this major environmental problem. |
| **Trevail, A. M., et al. (2015). "Elevated levels of ingested plastic in a high Arctic seabird, the northern fulmar (Fulmarus glacialis)." Polar Biology 38(7): 975-981.**  Plastic pollution is of worldwide concern; however, increases in international commercial activity in the Arctic are occurring without the knowledge of the existing threat posed to the local marine environment by plastic litter. Here, we quantify plastic ingestion by northern fulmars, Fulmarus glacialis, from Svalbard, at the gateway to future shipping routes in the high Arctic. Plastic ingestion by Svalbard fulmars does not follow the established decreasing trend away from human marine impact. Of 40 sampled individuals, 35 fulmars (87.5 %) had plastic in their stomachs, averaging at 0.08 g or 15.3 pieces per individual. Plastic ingestion levels on Svalbard exceed the ecological quality objective defined by OSPAR for European seas. This highlights an urgent need for mitigation of plastic pollution in the Arctic as well as international regulation of future commercial activity. |
| **Vlietstra, L. S. and J. A. Parga (2002). "Long-term changes in the type, but not amount, of ingested plastic particles in short-tailed shearwaters in the southeastern Bering Sea." Marine Pollution Bulletin 44(9): 945-955.**  We report the current (1997–1999, 2001) incidence and amount of ingested plastic in short-tailed shearwaters (Puffinus tenuirostris) in the southeastern Bering Sea and compare our results with plastic reported in shearwaters during 1970–1978. We also examine correlations between plastic loads and shearwater body mass. We found that 84% (N=330) of shearwaters sampled in 1997–1999 and 2001 contained plastic. The incidence and amount of ingested plastic have not significantly changed since the 1970s. In contrast, the predominant type of plastic has changed over time, from industrial plastic to user plastic. Seasonal patterns in the incidence and amount of ingested plastic also changed from peak levels during early and late summer in the 1970s to mid summer in the late 1990s and 2001. We suggest that the availability of neuston plastic to seabirds in the Bering Sea has undergone a shift in composition since the 1970s. Shearwater body mass appears little if at all impaired by plastic, at least at present levels of consumption. |
| **Zarfl, C. and M. Matthies (2010). "Are marine plastic particles transport vectors for organic pollutants to the Arctic?" Marine Pollution Bulletin 60(10): 1810-1814.**  Plastic litter accounts for 50–80% of waste items stranded on beaches, floating on the ocean surface and lodged in the seabed. Organic pollutants can be absorbed onto plastic particles from sea water, attached to their surfaces or included in the plastic matrix as additives. Such chemicals may be transported to remote regions by buoyant plastics and ocean currents. We have estimated mass fluxes of polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and perfluorooctanoic acid (PFOA) to the Arctic via the main ocean currents and compared them to those in the dissolved state and in air. Substance fluxes with atmospheric or sea water currents account for several tons per year, whereas those mediated by plastics are four to six orders of magnitude smaller. However, the significance of various pollutant transport routes does not depend only on absolute mass fluxes but also on bioaccumulation in marine food chains. |

# **5- RESPONSES**

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| **NOAA (2015). NOAA Marine Debris Program Strategic Plan 2016-2020, National Oceanic and Atmospheric Administration (NOAA).**  *No Abstract Available* |
| **OSPAR (2009). Marine litter in the North-East Atlantic Region: Assessment and priorities for response. London, United Kingdom.**  *No Abstract Avaliable* |
| **OSPAR (2010). Guideline for monitoring marine litter on the beaches in the OSPAR Maritime area - amendment 2014, OSPAR Agreement 2014-1.**  A guideline for monitoring marine litter on beaches has been developed by OSPAR as a tool to collect data on litter in the marine environment. This tool has been designed to generate data on marine litter according to a standardized methodology. |
| **OSPAR (2014). Overview and assessment of implementation reports Fishing for Litter (on Recommendation 2010/19). London, United Kingdom, OSPAR Commission**  *No Abstract Available* |
| **OSPAR (2014). Regional Action Plan for Prevention and Management of Marine Litter in the North-East Altantic, OSPAR Commission: 18p.**  *No Abstract Available* |
| **Pettipas, S., et al. (2016). "A Canadian policy framework to mitigate plastic marine pollution." Marine Policy 68: 117-122.**  Marine pollution from plastic debris is a global problem causing negative impacts in the marine environment. Plastic marine debris as a contaminant is increasing, especially in Canada. While the impacts of macroplastics are well known in the literature, there are relatively few policy studies related to mitigating microplastic toxicity in the environment. Despite overwhelming evidence of the threat of plastic in the marine environment, there remains inadequate or limited policies to address their mitigation, particularly microplastic debris. Existing policies for waste management, marine debris monitoring and awareness campaigns were evaluated from other jurisdictions. Policies and recommendations were developed for the Canadian context. Recommendations include improved practices for: (1) law and waste management strategies; (2) education, outreach and awareness; (3) source identification; and (4) increased monitoring and further research. |
