Plastic Packing Bands

Bibliography

Katie Rowley, Librarian, NOAA Central Library

NCRL subject guide 2021-02
https://doi.org/10.25923/457t-j775

April 2021

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
NOAA Central Library – Silver Spring, Maryland

Table of Contents

Background & Scope

The National Marine Fisheries Service, Alaska Region Protected Resources Division requested an annotated bibliography on the impacts of plastic packing bands (straps) to marine species and any available information about alternatives (new technology, biodegradable, reduction of bands, etc.) to the use of plastic packing bands. The intended use of this information is to have a starting point and knowledge base to know the extent of the problem, and any alternatives to packing band use to work toward greater prevention, outreach, and awareness.

Section I – Marine Impact of Plastic (Packing Bands)

This section explores the impact of plastic on the marine environment in general and includes all forms of plastics, with the requirement of plastic packing bands being represented and called out.

Section II – Pinnipeds and Marine Species

This section pulls out pinnipeds as a species disproportionately impacted by plastic packing bands, along with other marine species to a lesser degree.

Section III – Seabirds

This section highlights briefly the impact specifically by plastic packing bands on seabirds.

Section IV – Policy

This section pulls together various government and review journal articles on the state of plastic policy in the marine environment.

Section V – Alternatives & Technology

This section highlights alternative bioplastic solutions to plastic packing bands and the technology involved in biodegradation solutions.

Sources Reviewed

The following sources were consulted and searched in order to create this bibliography: Clarivate's Web of Science, ProQuest's Aquatic Science Fisheries Abstracts, Google Scholar, Dimensions, JSTOR, EBSCO's Academic Search Premier and Elsevier's ScienceDirect, BioOne Complete, Science.gov, and open web searching.

Section I: Marine Impact of Plastic (Packing Bands)

Alimba, C. G., & Faggio, C. (2019). Microplastics in the Marine Environment: Current Trends in Environmental Pollution and Mechanisms of Toxicological Profile. *Environmental Toxicology and Pharmacology, 68*, 61-74 https://doi.org/10.1016/j.etap.2019.03.001

The global plastics production has increased from 1.5 million tons in the 1950s to 335 million tons in 2016, with plastics discharged into virtually all components of the environment. Plastics rarely biodegrade but through different processes they fragment into microplastics and nanoplastics, which have been reported as ubiquitous pollutants in all marine environments worldwide. This study is a review of trend in marine plastic pollution with focus on the current toxicological consequences. Microplastics are capable of absorbing organic contaminants, metals and pathogens from the environment into organisms. This exacerbates its toxicological profile as they interact to induced greater toxic effects. Early studies focused on the accumulation of plastics in the marine environment, entanglement of and ingestions by marine vertebrates, with seabirds used as bioindicators. Entanglement in plastic debris increases asphyxiation through drowning, restrict feeding but increases starvation, skin abrasions and skeletal injuries. Plastic ingestion causes blockage of the guts which may cause injury of the gut lining, morbidity and mortality. Small sizes of the microplastics enhance their translocation across the gastro-intestinal membranes via endocytosis-like mechanisms and distribution into tissues and organs. While in biological systems, microplastics increase dysregulation of gene expression required for the control of oxidative stress and activating the expression of nuclear factor E2-related factor (Nrf) signaling pathway in marine vertebrates and invertebrates. These alterations are responsible for microplastics induction of oxidative stress, immunological responses, genomic instability, disruption of endocrine system, neurotoxicity, reproductive abnormities, embryotoxicity and trans-generational toxicity. It is possible that the toxicological effects of microplastics will continue beyond 2020 the timeline for its ending by world environmental groups. Considering that most countries in African and Asia (major contributors of global plastic pollutions) are yet to come to terms with the enormity of microplastic pollution. Hence, majority of countries from these regions are yet to reduce, re-use or re-circle plastic materials to enhance its abatement.

Blettler, M. C., & Wantzen, K. M. (2019). Threats Underestimated in Freshwater Plastic Pollution: Mini-Review. *Water, Air, & Soil Pollution, 230*(7), 1-11 https://doi.org/10.1007/s11270-019-4220-z

Plastic pollution is one of the most acute environmental topics of our time. While there is a great scientific effort to tackle this problem, it has not always been well-coordinated or properly targeted. In this short review, we call for scientists to get involved in three crucial topics (threats) underestimated—or ignored—in freshwater systems: (i) plastic-species entanglement, (ii) plastic as nesting material, and (iii) macroplastic debris coming from mismanaged household solid waste. Reducing the knowledge gaps between marine and freshwater environments will be crucial to solute the plastic pollution problem effectively and globally. Therefore, we make a plea here to reinforce research activities on these three issues in freshwater environments worldwide.

Chin, L. W., & Fung, T. H. (2018). Plastic in Marine Litter. In *Plastics and the Environment.* (pp. 21-59) https://doi.org/10.1039/9781788013314-00021

Anthropogenic litter is found in marine environments from the beach, beach sediment and surface water to the seafloor. Plastic can persist and accumulate in the marine environment for a long period because of its light weight and degradation-resistant properties. The global production of plastic increased from 230 million tonnes in 2005 to 322 million tonnes in 2015. It has been estimated that plastic production will increase to 330 million tonnes in 2017. Mismanaged plastic waste can enter the marine environment via both land-based sources and oceanic-based sources. Ocean gyres, oceanic convergence zones and even polar regions are regarded as plastic waste accumulation hotspots. Over 690 species including seabirds, turtles, and fish have been reported to ingest plastic debris. Additionally, large plastic debris, especially derelict fishing gear and packing bags, pose a plastic entanglement risk to marine organisms. Plastic debris can act as vectors for the accumulation of hydrophobic organic pollutants and heavy metals or metalloids, and thus potentially cause harmful effects to marine organisms, such as endocrine system disruption, liver and kidney failure, hormone alterations and teratogenicity. This chapter summarizes the sources, distributions and fates of plastic debris in the marine environment, as well as the physical and chemical effects induced by plastic debris. Finally, recommendations including legislation reinforcement, better management of waste collection systems and landfills, raising the awareness of different stakeholders and the application of advanced technology are suggested to reduce the amount of plastics in the marine environment.

Consoli, P., Romeo, T., Angiolillo, M., Canese, S., Esposito, V., Salvati, E., . . . Tunesi, L. (2019). Marine Litter from Fishery Activities in the Western Mediterranean Sea: The Impact of Entanglement on Marine Animal Forests. *Environmental Pollution, 249*, 472-481 https://doi.org/10.1016/j.envpol.2019.03.072

The anthropogenic marine debris, especially abandoned, lost or otherwise discarded Fishing Gear (ALDFG), represents a rising concern, because of its potential harmful impact on the marine animal forests. We carried out 13 km of video recordings, by means of a remotely operated vehicle, from 10 to 210 m depth, in an anthropised area of the Tyrrhenian Sea (Mediterranean Sea). This site, for its high ecological importance and biodiversity value, has been identified for the establishment of a new marine protected area (MPA). The aim of this paper was to assess marine litter abundance and its effects on the benthic fauna. The debris density, in the study area, ranged from 0.24 to 8.01 items/100 m2, with an average of 3.49 (±0.59) items/100 m2. The derelict fishing gear, mainly fishing lines, were the main source of marine debris, contributing 77.9% to the overall litter. The impacts of debris on the benthic fauna were frequently recorded, with 28.5% of the litter entangling corals and impacting habitats of conservation concern. These impacts were exclusively caused by the derelict fishing gear (91.2% by longlines), and the highest percentage (49.1%) of ALDFG causing impacts was observed from 41 to 80 m depth, in the coralligenous biocenosis. The results of the present study will help the fulfilment of “harm” monitoring, as recommended by the Marine Strategy Framework Directive (MSFD) and the UN Environment/MAP Regional Plan on the marine litter management in the Mediterranean Sea. Regarding the actions to reduce the derelict fishing gear, preventive measures are usually preferred instead of the extensive removals based on cost-effectiveness and sustainability. The establishment of a new MPA in the area could be a good solution to reduce ALDFG, resulting in the improvement of the ecological status of this coastal area.

Dayton, P. K., Thrush, S. F., Agardy, M. T., & Hofman, R. J. (1995). Environmental Effects of Marine Fishing. *Aquatic Conservation Marine and Freshwater Ecosystems, 5*(3), 205-232 https://doi.org/10.1002/aqc.3270050305

1. Some effects of fisheries on the associated biological systems are reviewed and management options and their inherent risks are considered. 2. In addition to the effects on target species, other sensitive groups impacted by fishing are considered including marine mammals, turtles, sea birds, elasmobranchs and some invertebrates with low reproductive rates. 3. Other impacts discussed include the destruction of benthic habitat, the provision of unnatural sources of food and the generation of debris. 4. Management options are considered including the designation of marine protected areas, risk aversion, and the burden of proof. 5. A balanced consideration of the risks and consequences of 'Type 1' and 'Type 11' errors is advocated.

Derraik, J. G. B. (2002). The Pollution of the Marine Environment by Plastic Debris: A Review. *Marine Pollution Bulletin, 44*(9), 842-852 https://doi.org/10.1016/S0025-326X(02)00220-5

The deleterious effects of plastic debris on the marine environment were reviewed by bringing together most of the literature published so far on the topic. A large number of marine species is known to be harmed and/or killed by plastic debris, which could jeopardize their survival, especially since many are already endangered by other forms of anthropogenic activities. Marine animals are mostly affected through entanglement in and ingestion of plastic litter. Other less known threats include the use of plastic debris by "invader" species and the absorption of polychlorinated biphenyls from ingested plastics. Less conspicuous forms, such as plastic pellets and "scrubbers" are also hazardous. To address the problem of plastic debris in the oceans is a difficult task, and a variety of approaches are urgently required. Some of the ways to mitigate the problem are discussed.

Edyvane, K. S., Dalgetty, A., Hone, P. W., Higham, J. S., & Wace, N. M. (2004). Long-Term Marine Litter Monitoring in the Remote Great Australian Bight, South Australia. *Marine Pollution Bulletin, 48*(11), 1060-1075 https://doi.org/10.1016/j.marpolbul.2003.12.012

The Anxious Bay beach litter clearance is the longest running annual survey of ocean-based litter in Australia. It's remoteness from centres of human population and location (with respect to prevailing winds and currents) make it an ideal place for monitoring ocean or ship-based litter in Australia's southern oceans and particularly, the Great Australian Bight. Over the 1991–1999 period, a large but gradual decline in the amount of beach washed litter was recorded (with minor peaks recorded during the 1992 and 1994 surveys). Beach washed litter decreased by approximately 86%, from 344 kg recorded in 1991 (13.2 kg/km) to 49 kg in 1999 (i.e. 1.9 kg/km), reaching a maximum of 390 kg in 1992 (or 15 kg/km of beach). However, a sharp increase in litter was recorded in 2000 (i.e. 252 kg or 9.7 kg/km). This increase in litter yield in 2000 is probably due to stronger than average onshore surface flow (or Ekman Transport) in the western Eyre Peninsula and Bight region. Prior to the survey in 2000, the results appeared to indicate that ocean litter on Anxious Bay beach was beginning to level out at around 50–70 kg/year (i.e. 2–3 kg/km). As the beach surveys involve the assumption that the beach is completely cleared of litter, this may represent a baseline level for ocean-based litter in the region. The yields and type of litter collected from the annual survey indicates that the majority of litter washed ashore originates from commercial fishing activities within the Great Australian Bight. Most of the fishing-related litter was directly sourced to the Southern Rock Lobster Fishery (i.e. bait buckets, baskets, pots), the Great Australian Bight Trawl Fishery (i.e. codends, trawl nets) and the Southern Shark Fishery (i.e. monofilament gillnets and longlines). Between 1994 and 1999, large reductions were observed in the amount of bait straps (77% reduction), lobster bait baskets/buckets (86% reduction), nets/ropes (62% reduction) and floats/buoys (83% reduction). Significantly, fishing-related litter in the Bight has reduced at a slower rate than domestic litter. While the level of glass and soft plastics on the beach have both reduced by almost 93% (i.e. 103–7 kg and 119–8 kg, respectively), the level of hard plastics, has diminished at a slower rate, with reductions of only 75% (i.e. 122–30 kg). Some fisheries (i.e. rock lobster, Southern Shark Fishery) have shown marked reductions in fishing-related litter. This is probably due, to some extent, to significant reductions in fishing effort in the region, although this requires further investigation. The information from the Anxious Bay beach litter survey is crucial in monitoring trends in ocean litter in Australia's southern oceans and compliance with international litter regulations. While fishing-related litter remains the major source of ship-based or ocean litter in Australia's southern oceans, the continued reduction in ship-based litter since 1991 supports increasing compliance to MARPOL (Annex V) by commercial fisheries and shipping in the Great Australian Bight. While Australia participates in marine debris monitoring programs in the Antarctic (under CCAMLR), there is currently no national program or management framework to assess, manage and monitor ocean-based litter along Australia's coasts, and monitor compliance with MARPOL. Apart from the commitments under CCAMLR for Antarctic (and sub-Antarctic) marine environments, there are no other regional programs, guidelines or monitoring protocols or to assess and manage ocean litter in the Southern Ocean.

Effects of Litter from Fishing Gear. (2000). In *Commercial Fishing: The Wider Ecological Impacts.* G. Moore & S. Jennings (Eds.), (pp. 17-18) https://doi.org/10.1002/9780470694961.ch3

No abstract

Goldstein, M. C., Carson, H. S., & Eriksen, M. (2014). Relationship of Diversity and Habitat Area in North Pacific Plastic-Associated Rafting Communities. *Marine Biology, 161*(6), 1441-1453 https://doi.org/10.1007/s00227-014-2432-8

Plastic and other anthropogenic debris (e.g., rubber, tar) augment natural floating substrates (e.g., algal rafts, pumice) in the open ocean, allowing “islands” of substrate-associated organisms to persist in an otherwise unsuitable habitat. We examined a total of 242 debris objects collected in the eastern Pacific in 2009 and 2011 (32–39°n, 130–142°W) and the western Pacific in 2012 (19–41°n, 143–156°e). Here, we ask: (a) What taxa are associated with plastic rafts in the north Pacific? and (b) Does the number of taxa associated with plastic debris vary with the size of the debris “island?” We documented 95 rafting taxa from 11 phyla. We identified several potentially invasive plastic-associated rafting taxa, including the coral pathogen Halofolliculina spp. In concordance with classic species–area curves, the number of rafting taxa was positively correlated with the size of the raft. Our findings suggest that diversity patterns on plastic debris are compatible with the concept of island biogeography.

Golik, A. (1997). Debris in the Mediterranean Sea: Types, Quantities, and Behavior. In *Marine Debris: Sources, Impacts, and Solutions.* J. M. Coe & D. B. Rogers (Eds.), (pp. 7-14). New York, NY: Springer New York https://doi.org/10.1007/978-1-4613-8486-1_2

The Mediterranean Sea, which occupies some 2.5 million km2, is an enclosed sea with only one opening for water exchange, the 14-km-wide Strait of Gibraltar. In the strait, surface water flows into the Mediterranean Sea and deeper water flows out. The water exchange rate of the Mediterranean is estimated to be 80 years. The sea is bordered by 18 countries, where more than 135 million people inhabit its coastal regions (Blue Plan 1987). The northwestern shores of the sea are heavily populated and highly urbanized, although its southern coast is sparsely populated. Major shipping lanes are found in the Mediterranean, with oil as probably the most important cargo. These physical and demographic conditions of the Mediterranean Sea make it a trap for marine- and land-derived litter.

Goñi, R. (1998). Ecosystem Effects of Marine Fisheries: An Overview. *Ocean & Coastal Management, 40*(1), 37-64 https://doi.org/10.1016/S0964-5691(98)00037-4

Most fisheries literature avoids speaking about ecosystem impacts of fishing, either because impacts are not demonstrated or because a causal relationship between impacts and fishing cannot be formally established with the available information. However, there is mounting evidence that fishing has undesired effects in the marine ecosystems. This overview examines the wide ecosystem effects of fishing, describing and illustrating the potential unintended effects of the main fisheries of the world. An operational framework for classifying the effects of fishing in terms of the mechanisms generating the effects is provided. The focus and, to a large extent, the recourse to examples is on those fisheries for which the impacts of fishing have been best studied such as those in the North Atlantic and the Northeast Pacific. Ecosystem effects are divided into direct and indirect: direct effects include the fishing mortality exerted on target populations (overfishing), the fishing mortality sustained by non-target populations (bycatch), and the physical impacts caused by towed gears on benthic organisms and on the seabed. Indirect effects include impacts mediated by biological interactions, the environmental effects of dumping discards and organic detritus (offal), and the mortality caused by lost gear (ghost fishing).

Haarr, M. L., Westerveld, L., Fabres, J., Iversen, K. R., & Busch, K. E. T. (2019). A Novel Gis-Based Tool for Predicting Coastal Litter Accumulation and Optimising Coastal Cleanup Actions. *Marine Pollution Bulletin, 139*, 117-126 https://doi.org/10.1016/j.marpolbul.2018.12.025

Effective site selection is a key component of maximising debris removal during coastal cleanup actions. We tested a GIS-based predictive model to identify marine litter hotspots in Lofoten, Norway based on shoreline gradient and shape. Litter density was recorded at 27 randomly selected locations with 5 transects sampled in each. Shoreline gradient was a limiting factor to litter accumulation when >35%. The curvature of the coastline correlated differently with litter density at different spatial scales. The greatest litter concentrations were in small coves located on larger headlands. A parsimonious model scoring sites on a scale of 1–5 based on shoreline slope and shape had the highest validation success. Sites unlikely to have high litter concentrations were successfully identified and could be avoided. The accuracy of hotspot identifications was more variable, and presumably more parameters influencing litter deposition, such as shoreline aspect relative to prevailing winds, should be incorporated.

Hasnat, A., & Rahman, M. A. (2018). A Review Paper on the Hazardous Effect of Plastic Debris on Marine Biodiversity with Some Possible Remedies. *Asian Journal of Medical and Biological Research, 4*(3), 233-241 https://doi.org/10.3329/ajmbr.v4i3.38461

The consequences of plastic debris in the marine environment were reviewed, and possible solutions were presented. The extent of marine plastic debris-related problems surpasses many other marine problems, as plastics may be transported globally and no unaffected areas seem to exist. Many animal species are in risk, most commonly studied are the effects on marine mammals and seabirds. Marine plastic debris creates new concerns such as entanglement, ghost fishing, and impaction of digestive tracts in animals. It also increases the severity of already existing concerns such as transport, exposure and uptake of organic pollution, with reduced fitness and impaired reproduction and increased mortality rates as consequences. To alleviate the problems, reducing the extent of marine plastic pollution is critical. Possible methods were identified as collecting and incentivizing recycling of marine plastic debris; redirecting production from petroleum plastics to biodegradable varieties; increase public awareness to reduce marine littering; stricter enforcement of current legislation as well as implementation of stricter legislation and harsher penalties for breaking it.

Kennish, M. J. (2020). *Pollution Impacts on Marine Biotic Communities* (1st ed.): CRC Press. https://doi.org/10.1201/9781003069003

Pollution of estuaries and coastal marine waters is of profound ecological and societal importance. These coastal environments serve as critical habitat for a multitude of organisms and are of great commercial and recreational value to humans. Designed to meet the research, monitoring, and assessment needs of scientists, administrators, planners, and managers, Pollution Impacts on Marine Biotic Communities is a uniquely comprehensive reference covering pollution in coastal marine and estuarine waters. The book provides a detailed look at the short- and long-term impacts of pollutants on these ecologically important regions. Case studies that reflect a broad range of pollution problems are analyzed, outlining the real-life issues and providing solutions to common problems.
Despite being highly sensitive systems, estuarine and coastal marine environments have served as repositories for dredge spoils, sewage sludge, and industrial and municipal effluents for many decades. The adverse effects of these pollutants are only now being fully realized and understood. Pollution Impacts on Marine Biotic Communities includes a basic introduction to the subject of pollution in estuarine and marine environments and also a detailed examination of specific marine pollutants. Both the coverage and the format - which includes abundant illustrations and tables - make this book a valuable reference for scientists, administrators, and students engaged in coastal research and planning.

Laist, D. W. (1987). Overview of the Biological Effects of Lost and Discarded Plastic Debris in the Marine Environment. *Marine Pollution Bulletin, 18*(6), 319-326 https://doi.org/10.1016/s0025-326x(87)80019-x

In the past thirty years, the use of plastics and other synthetic materials has expanded at a rapid pace. As new uses for these materials have been developed, applied, and made available to more people, the quantity of plastic debris entering the marine environment has undergone a corresponding increase. Many of these products degrade very slowly. Those that are buoyant remain suspended at the sea surface for a long time, and those that are not, sink and remain on the bottom for years or even decades. The accumulating debris poses increasingly significant threats to marine mammals, seabirds, turtles, fish, and crustaceans. The threats are straightforward and primarily mechanical. Individual animals may become entangled in loops or openings of floating or submerged debrijs or they may ingest plastic materials. Animals that become entangled may drown, have their ability to catch food or avoid predators impaired, or incur wounds from abrasive or cutting action of attached debris. Ingested plastics may block digestive tracts, damage stomach linings, or lessen feeding drives. The deceptively simple nature of the threat, the perceived abundance of marine life, and the size of the oceans have, until recently, caused resource managers to overlook or dismiss the proliferation of potentially harmful plastic debris as being insignificant. However, developing information suggests that the mechanical effects of these materials affect many marine species in many ocean areas, and that these effects justify recognition of persistent plastic debris as a major form of ocean pollution.

Lang, G. E. (1990). Plastics, the Marine Menace: Causes and Cures. *Journal of Land Use & Environmental Law, 5*(2), 729-752 Retrieved from http://www.jstor.org/stable/42842563

No abstract.

Law, K. L. (2017). Plastics in the Marine Environment. *Annual Review of Marine Science, 9*(1), 1-25 https://doi.org/10.1146/annurev-marine-010816-060409

Plastics contamination in the marine environment was first reported nearly 50 years ago, less than two decades after the rise ofcommercial plastics production, when less than 50 million metric tons were produced per year. In 2014, global plastics production surpassed 300 million metric tons per year. Plastic debris has been detected worldwide in all major marine habitats, in sizes from microns to meters. In response, concerns about risks to marine wildlife upon exposure to the varied forms of plastic debris have increased, stimulating new research into the extent and consequences of plastics contamination in the marine environment. Here, I present a framework to evaluate the current understanding ofthe sources, distribution, fate, and impacts ofmarine plastics. Despite remaining knowledge gaps in mass budgeting and challenges in investigating ecological impacts, the increasing evidence ofthe ubiquity ofplastics contamination in the marine environment, the continued rapid growth in plastics production, and the evidence—albeit limited—of demonstrated impacts to marine wildlife support immediate implementation of source-reducing measures to decrease the potential risks of plastics in the marine ecosystem.

Li, W. C., Tse, H. F., & Fok, L. (2016). Plastic Waste in the Marine Environment: A Review of Sources, Occurrence and Effects. *Science of The Total Environment, 566-567*, 333-349 https://doi.org/10.1016/j.scitotenv.2016.05.084

This review article summarises the sources, occurrence, fate and effects of plastic waste in the marine environment. Due to its resistance to degradation, most plastic debris will persist in the environment for centuries and may be transported far from its source, including great distances out to sea. Land- and ocean-based sources are the major sources of plastic entering the environment, with domestic, industrial and fishing activities being the most important contributors. Ocean gyres are particular hotspots of plastic waste accumulation. Both macroplastics and microplastics pose a risk to organisms in the natural environment, for example, through ingestion or entanglement in the plastic. Many studies have investigated the potential uptake of hydrophobic contaminants, which can then bioaccumulate in the food chain, from plastic waste by organisms. To address the issue of plastic pollution in the marine environment, governments should first play an active role in addressing the issue of plastic waste by introducing legislation to control the sources of plastic debris and the use of plastic additives. In addition, plastics industries should take responsibility for the end-of-life of their products by introducing plastic recycling or upgrading programmes.