| **Williams, M. and W. Ammann, Eds. (2009). Marine Debris in Alaska: Coordinating our efforts. University of Alaska Fairbanks, Alaska Sea Grant College Programe.**  *No Abstract Available* |

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# **6- CROSSCUTTING STUDIES**

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| **GESAMP (2015) Sources, fate and effects of microplastics in the marine environment: a global assessment (Kershaw, P. J., ed.). (IMO, FAO, UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Re. Stud. GESAMP No. 90, 96p.**  *No Abstract Available* |
| **GESAMP (2016) Sources, fate and effects of microplastics in the marine environment: part two of a global assessment (Kershaw, P. J., and Rochman, C. M. Eds.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 93, 220 p.**  *No Abstract Available* |
| **Bergmann, M., et al. (2015). Marine anthropogenic litter, Springer.**  *No Abstract Available* |
| **Strand, J., et al. (2015). Marine litter in Nordic waters, Nordic Council of Ministers.**  In recent years there has been an increased focus on environmental problems arising from litter pollution in the oceans after various studies have described instances of vast amounts of litter including microscopic particles consisting of plastic debris and other synthetic materials. International institutions such as EU, OSPAR, HELCOM and UN have identified marine litter as an important issue that should be prioritized both in terms of knowledge building and the development of environmental indicators that can be used for characterization of the environmental quality. In Europe, marine litter is now high on the environmental agenda, especially after the implementation of the Marine Strategy Framework Directive (MSFD) with obligations for all the EU member states. Subsequently, marine litter has also received increasing attention in the Nordic countries. In Nordic countries, there has been and are also several on-going field studies, including research, monitoring and other types of surveys. These studies demonstrate ubiquitous occurrence of marine litter in the Baltic Sea, the North Sea and the North Atlantic as well as in the Arctic, where marine litter have been found in all relevant marine compartments, i.e. at beaches, in the water column (incl. sea ice), on the sea floor (incl. in sediments) and in biota. This report provides an overview of the currently available data from studies on marine litter in the Nordic countries. This covers various field studies on amount, distribution, characteristics and impact of macro- and micro-litter particles. The data reported can provide a good basis for prioritisation of activities, especially having the establishment of marine litter indicators for MSFD monitoring and national management plans in the Nordic countries in mind. However, results from the different Nordic studies are not always comparable due to employment of different methodologies for sampling and analyses have been employed. There is therefore a need for a common assemblage of knowledge and experience, and also a standartisation of methods based on the regional conditions that facilitate the framing of this environmental problem in a Nordic perspective. This report compiles information tha tcan be used as a contribution to this process. |
| **do Sul, J. A. I. and M. F. Costa (2014). "The present and future of microplastic pollution in the marine environment." Environmental Pollution 185: 352-364.**  Recently, research examining the occurrence of microplastics in the marine environment has substantially increased. Field and laboratory work regularly provide new evidence on the fate of microplastic debris. This debris has been observed within every marine habitat. In this study, at least 101 peer-reviewed papers investigating microplastic pollution were critically analysed (Supplementary material). Microplastics are commonly studied in relation to (1) plankton samples, (2) sandy and muddy sediments, (3) vertebrate and invertebrate ingestion, and (4) chemical pollutant interactions. All of the marine organism groups are at an eminent risk of interacting with microplastics according to the available literature. Dozens of works on other relevant issues (i.e., polymer decay at sea, new sampling and laboratory methods, emerging sources, externalities) were also analysed and discussed. This paper provides the first in-depth exploration of the effects of microplastics on the marine environment and biota. The number of scientific publications will increase in response to present and projected plastic uses and discard patterns. Therefore, new themes and important approaches for future work are proposed. |