Lucas, Z. (1992). Monitoring Persistent Litter in the Marine Environment on Sable Island, Nova Scotia. *Marine Pollution Bulletin, 24*(4), 192-199 https://doi.org/10.1016/0025-326X(92)90529-F

Beach surveys of persistent litter were carried out on Sable Island, Canada, between 31 May 1984 and 10 September 1986, with supplementary observations to early 1991. Persistent litter found on Sable beaches comes from the ocean, and does not originate on the island itself. Deposition rates were fairly consistent from year to year, site to site, with some seasonal variation. A total of 11 183 persistent litter items were collected and sorted, representing 219 items/km/month. Ninety-two per cent of this total was plastic material. Types of litter found include tampon dispensers, polystyrene cups and packing materials, plastic containers for food, oil and cleansers, polyethylene bags and sheet, liquor and soft drink bottles, fluorescent tubes and incandescent bulbs, plastic strapping, polypropylene rope, and large amounts of fishing equipment. These items are generated by various marine activities, particularly the fishing industry. Entanglement of two species of seal and three species of seabird, and ingestion of plastic and latex by leatherback turtles, was observed. While litter in Scotian Shelf waters presents hazards to all marine animals, it does not appear to have a serious impact on seal populations at this time.

Nashoug, B. F. (2017). *"Sources of Marine Litter" –Workshop Report, Svalbard 4th -6th September 2016.* Published for the Norwegian Research Council Retrieved from https://pame.is/document-library/desktop-study-on-marine-litter-library/marine-litter-sources/577-nashoug-2017-sources-of-marine-litter-worksh/file

MARP3 -MARine Plastic Pollution in the Arctic: origin, status, costs and incentives for Prevention. The goal of this project is to strengthen the knowledge base on marine plastic debris in the Barents Sea and provide management-relevant reserach to increase awareness and recommend measures that can guide sustainable practices of human activities currently contributing to marine waste pollution in the region. Norut is project manager and SALT is responsible for a Marine Litter Workshop and dissimination. The objective of this workshop was to collate experts from relevant industries to determine the degree to which it is possible to precisely identify marine litter and examine the sources, causes of loss, and ages of different pieces of debris. Firstly, we concluded that without the help of experts we wouldn't have been able to read much out of the waste. In this case the fishers were our key experts as there are few people living in this region, but a large fishery around Svalbard and adjacent areas. Fisheries related waste and waste from other marine activities is therefore dominating what is found along the beaches of Svalbard. From the fishers we learned how we could tell if fishing equipment had been lost or dumped, they could also tell us what items belong under deck and therefore could not have been washed overboard in bad weather. What was more difficult to say, was the origin of the fishing equipment that was found, as this is traded internationally and is used on vessels of different nationalities. But there was not only fishing related litter in the pile of waste we looked through. Large amounts of household packaging tells us that a variety of actors contribute to the waste that is found. Due to the large size of some of this packaging, it is likely that some of this comes from larger vessels. While we found a number of packages of Norwegian origin, such as Idun tomato sauce and mustard, a large number of nationalities were represented in the waste.

Niaounakis, M. (2017). 2 - Environmental, Social, and Economic Impacts. In *Management of Marine Plastic Debris.* M. Niaounakis (Ed.), (pp. 57-126): William Andrew Publishing https://doi.org/10.1016/B978-0-323-44354-8.00002-1

This chapter presents the environmental, social, economical, and health effects of marine plastic debris (MPD) causing direct or indirect damage to marine ecosystems and human activities such as fishing and aquaculture, shipping, recreational activities, and tourism. The environmental impacts of MPD on sea life refer to increased levels of mortality or sublethal effects on biodiversity caused by (1) entanglement of marine animals in various types of plastic debris such as derelict fishing nets (also referred to as "ghost" nets) and plastic fragments; (2) ingestion of small pieces of MPD by marine (micro)organisms; (3) dispersal via rafting of many invasive species to distant places; (4) creation of new habitats of marine species; and (5) effect on existing habitats. The social impacts of MPD include deterioration in the quality of human life, reduced recreational opportunities, loss of aesthetic value, and loss of nonuse or vicarious value. The economic impacts relate to the reduction of opportunities to exploit the marine environment, for pleasure or profit.

Niaounakis, M. (2020). 2 - Environmental and Socio-Economic Effects. In *Recycling of Flexible Plastic Packaging.* M. Niaounakis (Ed.), (pp. 21-56): William Andrew Publishing https://doi.org/10.1016/B978-0-12-816335-1.00002-5

Chapter 2 studies the environmental and socio-economic effects of flexible plastic packaging. At first, the various degradation modes, including hydrolytic degradation, thermooxidative degradation, photodegradation, biodegradation, and mechanical degradation by which plastics can be degraded in the environment, are presented. Further, there are discussions on the dire consequences that the uncontrolled disposal of flexible plastic packaging can have on land and in the sea. There are also discussions on the damages inflicted to marine animals (mammals, turtles, birds, and fishes) by entanglement in and ingestion of plastic packaging debris. Finally, the socio-economic impact of plastic packaging litter on marine ecosystems and various human activities, such as fishing, shipping, recreational activities, and tourism, are examined.

Quayle, D. V. (1992). Plastics in the Marine Environment: Problems and Solutions. *Chemistry and Ecology, 6*(1-4), 69-78 https://doi.org/10.1080/02757549208035263

Plastics debris is known to be present in all of the world's oceans, and on most amenity beaches, although comparatively little data are available to provide reliable information on the extent of damage from this pollution, and on its spatial and temporal variations.

Marine pollution by plastics has been shown to be damaging to marine mammals, birds and reptiles. This is due to entanglement in packaging bands, synthetic ropes and lines, or drift nets; or by the ingestion of small items of plastics debris. More research is needed to quantify the extent of the problems.

Wider use of degradable plastics will not solve the problems of plastics pollution. Their lifetimes are relatively long and unpredictable, and they are not generally acceptable for recycling.

Marine plastics pollution may be alleviated by the judicious application of both economic incentives and legislation, designed to decrease their use, to increase the rate of recycling, and to restrict uncontrolled discards.

Ryan, P. G., Musker, S., & Rink, A. (2014). Low Densities of Drifting Litter in the African Sector of the Southern Ocean. *Marine Pollution Bulletin, 89*(1), 16-19 https://doi.org/10.1016/j.marpolbul.2014.10.043

Only 52 litter items (>1cm diameter) were observed in 10,467km of at-sea transects in the African sector of the Southern Ocean. Litter density north of the Subtropical Front (0.58 items km^{-2}) was less than in the adjacent South Atlantic Ocean (1–6itemskm^{-2}), but has increased compared to the mid-1980s. Litter density south of the Subtropical Front was an order of magnitude less than in temperate waters (0.032 items km^{-2}). There was no difference in litter density between sub-Antarctic and Antarctic waters either side of the Antarctic Polar Front. Most litter was made of plastic (96%). Fishery-related debris comprised a greater proportion of litter south of the Subtropical Front (33%) than in temperate waters (13%), where packaging dominated litter items (68%). The results confirm that the Southern Ocean is the least polluted ocean in terms of drifting debris and suggest that most debris comes from local sources.

Ryan, P. G., Weideman, E. A., Perold, V., Durholtz, D., & Fairweather, T. P. (2020). A Trawl Survey of Seafloor Macrolitter on the South African Continental Shelf. *Marine Pollution Bulletin, 150*, 110741 https://doi.org/10.1016/j.marpolbul.2019.110741

Demersal trawls provide an index of seafloor macrolitter abundance, but there are no published data from sub-Saharan Africa. We collected litter items from 235 trawls conducted to assess fish abundance off South Africa. Only 17% of trawls contained litter (3.4 items·km^{-2}, 2.1 kg·km^{-2} but only 0.2 kg·km^{-2} excluding four megalitter items). Plastic items predominated (88%), of which 77% floated once cleaned of epibionts. One LDPE bag manufactured three months before being caught carried pelagic goose barnacles Lepas anserifera, confirming that biofouling leads to rapid sinking of floating plastics. Fishery/shipping wastes comprised 22% of litter items (98% by mass; 73% excluding megalitter items); the remainder was general waste – mostly packaging or other single-use items – that could come from land- or ship-based sources. Litter was more abundant in deep water close to Cape Town. The annual demersal trawl survey is a useful way to monitor seafloor litter off South Africa.

Sibley, T. H., & Strickland, R. M. (1989). *Potential Effects of Marine Debris on Benthic Communities.* P. f. N. E. Project Retrieved from http://hdl.handle.net/1773/4118

Anthropogenic debris is entering the world's oceans from various sources. Although the impacts of debris at the surface and on beaches has received consider able attention, there is extremely little information available on the potential impacts to benthic organisms. This project was conducted to evaluate our current know ledge of benthic impacts and to propose future research programs to improve our understanding ofpotential effects. Information was obtained through a review of the available literature on marine debris and discussions with benthic ecologists. A case study approach was used to evaluate potential impacts to benthic resources in the North Pacific Ocean because more information on debris is available there than for most other regions. Debris includes paper, metal, glass and cloth. Although plastics are a small percentage of total debris, they are the best studied because they are persistent and evident in marine environments. Debris can enter the oceans from landbased sourc es and from military, recreational or passenger ships. In the open ocean, however, the principal sources appear to be merchant shipping and commercial fishing ships. Although the greatest source of total debris may be merchant ships, derelict fishing gear seems to produce the greatest biological impacts. Debris found on beaches in the North Pacific is dominated by trawl webbing (by weight) and gilinet floats (by number). It is unknown what type of debris is most common on the sea floor. The principal concerns for producing benthic impacts are lost or abandoned crab pots and gill nets that may be suspended vertically from the ocean bottom because they may continue to “ghost-fish” for an extended time after being lost. There is little information on the fate and impacts of benthic debris. It is clear that crab pots and gill nets do continue to fish. Gill nets will ball up and become fouled with algae that makes them visible. They will then be less effective for fishing but may catch some fish for several years. The principal impact appears to be on non-commercial species. Crab pots also may fish for several years although new regulations require biodegradable panels that allow organisms to escape. Or ganic debris probably provides additional food for benthic organisms and metal may provide hard substrate for attachment of benthic species. Thus, all impacts of debris are not necessarily negative. Several international conventions as well as federal laws in the United States regulate discharge of wastes in the oceans. Enforcement of these regulations at sea is extremely difficult, however. The most successful methods for decreasing input of debris probably involves educational programs for fishermen as well as recrea tional sailors. Merchant shipping and military vessels have space on board to store debris and can establish procedures on ship to reduce their inputs. A number of research projects are proposed to determine the quantity and type of debris on the sea floor and the potential impacts on benthic organisms. Two types of projects are particularly important: (1) monitoring programs to quantify the types of debris on the bottom, and (2) long-term observational projects to determine the interactions between various types of debris and benthic organisms.

Vianello, A., Da Ros, L., Boldrin, A., Marceta, T., & Moschino, V. (2018). First Evaluation of Floating Microplastics in the Northwestern Adriatic Sea. *Environmental Science and Pollution Research, 25*(28), 28546-28561 https://doi.org/10.1007/s11356-018-2812-6

Plastic pollution in the marine environment is becoming a problem of global concern, and the Mediterranean is believed to be one of the worst affected regional seas. The present study presents data on floating microplastics in the Northwestern Adriatic Sea in order to evaluate the possible contribution of two significant potential sources: the lagoon of Venice and the Po River. Samples were collected in March and April 2014 along two transects located off Pellestrina Island (Venice) and the Po Delta, each consisting of four sampling stations at 0.5, 3, 10, and 20 km from the shoreline. Microplastics were quantified and classified according to their colors and shapes and analyzed by micro-attenuated total reflection-FT-IR. Microplastics were found in all samples, albeit with high spatial and temporal variability. The highest concentrations were observed in March at the offshore station of the Pellestrina transect (10.4 particles m^{-2}) and the two landward stations off the Po Delta (2.1 and 4.3 particles m^{-2}), highlighting the influence of various factors, such as surface circulation and river discharges, in determining specific accumulation patterns. The most common polymers were polyethylene and polypropylene, and most of the particles were secondary microplastics (83.5%). The patchy distribution of microplastics observed in the study area is driven by hydrodynamic and meteorological factors acting on short time scales.

Welden, N. A. (2020). Chapter 8 - the Environmental Impacts of Plastic Pollution. In *Plastic Waste and Recycling.* T. M. Letcher (Ed.), (pp. 195-222): Academic Press https://doi.org/10.1016/B978-0-12-817880-5.00008-6

Globally, mass production of polymers and poor control of plastic products at end of life have led to annual increases in plastic entering the marine environment. Their durability and density allow plastic to be transported over large distances and to persist for long periods in the marine environment. The proliferation of plastics has resulting in contamination across a range of environments, from remote lakes to the deepest oceans; however, the effects in the marine environment remain the most studied. Here, plastic have been observed to negatively affect habitats by altering species distribution, entangling organisms, and causing damage and even increasing mortality as a result of ingestion. Nevertheless, the increasing number of studies in freshwater environments may help to predict previously unexplored impacts in the marine realm.

Section II: Pinniped and Marine Species

Allyn, E. M., & Scordino, J. J. (2020). Entanglement Rates and Haulout Abundance Trends of Steller (*Eumetopias jubatus*) and California (*Zalophus Californianus*) Sea Lions on the North Coast of Washington State. *PLOS ONE, 15*(8) https://doi.org/10.1371/journal.pone.0237178

Entanglements affect marine mammal species around the globe, and for some, those impacts are great enough to cause population declines. This study aimed to document rates and causes of entanglement and trends in local haulout abundance for Steller and California sea lions on the north coast of Washington from 2010-2018. We conducted small boat surveys to count sea lions and document entangled individuals. Rates of entanglement and entangling material occurrence were compared with records of stranded individuals on the Washington and Oregon coast and with packing bands recorded during beach debris surveys. The rate of entanglement for California sea lions was 2.13%, almost entirely composed of adult males, with a peak rate during June and July potentially due to some entangled individuals not migrating to their breeding grounds. For Steller sea lions, the rate of entanglement was 0.41%, composed of 77% adults (32.4% male, 63.3% female), 17.1% juveniles, 5.9% unknown age, and no pups. Steller sea lions exhibited a 7.9% +/- 3.2 rate of increase in abundance at the study haulouts, which was similar to that seen in California sea lions (7.8% +/- 4.2); both increases were greater than the population growth rates observed range-wide despite high rates of entanglement. Most entanglements for both species were classified as packing bands, followed by entanglement scars. Salmon flashers were also prevalent and only occurred from June-September during the local ocean salmon troll fishery. Packing band occurrence in beach debris surveys correlated with packing band entanglements observed on haulouts. However, no packing band entanglements were observed in the stranding record and the rate of stranded animals exhibiting evidence of entanglement was lower than expected, indicating that entanglement survival is higher than previously assumed. Future studies tracking individual entanglement outcomes are needed to develop effective, targeted management strategies.

Arnould, J. P. Y., & Croxall, J. P. (1995). Trends in Entanglement of Antarctic Fur Seals (*Arctocephalus gazella*) in Man-Made Debris at South Georgia. *Marine Pollution Bulletin, 30*(11), 707-712 https://doi.org/10.1016/0025-326X(95)00054-Q

A study conducted at South Georgia in 1988/1989 indicated that several thousand Antarctic fur seals were entangled mainly in man-made material originating from fishing vessels. Consequently, the authority responsible for the management of Southern Ocean marine resources (CCAMLR) actively campaigned for compliance with the MARPOL provisions relating to waste disposal at sea, and for cutting of any material unavoidably jettisoned which could form collars to entangle seals. Five subsequent years of recording entangled fur seals confirms that entanglement is a persistent problem, although its incidence has been halved in recent years. However, the South Georgia fur seal population has approximately doubled in the same period, so that the overall total of animals entangled may even have increased. Nevertheless, because most seals entangled are juvenile males, the current rate of entanglement will have negligible effects on the reproductive rate of the South Georgia population, especially in relation to its current rate of population increase. The reduction in observed entanglement incidence cannot be attributed mainly to improved waste disposal practices because it has coincided with substantial reductions in fishing activity around South Georgia. However, the particular reduction in entanglement due to packing bands and the fact that all such bands washed ashore over the last 2 years have been cut, does suggest a general improvement in standards of waste disposal on Southern Ocean fishing vessels.

Baulch, S., & Perry, C. (2014). Evaluating the Impacts of Marine Debris on Cetaceans. *Marine Pollution Bulletin, 80*(1), 210-221 https://doi.org/10.1016/j.marpolbul.2013.12.050

Global in its distribution and pervading all levels of the water column, marine debris poses a serious threat to marine habitats and wildlife. For cetaceans, ingestion or entanglement in debris can cause chronic and acute injuries and increase pollutant loads, resulting in morbidity and mortality. However, knowledge of the severity of effects lags behind that for other species groups. This literature review examines the impacts of marine debris on cetaceans reported to date. It finds that ingestion of debris has been documented in 48 (56% of) cetacean species, with rates of ingestion as high as 31% in some populations. Debris-induced mortality rates of 0–22% of stranded animals were documented, suggesting that debris could be a significant conservation threat to some populations. We identify key data that need to be collected and published to improve understanding of the threat that marine debris poses to cetaceans.

Boren, L. J., Morrissey, M., Muller, C. G., & Gemmell, N. J. (2006). Entanglement of New Zealand Fur Seals in Man-Made Debris at Kaikoura, New Zealand. *Marine Pollution Bulletin, 52*(4), 442-446 https://doi.org/10.1016/j.marpolbul.2005.12.003

New Zealand fur seals in the Kaikoura region breed near a town with expanding tourist and fishing industries and commonly come ashore entangled in nets and plastic debris. However, the rate at which entanglement occurs was previously unknown. A decade of Department of Conservation seal callout data was analysed to determine the level of entanglement in the region and the most common debris type. Monitoring of adult female fur seals released from entanglement provided information on the potential for serious wounds to heal and survivorship of released individuals. Entanglement rates of pinnipeds in Kaikoura are some of the highest reported world-wide (average range: 0.6–2.8%) with green trawl net (42%), and plastic strapping tape (31%) together contributing the most to debris types. Nearly half of the reported entangled seals are successfully released (43%) and post-release monitoring shows that with appropriate intervention the chance of an individual surviving even with a significant entanglement wound is high. Our study demonstrates that while entanglement in the region is high, a successful intervention protocol may help reduce the potential for entanglement-related mortality in the region.

Butterworth, A. (2016). A Review of the Welfare Impact on Pinnipeds of Plastic Marine Debris. *Frontiers in Marine Science, 3* https://doi.org/10.3389/fmars.2016.00149

Uncounted, and usually unobserved, numbers of pinnipeds find themselves entangled in lost fishing gear, monofilament line, nets, rope, plastic packaging in the ocean or on the shoreline. These animals may carry debris wrapped around themselves for long periods, and often die as a result, sometimes from deep chronic wounds. The pinniped species most affected by this modern and manmade phenomenon are fur seals, monk seals, and California sea lions, and to a lesser extent gray, common, and monk seals. Entanglement rates described range up to 7.9% of local populations annually, and the common entangling materials; packing bands, fragments of lost net, rope, monofilament line, fishery flashers and lures, long-line fishing gear, hooks and line, and bait hooks are discussed. Awareness of this issue is increasing, and local action is reported to have made measurable differences in entanglement rates, however, plastic material in the ocean is likely to be long lived, and will leave many entangled pinnipeds unreported and result in a hidden and potentially significant effect on wild animal welfare.

Butterworth, A., & Sayer, S. (2017). The Welfare Impact on Pinnipeds of Marine Debris and Fisheries. In *Marine Mammal Welfare.* (pp. 215-239) https://doi.org/10.1007/978-3-319-46994-2_13

Uncounted, and usually unobserved, numbers of the animals that live in the oceans find themselves snared, trapped or entangled in lost fishing gear, monofilament line, nets, rope, plastic packaging and packing bands from crates, or become hooked on discarded fishing gear, or ingest human marine debris. Seals, sea lions and walrus (the pinnipeds) seem particularly susceptible to entanglement in marine debris—their exploratory natures may make this more likely, or perhaps they come upon plastic waste and rope on the shoreline to a greater extent than the other fully aquatic mammals. Pinnipeds meeting with plastic, either in the sea or on the shoreline, may carry debris wrapped around themselves for long periods. They often die as a result, sometimes from major chronic wounds. Although a wide range of the global species of seals can be affected by marine debris, some species are much more significantly affected than others. The key seal species affected by entanglement are monk seals, fur seals and California sea lions. Seals which become entangled or who ingest marine debris may be subjected to distress, pain, trauma, infection, skin and muscle lesions and compromised ability to move, feed and carry out normal behaviour. For these reasons marine debris has the capacity to present a significant and global issue with respect to animal welfare, as well as to more immediately apparent concerns regarding habitats and the quality of the marine environment.

Campagna, C., Falabella, V., & Lewis, M. (2007). Entanglement of Southern Elephant Seals in Squid Fishing Gear. *Marine Mammal Science, 23*(2), 414-418 https://doi.org/10.1111/j.1748-7692.2007.00105.x

Although southern elephant seals, Mirounga leonina, prey upon fish and squid species that are targeted by large commercial operations that overlap with their foraging range (Daneri and Carlini 2002, van den Hoff et al. 2002, Bradshaw et al. 2003 and references therein), direct interactions with fisheries have not been widely reported. Most of the available evidence concerns interaction with fisheries targeting toothfish, Dissostichus spp. (Slip 1995, McMahon et al. 2000, van den Hoffet al. 2002, Hindell et al. 2003). We report on the entanglement of southern elephant seals from coastal Patagonia, Argentina, in squid fishing gear (Fig. 1). To our knowledge, this is the first description ofa direct interaction of a squid commercial fishery with southern elephant seals.

Colmenero, A. I., Barría, C., Broglio, E., & García-Barcelona, S. (2017). Plastic Debris Straps on Threatened Blue Shark *Prionace Glauca*. *Marine Pollution Bulletin, 115*(1), 436-438 https://doi.org/10.1016/j.marpolbul.2017.01.011

Juveniles of blue shark *Prionace glauca* caught in pelagic longlines targeting tuna and swordfish in the Atlantic Ocean and the Mediterranean Sea were found entangled with plastic straps around their gill region. The plastic debris were identified as strapping bands and caused several degrees of injuries on the dorsal musculature and pectoral fins. They were also obstructing the gill slits probably causing breathing issues. These records were uploaded in the web site seawatchers.org, and highlight the potential of citizen science in revealing the occurrence of such problems which could help to measure the effects of plastic debris on marine life.

Croxall, J. P. (1990). Impact of Incidental Mortality on Antarctic Marine Vertebrates. *Antarctic Science, 2*(1), 1-1 https://doi.org/10.1017/s0954102090000013

No abstract.