| **Trevail, A. M., et al. (2015). “The state of marine microplastic pollution in the Arctic”. Kortrapport/Brief Report No. 033, Norsk Polarinstitutt.**  The problem of global plastic pollution is one of the most visible, and well documented, environmental changes of recent decades. The Arctic region is opening up to increasing commercial activity as sea ice melts, and will become increasingly influenced due to the detrimental effects caused by the trillions of pieces of plastic floating in our world’s oceans today.  Microplastics (< five mm in diameter) can flow directly to the environment undisturbed by waste water treatment plants from applications in cosmetics, for example, or can result from eventual fragmentation of larger plastics. By nature of their small size and ubiquitous presence across different ecosystems, microplastics are available for ingestion by all trophic levels, thus the potential for detrimental effects is substantial. Plastics can transport invasive species and pollutants over long distances, both of which could act as further stressors in the Arctic under climate warming scenarios. Plastic ingestion can disrupt functions of invertebrates, and can transfer a chemical burden to organisms. Population effects of plastic ingestion are largely unknown.  Here we collate and summarise accounts of microplastic pollution in the Arctic. Very little information exists about microplastic pollution in the Arctic. This review found no records for surface trawls in the Arctic, sediment microplastic loads or coastal shore pollution. The only quantitative records that exist are biological records and sea ice records. Microplastic encounters by Arctic animals exist for seven species, of which four are seabirds, two cetaceans and one shark species. From comparative studies with northern fulmars, plastic pollution levels in the European Arctic are higher than expected when compared to lower latitudes, most likely because of water currents. Levels of plastic in sea ice are higher than in the most polluted of oceanic gyres (38 to 234 pieces per m3), and warn of a legacy of plastic that will be released as sea ice melts.  The many gaps in our knowledge of microplastic pollution in the Arctic require further studies. Nevertheless, a lack of information in the region should not be considered as a lack of a problem, and should not hold back any action intending to reduce marine litter in the region. |
| **UNEP (2015) Biodegradable Plastics and Marine Litter. Misconceptions concerns an impacts on marine environments. United Nations Environment Programme (UNEP), Nairobi.**  The development and use of synthetic polymers, and plastics has conferred widespread benefits on society. One of the most notable properties of these materials is their durability which, combined with their accidental loss, deliberate release and poor waste management has resulted in the ubiquitous presence of plastic in oceans. As most plastics in common use are very resistant to biodegradation, the quantity of plastic in the ocean is increasing, together with the risk of significant physical or chemical impacts on the marine environment. The nature of the risk will depend on: the size and physical characteristics of the objects; the chemical composition of the polymer; and, the time taken for complete biodegradation to occur (GESAMP 2015).  Synthetic polymers can be manufactured from fossil fuels or recently-grown biomass. Both sources can be used to produce either non-biodegradable or biodegradable plastics. Many plastics will weather and fragment in response to UV radiation – a process that can be slowed down by the inclusion of specific additives. Complete biodegradation of plastic occurs when none of the original polymer remains, a process involving microbial action; i.e. it has been broken down to carbon dioxide, methane and water. The process is temperature dependent and some plastics labelled as ‘biodegradable’ require the conditions that typically occur in industrial compositing units, with prolonged temperatures of above 50°C, to be completely broken down. Such conditions are rarely if ever met in the marine environment.  Some common non-biodegradable polymers, such as polyethylene, are manufactured with a metal-based additive that results in more rapid fragmentation (oxo-degradable). This will increase the rate of microplastic formation but there is a lack of independent scientific evidence that biodegradation will occur any more rapidly than unmodified polyethylene. Other more specialised polymers will break down more readily in seawater, and they may have useful applications, for example, to reduce the impact of lost or discarded fishing gear. However, there is the potential that such polymers may compromise the operational requirement of the product. In addition, they are much more expensive to produce and financial incentives may be required to encourage uptake.  A further disadvantage of the more widespread adoption of ‘biodegradable’ plastics is the need to separate them from the non-biodegradable waste streams for plastic recycling to avoid compromising the quality of the final product. In addition, there is some albeit limited evidence to suggest that labelling a product as ‘biodegradable’ will result in a greater inclination to litter on the part of the public (GESAMP 2015).  In conclusion, the adoption of plastic products labelled as ‘biodegradable’ will not bring about a significant decrease either in the quantity of plastic entering the ocean or the risk of physical and chemical impacts on the marine environment, on the balance of current scientific evidence. |
| **UNEP (2016) Marine Plastic debris and microplastics – Global lessons and research to inspire action and guide policy change. United Nations Environment Programme, Nairobi.**  *No Abstract Available.* |
| **UNEP and GRID-Arendal (2016) Marine Litter Vital Graphics. United Nations Environment Programme and GRID-Arendal. Nairobi and Arendal.**  *No Abstract Available* |