Croxall, J. P., Rodwell, S., & Boyd, I. L. (1990). Entanglement in Man-Made Debris of Antarctic Fur Seals at Bird Island, South Georgia. *Marine Mammal Science, 6*(3), 221-233 https://doi.org/10.1111/j.1748-7692.1990.tb00246.x

Neck collars of man-made marine debris were seen on 208 Antarctic fur seals (and removed from 170) during the 142 days of the 1988-1989 pup-rearing season at Bird Island, South Georgia. This represents at least 0.1% of the total Bird Island population and a minimum of 0.4% of animals in the best covered areas; a maximum value might approach 1%. Polypropylene straps (packaging bands) formed 59% of collars, nylon string (16%), fishing net (13%) and six other materials comprised the rest. Males accounted for 71% of entanglements, 88% of which were of young (1-4 yr old) animals; females accounted for 64% of animals older than this. Obvious physical injury was being caused to 30% of animals and only on 19% of animals was the collar loose enough potentially to come off. The magnitude of the problem at South Georgia is similar to that with northern fur seals at the Pribilof Islands, where a significant population decline has occurred concurrently. Antarctic fur seals are still increasing in numbers but stricter controls on the jettisoning of debris into the Southern Ocean ate needed if the entanglement problem is not to increase beyond the level of a potential threat.

de Vere, A. J., Lilley, M. K., & Frick, E. E. (2018). Anthropogenic Impacts on the Welfare of Wild Marine Mammals. *Aquatic Mammals, 44*(2), 150-180 http://dx.doi.org/10.1578/AM.44.2.2018.150

Marine mammal welfare has most frequently been a topic of discussion in reference to captive animals. However, humans have altered the marine environment in such dramatic and varied ways that the welfare of wild marine mammals is also important to consider as most current publications regarding anthropogenic impacts focus on population-level effects. While the preservation of the species is extremely important, so too are efforts to mitigate the pain and suffering of marine mammals affected by noise pollution, chemical pollution, marine debris, and ever-increasing numbers of vessels. The aim of this review is to define welfare for wild marine mammals and to discuss a number of key anthropogenic effects that are currently impacting their welfare.

Fowler, C. W. (1987). Marine Debris and Northern Fur Seals: A Case Study. *Marine Pollution Bulletin, 18*(6, Supplement B), 326-335 https://doi.org/10.1016/S0025-326X(87)80020-6

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 approximately equals 0.4%, a level at least two orders of magnitude greater than observed in the 1940s. Mortality of fur seals due to entanglement in marine debris contributes significantly to declining trends of the population on the Pribilof Islands.

Franco-Trecu, V., Drago, M., Katz, H., Machín, E., & Marín, Y. (2017). With the Noose around the Neck: Marine Debris Entangling Otariid Species. *Environmental Pollution, 220*, 985-989 https://doi.org/10.1016/j.envpol.2016.11.057

Plastic debris in marine environments and its impact on wildlife species is becoming a problem of increasing concern. In pinnipeds, entanglements commonly consist of loops around the neck of non-biodegradable materials from fishing gear or commercial packaging, known as “neck collars”. These entanglements can cause injuries, death by suffocation and starvation, and therefore they may add to the overall decrease in population. Our objective was to describe the entanglement of two species of otariids (Arctocephalus australis and Otaria flavescens) in the South West Atlantic Ocean. These two species have widely different population sizes and contrasting trends, being the O. flavescens population one order of magnitude lower in abundance with a negative population trend. A total number of 47 entangled individuals and the ingestion of a fishing sinker were recorded (A. australis: n = 26; O. flavescens: n = 22). For A. australis about 40% of the objects came from industrial fishing with which this species overlap their foraging areas, although also its lost or discarded gear can travel long distances. In O. flavescens 48% of observed injuries were very severe, which might indicate that they had been entangled for a long time. More than 60% of the objects came from artisanal and recreational fishing that operates within 5 nautical miles off the coast, which is probably related to coastal foraging habits of this species. Due to the frequent interaction between artisanal fisheries and O. flavescens, it is possible that entangled nets could be active gears. An important contribution to mitigate entanglements can be the development of education programs setting the scenario for effective communication, and exchange with involved fishermen to collect and recycle old fishing nets. Returning to natural fibers or replacement of the current materials used in fishing gear for biodegradable materials can also be a recommended mitigation measure.

Hanni, K. D., & Pyle, P. (2000). Entanglement of Pinnipeds in Synthetic Materials at South-East Farallon Island, California, 1976–1998. *Marine Pollution Bulletin, 40*(12), 1076-1081 https://doi.org/10.1016/S0025-326X(00)00050-3

Entanglement records of hauled out pinnipeds are useful for monitoring trends in impacts of synthetic materials, a principal contaminant, upon pinniped populations. This report documents entanglement of five species (California Sea Lions, Northern Elephant Seals, Steller Sea Lions, Pacific Harbor Seals, and Northern Fur Seals) at South-east Farallon Island (SEFI), an island in Northern California, 1976–1998, when a total of 914 pinnipeds were observed entangled in or with body constrictions from synthetic material. There was a significant decrease in entangled Northern Elephant Seals over the study period. Of the 27 Steller Sea Lions observed entangled, 37% were adult Steller Sea Lions entangled in salmon fishing gear. This report highlights an ongoing problem of entanglement of pinnipeds in synthetic materials in Northern California.

Harcourt, R., Aurioles, D., & Sanchez, J. (1994). Entanglement of California Sea Lions at Los Islotes, Baja California Sur, Mexico. *Marine Mammal Science, 10*(1), 122-125 https://doi.org/10.1111/j.1748-7692.1994.tb00399.x

No abstract.

Henderson, J. R. (2001). A Pre- and Post-Marpol Annex V Summary of Hawaiian Monk Seal Entanglements and Marine Debris Accumulation in the Northwestern Hawaiian Islands, 1982–1998. *Marine Pollution Bulletin, 42*(7), 584-589 https://doi.org/10.1016/S0025-326X(00)00204-6

Entanglements of Hawaiian monk seals, *Monachus schauinslandi*, were documented in the northwestern Hawaiian Islands (NWHI) from 1982 to 1998, and debris which presented a threat of entanglement was inventoried and removed from 1987 to 1996. A total of 173 entanglements was documented. The number of entanglements did not change after implementation of MARPOL Annex V in 1989. Pups and juvenile seals were more likely to become entangled than older seals, and became entangled primarily in nets, whereas entanglement of subadults and adults was more likely to involve line. The subpopulation of seals at Lisianski Island experienced the most entanglements, although Lisianski did not accumulate the most debris. Localized high entanglement rates may gravely affect individual monk seal subpopulations. Accumulation of debris has not diminished since implementation of Annex V, nor has occurrence of derelict drift nets abated since a 1989 moratorium. Debris washing ashore has likely been circulating in the North Pacific Ocean for some time.

Hofmeyr, G. G., Bester, M. N., Kirkman, S. P., Lydersen, C., & Kovacs, K. M. (2006). Entanglement of Antarctic Fur Seals at Bouvetøya, Southern Ocean. *Marine Pollution Bulletin, 52*(9), 1077-1080 https://doi.org/10.1016/j.marpolbul.2006.05.003

Entanglements of Antarctic fur seals *Arctocephalus gazella* were recorded during four summers from 1996 to 2002 at the subantarctic island, Bouvetøya. Rates of entanglement varied between 0.024% and 0.059%. These rates are low for a pinniped population and might be because of the geographic isolation of the haulout site. An apparent decrease in the levels of entanglement over the course of the study was likely due, at least in part, to the removal of entanglements by observers. At least two-thirds of entangling materials were generated by fishery sources. Since there is no known local source of anthropogenic marine pollution, seals become entangled either in waters distant from the island, or when materials drift into local waters. Significantly more subadults were found entangled than expected from the postulated population age class distribution.

Hogan, E., & Warlick, A. (2017). Packing Bands Entangling Pinnipeds around the World: Global Review and Policy. *Journal of International Wildlife Law & Policy, 20*(1), 75-83 https://doi.org/10.1080/13880292.2017.1309869

No abstract.

Jepsen, E. M., & de Bruyn, P. N. (2019). Pinniped Entanglement in Oceanic Plastic Pollution: A Global Review. *Marine Pollution Bulletin, 145*, 295-305 https://doi.org/10.1016/j.marpolbul.2019.05.042

Oceanic plastic pollution is a growing worldwide environmental concern, endangering numerous marine species. Pinnipeds are particularly susceptible to entanglement, especially in abandoned, lost or discarded fishing gear and packaging straps. We searched three international databases to compile a comprehensive review of all reported pinniped entanglements over the last 40 years, with the aim to identify areas of concern and foci for mitigation. The majority of published records of entanglement emanate from North America and Oceania and are focused on a few populous species (notably, *Zalophus Californianus* and *Arctocephalus gazella*). Reporting bias, skewed research effort and incomplete understanding of plastic pollution and pinniped abundance overlap, combine to cloud our understanding of the entanglement problem. Broader geographical effort in entanglement data collection, reporting of such data, and improved quantification of the proportions of populations, sexes and ages that are most susceptible, will aid our efforts to pinpoint priority mitigation measures.

Kiyota, M., & Baba, N. (2001). Entanglement in Marine Debris among Adult Female Northern Fur Seals at St. Paul Island, Alaska in 1991-1999. [Arasuka shu Sentoporu tou ni okeru kitaottosei seiju mesu no kaiyo haikibutsu karamari, 1991-1999 nen]. *Bulletin. National Research Institute of Far Seas Fisheries*(38), 13-20 Retrieved from http://fsf.fra.affrc.go.jp/eng/index-e.htm

Sighting surveys of adult female northern fur seals were conducted at St. Paul Island, Alaska in 1991-1999 to monitor the incidence of entanglement in marine debris. Based on the counts of 244,225 individuals, average incidence of entangled females over the entire survey years was estimated at 0.013% and that of females with scars caused by previous entanglement was 0.029%. Trawl nets, monofilament gillnets, polypropylene packing bands, twines and lines and a plastic frame of laundry detergent box were observed entangled in female seals. Trawl nets were the most numerous, constituting 49% of the entangled debris. Annual incidence of entanglement was higher in 1991 and 1994, but was stabilized at around 0.01% after that. Composition of beach debris indicated recent decrease in trawl nets and packing bands and increase in ropes and lines, possibly related to the trends in commercial fisheries around the breeding island.

Laist, D. W. (1997). Impacts of Marine Debris: Entanglement of Marine Life in Marine Debris Including a Comprehensive List of Species with Entanglement and Ingestion Records. In *Marine Debris.* (pp. 99-139) https://doi.org/10.1007/978-1-4613-8486-1_10

Lost and discarded marine debris, particularly items made of persistent synthetic materials, is now recognized as a major form of marine pollution. This perception was a seminal finding of the 1984 International Workshop on the Fate and Impact of Marine Debris (Shomura and Yoshida 1985). A major factor leading to this conclusion was information on the nature and extent of interactions between marine debris and marine life gathered by researchers working independently in different ocean areas during the 1970s and early 1980s. Compiled for the first time at the 1984 workshop, the information highlighted two fundamental types of biological interactions: (1) entanglement, whereby the loops and openings of various types of debris entangle animal appendages or entrap animals; and (2) ingestion, whereby debris items are intentionally or accidentally eaten and enter the digestive tract.

Lawson, T. J., Wilcox, C., Johns, K., Dann, P., & Hardesty, B. D. (2015). Characteristics of Marine Debris That Entangle Australian Fur Seals (*Arctocephalus pusillus doriferus*) in Southern Australia. *Marine Pollution Bulletin, 98*(1), 354-357 https://doi.org/10.1016/j.marpolbul.2015.05.053

Marine debris is a global issue that can have devastating impacts on marine mammals. To understand the types of materials that result in entanglement and thus the potential impact of entangling items on marine wildlife, we analysed data collected from items in which Australian fur seals had been entangled in southern Victoria, Australia over a 15year period. From 1997 to 2012, 138 entangling items were removed from seals. The majority of these entanglements were plastic twine or rope, and seals were entangled in green items more than in any other colour. In general, younger seals were more likely to be entangled than adults. Understanding the effects of marine debris entanglement on the Australian fur seal population can lead to more effective management of the sources of debris and the wildlife that interact with it.

Mucientes, G., & Queiroz, N. (2019). Presence of Plastic Debris and Retained Fishing Hooks in Oceanic Sharks. *Marine Pollution Bulletin, 143*, 6-11 https://doi.org/10.1016/j.marpolbul.2019.04.028

In a context where the problem of plastic pollution is globally increasing, more studies are needed to assess the real impact in oceanic megafauna. Here, we reported on the incidence of plastic and also retained hooks in two species of commercially exploited pelagic sharks in two ocean basins, the North Atlantic and South Pacific. In the South Pacific, 1.18% of caught blue sharks were observed with plastic debris on their body and 4.82% and with retained hooks, while 0.00% of shortfin makos had plastic debris and 1.76% were recorded with retained hooks. In the North Atlantic, 0.21% of blue sharks had plastic debris and 0.37% of blue, and 0.78% of shortfin makos were observed with retained hooks.

Nicolau, L., Marçalo, A., Ferreira, M., Sá, S., Vingada, J., & Eira, C. (2016). Ingestion of Marine Litter by Loggerhead Sea Turtles, *Caretta caretta*, in Portuguese Continental Waters. *Marine Pollution Bulletin, 103*(1), 179-185 https://doi.org/10.1016/j.marpolbul.2015.12.021

The accumulation of litter in marine and coastal environments is a major threat to marine life. Data on marine litter in the gastrointestinal tract of stranded loggerhead turtles, *Caretta caretta*, found along the Portuguese continental coast was presented. Out of the 95 analysed loggerheads, litter was present in 56 individuals (59.0%) and most had less than 10 litter items (76.8%) and less than 5g (dm) (96.8%). Plastic was the main litter category (frequency of occurrence=56.8%), while sheet (45.3%) was the most relevant plastic sub-category. There was no influence of loggerhead stranding season, cause of stranding or size on the amount of litter ingested (mean number and dry mass of litter items per turtle). The high ingested litter occurrence frequency in this study supports the use of the loggerhead turtle as a suitable tool to monitor marine litter trends, as required by the European Marine Strategy Framework Directive.

Owen, H., Flint, J., & Flint, M. (2017). Impacts of Marine Debris and Fisheries on Sirenians. In *Marine Mammal Welfare: Human Induced Change in the Marine Environment and Its Impacts on Marine Mammal Welfare.* A. Butterworth (Ed.), (pp. 315-331). Cham: Springer International Publishing https://doi.org/10.1007/978-3-319-46994-2_18

Harmful marine debris includes land and ship-sourced waste and abandoned fishing gear from recreational and commercial fisheries; these forms of debris are making their way into waterways and oceans with increasing frequency. For sirenians, marine debris and fisheries pose a significant risk to their well-being through entanglement, ingestion and hunting, both legal and illegal, as well as through more indirect ways, such as changing social structures and creating orphans through loss of cohorts. This chapter addresses the welfare impacts of marine debris and fisheries on sirenians. It also explores the changes in attitude that are occurring in many of the stakeholders involved and how these are translating into positive outcomes.

Perez-Venegas, D. J., Valenzuela-Sánchez, A., Montalva, F., Pavés, H., Seguel, M., Wilcox, C., & C, G.-M. (2021). Towards Understanding the Effects of Oceanic Plastic Pollution on Population Growth for a South American Fur Seal (*Arctocephalus australis australis*) Colony in Chile. *Environmental Pollution*, 116881 https://doi.org/10.1016/j.envpol.2021.116881

Entanglement of pinnipeds with plastic debris is an emerging conservation and animal welfare issue worldwide. However, the origins and long-term population level consequences of these entanglements are usually unknown. Plastic entanglement could produce a combination of wounds, asphyxiation, or inability to feed that results in the death of a certain percentage of individuals from the total population. In this research, we report on the consequent effect of plastic entanglement on population growth demographics in a South American fur seal (*Arctocephalus australis australis*) colony on Guafo Island, southern Chile. Using a stochastic matrix population model structured according to age and sex, and assuming an otherwise stable population, we explored population growth rates under five scenarios with differing rates of entanglement: A) a zero rate of plastic entanglement, B) entanglement rates (number of entangled individuals as a proportion of the total number of individuals) as observed in our study population (overall entanglement ratio of 1.2×10^{-3}); and for the other scenarios, entanglement ratios as reported in the literature for other pinniped colonies around the world: C) 3.04×10^{-3}, D) 4.42×10^{-2}, and E) 8.39×10^{-2}. Over the 30 years forecasting period and starting with a population size of

~2950 individuals, the population growth rate was lower under all scenarios with rates of entanglement greater than zero (scenarios B-E). In comparison with scenario A, at the end of the 30-year period forecasted, we calculated a projected decrease in population size of between 20.34% (scenario B) and 91.38% (scenario E). These results suggest that even the lowest levels of entanglement in pinnipeds as reported in the literature might have significant effects over time on population-level dynamics. Our research offers potential insight when devising policy for the management and limitation of plastic pollution in the oceans, and indeed for the conservation and management policy of affected marine species. Furthermore, whilst there are some limitations to our methodology, it offers a straightforward and potentially useful approach for the standardized prediction of impacts at a population level of different rates of plastic pollution and entanglement and could be applied in distinct populations of the same species around the world.

Raum-Suryan, K. L., Jemison, L. A., & Pitcher, K. W. (2009). Entanglement of Steller Sea Lions (*Eumetopias jubatus*) in Marine Debris: Identifying Causes and Finding Solutions. *Marine Pollution Bulletin, 58*(10), 1487-1495 https://doi.org/10.1016/j.marpolbul.2009.06.004

Entanglement in marine debris is a contributing factor in Steller sea lion (SSL; *Eumetopias jubatus*) injury and mortality. We quantified SSL entanglement by debris type, sex and age class, entanglement incidence, and estimated population level effects. Surveys of SSL haul-outs were conducted from 20002007 in Southeast Alaska and northern British Columbia. We recorded 386 individuals of all age classes as being either entangled in marine debris or having ingested fishing gear. Packing bands were the most common neck entangling material (54%), followed by rubber bands (30%), net (7%), rope (7%), and monofilament line (2%). Ingested fishing gear included salmon fishery flashers (lures: 80%), longline gear (12%), hook and line (4%), spinners/spoons (2%), and bait hooks (2%). Entanglement incidence was 0.26% (SD = 0.0064, n = 69 sites). "Lose the Loop!" Simple procedures such as cutting entangling loops of synthetic material and eliminating the use of packing bands can prevent entanglements.

Spraker, T. R., & Lander, M. E. (2010). Causes of Mortality in Northern Fur Seals (*Callorhinus ursinus*), St. Paul Island, Pribilof Islands, Alaska, 19862006. *Journal of Wildlife Diseases, 46*(2), 450-473 https://doi.org/10.7589/0090-3558-46.2.450

To determine whether infectious diseases might have contributed to the present-day decline of northern fur seals (*Callorhinus ursinus*), preweaned pups (n52,735), subadult males (n598), and adults (n5179) were examined postmortem from 1986 to 2006 on St. Paul Island, Alaska. Gross necropsy findings and histologic lesions were used to determine causes of death. Five general categories of mortality were identified for pups: emaciation (1,454 pups, 53%), trauma (497 pups, 18%), perinatal mortality (516 pups, 19%), infectious diseases (82 pups, 3%), and miscellaneous causes (186 pups, 7%). A condition of unknown etiology characterized by multifocal necrotizing myopathy and cardiomyopathy was found in 92 pups. Thirty-three congenital anomalies were identified in 49 pups, including a rare multicentric ganglioneuroblastoma. General linear models were used to examine change in pup mortality and condition (i.e., pup mass) over time. The prevalence of perinatal mortality appeared to increase during the study and relative to past reports. Trauma and infectious conditions appeared to decrease slightly from 1986 to 2006. Although relatively stable during this investigation, emaciation was greater than that reported for past studies. Emaciated pups weighed less than expected during 1988, 1996, and 2004 and more than expected during 1987, 1989, 1990, and 1994 (P#0.003). Average annual weights for all other categories ofmortality did not change significantly from 1986 to 2006. Fatal conditions for subadult males included hyperthermia, blunt trauma, entanglement, and bite wounds; nonfatal conditions included seizures, orange discoloration of the blubber, neoplasia, and parasitism. Causes of mortality for most adults included bite wounds with cellulitis and secondary infections, pulmonary edema, dystocia, blunt trauma, and neoplasia. We found no evidence to implicate infectious diseases as a cause in the recent decline of northern fur seals.

Stewart, B. S., & Yochem, P. K. (1987). Entanglement of Pinnipeds in Synthetic Debris and Fishing Net and Line Fragments at San Nicolas and San Miguel Islands, California, 1978–1986. *Marine Pollution Bulletin, 18*(6), 336-339 https://doi.org/10.1016/s0025-326x(87)80021-8

Since 1978 we have documented cases of pinnipeds (northern elephant seals, California sea lions, harbour seals, northern fur seals) at San Nicolas and San Miguel islands that were entangled in various kinds of synthetic debris and fishing gear. In 1983 we began systematic surveys to quantify the incidence of entanglement and to examine the effects of entanglement-related mortality on the population growth of each species. The incidence of entanglement observed among pinnipeds that were hauled out at San Nicolas and San Miguel islands was greater from December 1984 through July 1986 (California sea lions, 0.16%; northern elephant seals, 0.16%; harbour seals, 0.09%) than it was from December 1983 through November 1984 (California sea lions, 0.08%; northern elephant seals, 0.15% harbour seals, 0.05%). However, only about one-half, or fewer, of the entangled California sea lions and northern elephant seals were evidently entangled in synthetic debris. Additional cases of entanglement were probably related to commercial fishing operations rather than to marine debris.

Trends in abundance of pinnipeds in Southern California have apparently not been significantly influenced by entanglement of individuals in marine debris. Juveniles may be the most susceptible to entanglement in debris and the effects of any recent declines in survival of younger age classes on trends in annual numbers of births may not be detectable for several years. Further studies are needed to document trends in debris-related entanglement and the effects of this entanglement on juvenile survival and subsequent recruitment.

Wade, P. R., Burkanov, V. N., Dahlheim, M. E., Friday, N. A., Fritz, L. W., Loughlin, T. R., . . . Clapham, P. J. (2007). Killer Whales and Marine Mammal Trends in the North Pacific—a Re-Examination of Evidence for Sequential Megafauna Collapse and the Prey-Switching Hypothesis. *Marine Mammal Science, 23*(4), 766-802 https://doi.org/10.1111/j.1748-7692.2006.00093.x

Springer et al. (2003) contend that sequential declines occurred in North Pacific populations ofharbor and fur seals, Steller sea lions, and sea otters. They hypothesize that these were due to increased predation by killer whales, when industrial whaling’s removal oflarge whales as a supposed primary food source precipitated a prey switch. Using a regional approach, we reexamined whale catch data, killer whale predation observations, and the current biomass and trends of potential prey, and found little support for the prey-switching hypothesis. Large whale biomass in the Bering Sea did not decline as much as suggested by Springer et al., and much of the reduction occurred 50–100 yr ago, well before the declines of pinnipeds and sea otters began; thus, the need to switch prey starting in the 1970s is doubtful. With the sole exception that the sea otter decline followed the decline of pinnipeds, the reported declines were not in fact sequential. Given this, it is unlikely that a sequential megafaunal collapse from whales to sea otters occurred. The spatial and temporal patterns ofpinniped and sea otter population trends are more complex than Springer et al. suggest, and are often inconsistent with their hypothesis. Populations remained stable or increased in many areas, despite extensive historical whaling and high killer whale abundance. Furthermore, observed killer whale predation has largely involved pinnipeds and small cetaceans; there is little evidence that large whales were ever a major prey item in high latitudes. Small cetaceans (ignored by Springer et al.) were likely abundant throughout the period. Overall, we suggest that the Springer et al. hypothesis represents a misleading and simplistic view of events and trophic relationships within this complex marine ecosystem.

Warlick, A. J., Duffield, D. A., Lambourn, D. M., Jeffries, S. J., Rice, J. M., Gaydos, J. K., . . . Norman, S. A. (2018). Spatio-Temporal Characterization of Pinniped Strandings and Human Interaction Cases in the Pacific Northwest, 1991-2016. *Aquatic Mammals, 44*(3), 299-318 http://dx.doi.org/10.1578/AM.44.3.2018.299

Pinniped strandings can be used as a proxy to evaluate the impacts of anthropogenic activities on the local marine environment. Stranding data from Oregon and Washington from 1991 to 2016 were used to examine regional and temporal patterns in strandings and human interaction cases across age and sex for six species. Over the study period, 14,729 pinnipeds were reported stranded along the coast in the Pacific Northwest, 11% of which were documented as human interaction cases. Total strandings and the number of reported human interaction cases increased over time for most species. The composition of age and sex classes varied for each species, as did the proportion of strandings identified as human interaction cases. Gunshot wounds and fisheries entanglements were concentrated in clusters along the coast and together constituted the majority of human interaction cases. Stranding and human interaction case hotspots were different across species and varied seasonally, likely due to the distribution of pinnipeds and human activities along the coast. Despite the challenges and uncertainties inherent in using stranding data as an indicator of pinniped health and anthropogenic impacts, modeling spatio-temporal patterns is useful for stranding response practitioners and natural resource managers when evaluating the scope and magnitude of threats to pinniped populations.

Section III: Seabirds

Hidalgo-Ruz, V., Luna-Jorquera, G., Eriksen, M., Frick, H., Miranda-Urbina, D., Portflitt-Toro, M., . . . Thiel, M. (2021). Factors (Type, Colour, Density, and Shape) Determining the Removal of Marine Plastic Debris by Seabirds from the South Pacific Ocean: Is There a Pattern? *Aquatic Conservation Marine and Freshwater Ecosystems, 31*(2), 389-407 https://doi.org/10.1002/aqc.3453

1. While floating near the sea surface plastic debris interacts with a number of external factors, including many different organisms. Seabirds have the most extensive documented history of interactions with plastics, through ingestion, entanglement, and nest construction.
2. In the present study, eight seabird species from the South Pacific Ocean were used as a proxy to determine potential patterns of removal of marine plastic debris, and three hypotheses were tested in relation to their feeding habits and nesting areas.

3. Plastics from abiotic compartments (Chilean continental coast, South Pacific Gyre, and Rapa Nui beaches) and biotic compartments (surface-feeding seabirds, diving seabirds, and nesting areas) were compared, according to their type, colour, shape, and density.
4. Continental beaches had a relatively wide range of colours and shapes, with many non-buoyant plastics. Samples from the South Pacific Gyre (SPG) and Rapa Nui (Easter Island) beaches comprised mainly hard, rounded, buoyant, and white/grey plastics.
5. These results indicate that the composition of floating plastics from terrestrial sources changes during transport with oceanic currents, reducing the proportion of prey-like plastics present in the subtropical gyres.
6. The stomach contents of surface-feeding and diving seabirds were dominated by hard, white/grey, and round plastic items, similar to plastics from the SPG, suggesting non-selective (accidental or secondary) ingestion.
7. Nesting areas had a more variable composition of brightly coloured plastics, suggesting a pattern of selective removal of plastics by seabirds, probably from oceanic sources.
8. The present study reveals extensive interactions of seabirds with plastics on a broader scale, which is highly relevant given that the impacts of plastics on seabirds are increasing worldwide, compromising their efficient conservation.

Ryan, P. G. (2018). Entanglement of Birds in Plastics and Other Synthetic Materials. *Marine Pollution Bulletin, 135*, 159-164 https://doi.org/10.1016/j.marpolbul.2018.06.057

Entanglement of animals is one of the main environmental impacts of waste plastic. A 2015 review of entanglement records found that the proportion of affected seabirds increased from 16% of species to 25% over the last two decades. However, this was restricted to published records; Google Images and other web-based sources indicate that at least 147 seabird species (36%), as well as 69 freshwater birds (10%) and 49 landbirds (0.5%) from 53 families have been entangled in plastic or other synthetic materials. Fishing gear is responsible for entangling most species (83%), although it is often difficult to differentiate entanglement from bycatch on active gear. Mitigation measures include banning high-risk applications where there are alternatives (e.g. six-pack rings), discouraging the use of high-risk items (e.g. balloons on strings, 'manja' kites), and encouraging fishers to not discard waste fishing gear by providing specific receptacles and associated educational signage in fishing areas.

Ryan, P. G. (2020). Using Photographs to Record Plastic in Seabird Nests. *Marine Pollution Bulletin, 156*, 111262 https://doi.org/10.1016/j.marpolbul.2020.111262

The incidence of plastic in seabird nests can be used to track changes in the amounts of marine debris, but large sample sizes are needed for accurate estimates. Surveys of active nests cause disturbance to breeding birds, so we need an efficient way to sample nest plastics. Photographs of brown noddy Anous stolidus nests at Ducie Atoll, southeast Pacific Ocean, allowed rapid characterisation of plastic use with limited disturbance, and showed selection for blue-green items. Plastic was more prevalent in noddy nests at Ducie Atoll (97%) than at Inaccessible Island, South Atlantic Ocean (41%), despite lower debris densities at Ducie. Differences in nesting habitat and the resultant availability of natural nesting material drive this difference in plastic loads. Using photographs to record plastic in seabird nests reduces disturbance to breeding birds and might decrease the risk of missing cryptic debris items. Photographs also provide a permanent record of pollution levels.

Section IV: Policy

Adam, R., & Schaffner, J. (2017). International Law and Wildlife Well-Being: Moving from Theory to Action. *Journal of International Wildlife Law & Policy, 20*(1), 84-100 https://doi.org/10.1080/13880292.2017.1315277

No abstract.

Convey, P., Barnes, D., & Morton, A. (2002). Debris Accumulation on Oceanic Island Shores of the Scotia Arc, Antarctica. *Polar Biology, 25*(8), 612-617 https://doi.org/10.1007/s00300-002-0391-x

The oceanic islands in the Southern Ocean can be considered amongst the remotest shores as, not only are they uninhabited (except for small research stations) and geographically isolated, but they are also enclosed by the oceanographic barrier of the Polar Frontal Zone. We survey island shores in the Scotia Arc mountain chain linking Antarctica to South America, including South Georgia, the South Sandwich archipelago and Adelaide Island off the west coast of the Antarctic Peninsula, and compare our findings to literature reports from two other Scotia Arc island groups (South Orkney and South Shetland archipelagos). The presence of marine pollution (in the form of beached debris) in this region is significant, both as a measure of man's influence on this isolated environment, and due to direct dangers posed to the fauna. This paper reports the results of surveys of beached marine debris at various times in the last decade for each island group. The majority (>70%) of the items recovered were anthropogenic in origin and most of these were synthetic (plastic or polystyrene). Debris densities varied from zero to 0.3 items m–1 but were typically lower than those reported from other regions of the globe. At some localities (South Georgia), marine-debris data showed a close relationship with local fishery activity, whilst at others (South Sandwich Islands) debris appeared to have a more distant origin. Unlike oceanic debris in warm (non-polar) water localities, there was no evidence of any colonisation by biota. Debris accumulation may provide a useful indirect measure of local fishery activity and compliance with CCAMLR regulations, as well as monitoring the state of the oceans and island shores.

Fonner, R., & Warlick, A. (2018). Marine Protected Resources on the U.S. West Coast: Current Management and Opportunities for Applying Economic Analysis. https://doi.org/10.25923/vprp-1507

The National Marine Fisheries Service (NMFS), also called NOAA Fisheries, manages both the listing and recovery of marine species under the Endangered Species Act (ESA) and the protection of marine mammals under the Marine Mammal Protection Act (MMPA). This report focuses on NOAA's West Coast Region, which includes marine resources in California, Oregon, Washington, and Idaho. The region is host to 46 ESA-listed species, or distinct population segments (DPSs),1 1 Under the U.S. Endangered Species Act, the listing unit for invertebrates is the taxonomic species; however, the listing unit for vertebrates includes species, subspecies, or distinct population segment. For Pacific salmon, the DPS equivalent is the evolutionarily significant unit, as described by Waples (1991). and over 30 species of marine mammals protected by the MMPA. Salmon and steelhead (salmonids, Oncorhynchus spp.) are at the forefront of marine protected resources (MPR) management in the West Coast Region, where 28 evolutionarily significant units (ESUs) of ESA-listed salmonids from six species are listed under the ESA. Other ESA-listed species in the region include killer whales (Orcinus orca), eulachon (Thaleichthys pacificus), yelloweye rockfish (Sebastes ruberrimus), bocaccio (Sebastes paucispinis), and green sturgeon (Acipenser medirostris).

Goverment of Western Australia. (18/05/2012). Ban on Possession of Plastic Bait Bands at Sea. Retrieved from http://www.fish.wa.gov.au/Pages/media_archive/Ban-on-possession-of-plastic-bait-bands-at-sea.aspx

No abstract.

Hogan, E., & Warlick, A. (2017). Packing Bands Entangling Pinnipeds around the World: Global Review and Policy. *Journal of International Wildlife Law & Policy, 20*(1), 75-83 https://doi.org/10.1080/13880292.2017.1309869

No abstract.

Karasik, R., Vegh, T., Diana, Z., Bering, J., Caldas, J., Pickle, A., . . . Virdin, J. (2020). *20 Years of Government Responses to the Global Plastic Pollution Problem: The Plastics Policy Inventory.* Duke University Durham, NC:. Retrieved from https://nicholasinstitute.duke.edu/sites/default/files/publications/20-Years-of-Government-Responses-to-the-Global-Plastic-Pollution-Problem-New_1.pdf

Plastic pollution in the ocean is a global problem that requires cooperation from a wide range of groups (e.g., governments, producers, consumers, researchers, civil society). However, by virtue of their core regulatory powers, governments have a critical role to play in helping to solve this problem. This study aims to synthesize the policy response of governments to the global plastic pollution problem, as a basis for more rigorous monitoring of progress (as called for in Resolution 4/6 of the 2019 United Nations Environment Assembly (UNEA) meeting) and to inform future public policies.

The scope of the study is limited to public policies introduced during the period from January 2000 to July 2019, prior to the onset of the COVID-19 pandemic. As governments mobilize to respond to the pandemic, certainly these policies may change, so that this study may provide a baseline for "beforeafter" comparisons. Additionally, the scope of this study is limited to those polices explicitly aiming to reduce plastic leakage. At the same time, generally applicable waste management policies are considered to be fundamental to addressing the problem, even if they are not explicitly intending to do so (i.e., they were not designed at least partially in response to the problem of leakage of plastic into the ocean). For the purpose of this study, the current and future trends in these generally applicable policies are considered as part of the baseline or business-as-usual scenario, unless they have been amended or adjusted explicitly to respond to the plastic pollution problem. This study aims to identify and characterize the additional response from governments, which in combination with general waste management policies, equals the total possible government response to the marine plastic pollution problem.

Lang, G. E. (1990). Plastics, the Marine Menace: Causes and Cures. *Journal of Land Use & Environmental Law, 5*(2), 729-752 Retrieved from http://www.jstor.org/stable/42842563

No abstract.

Perez-Venegas, D., Pavés, H., Pulgar, J., Ahrendt, C., Seguel, M., & Galbán-Malagón, C. J. (2017). Coastal Debris Survey in a Remote Island of the Chilean Northern Patagonia. *Marine Pollution Bulletin, 125*(1), 530-534 https://doi.org/10.1016/j.marpolbul.2017.09.026

Global marine litter pollution is increasing dramatically, and oceanic islands are one of the most vulnerable ecosystems due to their high debris accumulation rate compared to continental sites. Remote areas, such as inhabited islands, represent a perfect study case to track marine debris sources, due to the assumed low rates of local production of debris. Guafo Island is one of the largest islands of the Chilean Northern Patagonia and is considered a remote zone. The accessible coast of Guafo Island was monitored during four austral summers revealing higher levels of marine debris accumulation than continental Chile. Plastic was the most abundant type of debris constituting 50% of the total litter monitored. Our results suggest that most of the plastic identified is likely to be related to local fisheries activities. Mitigation measures including collaboration among fishing communities and scientists could contribute to reduce the coastal debris pollution in remote areas.

Smith, W. (2018). *Plastic Strapping Bands & the Ban Case Study*. Tangaroa Blue Foundation Retrieved from https://southwestsnapshot.com.au/wp-content/uploads/2018/07/SW-SShot-CS-PLASTIC-STRAPPING-BANDS-FINAL_20180720.pdf

No abstract.

Topping, P., Morantz, D., & Lang, G. (1997). Waste Disposal Practices of Fishing Vessels: Canada's East Coast, 1990–1991. In *Marine Debris.* (pp. 253-262) https://doi.org/10.1007/978-1-4613-8486-1_22

No abstract.

Walker, T. R., Grant, J., & Archambault, M. C. (2006). Accumulation of Marine Debris on an Intertidal Beach in an Urban Park (Halifax Harbour, Nova Scotia). *Water Quality Research Journal of Canada, 41*(3), 256-262 Retrieved from https://iwaponline.com/wqrj/article/41/3/256/39831/Accumulation-of-Marine-Debris-on-an-Intertidal

This study evaluated monthly accumulation rates and types of marine debris washed ashore at a recreational beach in Point Pleasant Park, Halifax Harbour, between April and September 2005. Black Rock Beach is 70 m long and a total of 2129 marine debris items were collected and sorted, representing a mean accumulation rate of 355 (+/- 68 SE) items month(-1). The total weight of debris items was only 10.8 kg (mean 2 kg +/- 0.4 SE), however eighty-six percent of this debris was plastic material. The types of litter found included: tampon applicators, condoms (i.e., sewage-related debris [SRD]); plastic fast food packaging, confectionary wrappers, Styrofoam fragments, plastic bottles and caps, items of clothing, soft drink cans, cigarettes and cigarette holders (i.e., recreational or land-based debris); packing bands, nylon rope and nets (i.e., shipping- or fishing-related debris). These items were generated by recreational use of the park (52%), sewage disposal (14%) and from shipping and fishing activities (7%). It is suggested that a significant reduction in marine debris at recreational beaches may arise by improving public awareness of the environmental and aesthetic impacts of marine litter and future improvements to the municipal sewage disposal system.

Whitehead, J. R. (1988). *Reducing Plastic Pollution in the Marine Environment: The U.S. Coast Guard and Implementation of Annex V of Marpol 73/78.* Paper presented at the OCEANS '88. 'A Partnership of Marine Interests'. Proceedings. https://doi.org/10.1109/OCEANS.1988.794993

This paper explores the U.S. Coast Guard's efforts to reduce ocean pollution by plastics and other ship-gener&ed refuse. Implementation of Annex V of the International Convention for the Prevention of Pollution by Ships, 1973 (MARPOL 73/78) will outlaw dumping of plastics at sea from vessels of signatory nations. It will also severely restrict vessels from discharging other types of garbage at sea and will require nations which are party to the Convention to provide adequate reception facilities for ships' refuse. This paper discusses the problems caused by shipgenerated garbage and traces the Coast Guard's role in reducing marine pollution through MARPOL 73/78 and particularly through Annex V.

Yokota, K., Minami, H., & Kiyota, M. (2011). Effectiveness of Tori-Lines for Further Reduction of Incidental Catch of Seabirds in Pelagic Longline Fisheries. *Fisheries Science, 77*(4), 479-485 https://doi.org/10.1007/s12562-011-0357-4

To improve the performance of tori-lines (bird-scaring lines) in reducing incidental catch of large seabirds (albatrosses and giant petrels) in the pelagic longline fishery, we analyzed factors affecting the performance of tori-lines based on data collected by Japanese scientific observers in the southern bluefin tuna Thunnus maccoyii fishery from 2002 to 2005. We classified the variety of tori-lines by the main tori-line length and the streamer type. Two types of streamers were identified: type A, several long streamers made of nylon cord attached to the main tori-line by metal swivels; type B, many short streamers made of polypropylene packing bands braided into the main tori-line. In a model analysis, we found that the main tori-line length was an important factor affecting tori-line performance, and the two types of streamers had similar effectiveness. Since the light type B streamer has the advantage of practical feasibility, this type can be another option for use in tori-lines if used with a main tori-line of sufficient length.

Section V: Alternatives & Technology

Athanasopoulou, K. P. (2015). *Benthic Plastic Debris in Ionian Sea. How Long until They Degrade?.* University of Patras, Retrieved from http://hdl.handle.net/10889/11775

The ecological problems related to environmental pollution by synthetic polymers like plastics are one of the major concerns of the present days; especially because the degradation rate of the polymers is significally slow, which makes them extremely persistent. Understanding the surface alteration of plastics while in the marine environment assists to the understanding of the interaction between pollutant and plastic debris and estimating the duration of their existence in the marine environment. In the present study, polyethylene terephthalate bottles were collected from a submarine environment and analyzed with respect to environmental degradation. In order to estimate the period of existence of PETs in the marine environment, a temporal indication was used. Additionally, surface properties, for instance surface functional groups and surface topography are important indicators for the purpose of observing the degradation of plastic. A significant decrease in Fourier transform infrared peaks for eroded PETs were recorded; some native functional groups even disappear; or new -not typical for PETs- are created. Simultaneously, degraded PET surface was rough, uneven and occasionally, colonized by microorganisms. These surface properties were obtained due to degradation and could be used to explain the interaction between plastics, microorganisms and pollutants. Ultimately, the present research shows that plastic still exists for many decades after its generation. PET was found to degrade very slowly, as at least a decade is needed until the formation of a new chemical surface which would interact with pollutants or microorganisms.

Jeremic, S., Milovanovic, J., Mojicevic, M., Skaro-Bogojevic, S., & Nikodinovic-Runic, J. (2020). Understanding Bioplastic Materials - Current State and Trends. *Journal of the Serbian Chemical Society, 85*(12), 1507-1538 https://doi.org/10.2298/jsc200720051j

Plastic pollution is now considered one of the largest environmental threats facing humans and animals globally. Development of bioplastic materials may offer part of the solution as bioplastics include both nondegradable and biodegradable materials with both being important for sustainability. Bioplastic materials are currently being designed to encompass minimal carbon footprint, high recycling value and complete biodegradability. This review examines recent developments and trends in the field of bioplastic materials. A range of the most utilized bioplastic materials is presented (poly(lactic acid) (PLA), polyhydroxyalkanoate (PHA), starch, cellulose, bio-based poly(butylene succinate) (bio-PBS) and bio-polyethylene (bio-PE)) including their production, application and degradation options.

Karan, H., Funk, C., Grabert, M., Oey, M., & Hankamer, B. (2019). Green Bioplastics as Part of a Circular Bioeconomy. *Trends in Plant Science, 24*(3), 237-249 https://doi.org/10.1016/j.tplants.2018.11.010

The rapid accumulation of plastic waste is driving international demand for renewable plastics with superior qualities (e.g., full biodegradability to CO2 without harmful byproducts), as part of an expanding circular bioeconomy. Higher plants, microalgae, and cyanobacteria can drive solar-driven processes for the production of feedstocks that can be used to produce a wide variety of biodegradable plastics, as well as bioplastic-based infrastructure that can act as a long-term carbon sink. The plastic types produced, their chemical synthesis, scaled-up biorefinery concepts (e.g., plant-based methane-to-bioplastic production and co-product streams), bioplastic properties, and uses are summarized, together with the current regulatory framework and the key barriers and opportunities.

Liu, Y., Huang, J., Jin, J., Lou, S., Shen, C., Zang, H., & Wang, L. (2020). The Classification of Micro-Plastics and Biodegradation of Plastics/Micro-Plastics. *Academic Journal of Engineering and Technology Science, 3*(6) https://doi.org/10.25236/AJETS.2020.030618

Plastic wastes have been accumulated in the environment, and these plastics finally fragmented into smaller debris. There are three common standards used to classify micro-plastics, which are diameters, origins (primary or secondary), and monomers. In addition, various techniques and methods are applied to examine the changes before and after biodegradation. This paper also introduces several methods used to improve the efficiency of biodegradation. In the end, there is a summary about some progresses of biodegradation of plastics/micro-plastics.

Murray-Smith, R. (2020). How to Make a Seaweed Bioplastic - the Basics. Retrieved from https://youtu.be/7BMtchgejK0

No abstract.

Paper Strapping – the Alternative to Plastic Strapping. (2020). Retrieved from https://www.maxpack.co.uk/paperstrap-recyclable-strapping-warehouse-paperstrapping/

No abstract.

Pegram, J. E., & Andrady, A. L. (1989). Outdoor Weathering of Selected Polymeric Materials under Marine Exposure Conditions. *Polymer Degradation and Stability, 26*(4), 333-345 https://doi.org/10.1016/0141-3910(89)90112-2

Several types of thermoplastic and latex rubber materials commonly encountered in marine plastic debris were weathered in air and while floating in sea water, under North Carolina climatic conditions. The degradation of the different samples was monitored by tensile property determination.

In general, the various materials tested tended to weather at a slower rate when exposed in sea water compared to that in air. This retardation of weathering is probably a result of lack of heat build-up in samples exposed at sea.

ScienceLuxembourg. (2016). Make Your Very Own Bioplastic Bowl! Retrieved from https://youtu.be/8nxuO3SjMQM

No abstract.

Seaweed Packaging. Retrieved from https://seaweedpackaging.com/seaweed-packaging-products/

No abstract.

Singh, N., Ogunseitan, O. A., Tang, Y., & Wong, M. H. (2021). *Preventing Petrochemical Plastics Pollution: Sustainable Material Alternatives*. engrXiv. Retrieved from https://doi.org/10.31224/osf.io/xemny

Achievement of some of the United Nation's Sustainable Development Goals will not be possible if global trends in pollution associated with petrochemical-based plastics continue. Alternatives to petrochemical plastics have been researched intensely, but they have not been developed to replace current plastic products in a commercially viable way. The demand for single-use plastic personal protective equipment created by the COVID-19 pandemic has stimulated urgency in developing pollution prevention strategies that transcend reliance on highly variable consumer behavior. Biological material plastics are potentially sustainable because their manufacture utilizes renewable resources, and they are biodegradable. In this paper, challenges facing the sustainable management of discarded single-use petrochemical plastics are discussed, and a material lifecycle perspective is proposed that would be integrated into a circular economy of biological plastics. Preventing petrochemical plastics pollution requires a shift to fossilfree feedstock and energy and the design of biopolymers with desired properties. In this work, strategies for improving the performance and recyclability of biological plastics by designing polymers with diversified functionalities are presented.

wikiHow Staff. (2020). How to Make Bioplastic. Retrieved from https://www.wikihow.com/Make-Bioplastic#Using-Gelatin-or-Agar

A bioplastic is a type of plastic that can be made from plant starches or gelatins/agars. They are better for the environment because they are not derived from petroleum. They can also be easily made at home with a few simple ingredients and a stove!

Ye, S., & Andrady, A. L. (1991). Fouling of Floating Plastic Debris under Biscayne Bay Exposure Conditions. *Marine Pollution Bulletin, 22*(12), 608-613 https://doi.org/10.1016/0025-326X(91)90249-R

Six plastic/rubber materials commonly encountered in marine debris and beach litter were studied under Biscayne Bay (Florida, USA) exposure conditions to determine the effect of fouling on buoyancy. Studies under restricted floating, and restricted submerged exposure conditions suggest that most plastic samples undergo fouling to an extent to cause the sample to be negatively buoyant in sea water. Rapid defouling of the submerged fouled samples was observed. The findings suggest that free-floating plastics at sea may, under certain conditions, undergo fouling-induced sinking followed by resurfacing as floating debris.