Ship-based Marine Plastic Litter

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Background & Scope

Under the International Convention for the Prevention of Pollution from Ships (MARPOL), the discharge of plastics into the sea is prohibited (Annex-V 1988). Pursuant to this regulation, governments are also required to ensure adequate port reception facilities to receive ship waste. Furthermore, the London Convention of 1972 and Protocol of 2006 limit material that can be dumped at sea. Recognizing the need to do more in the area of ship-based marine plastic litter, the International Maritime Organization's Marine Protection Committee (MEPC) adopted an action plan to enhance existing regulations in support of reducing marine plastic litter from ships in October of 2018. This bibliography was developed in support of the NOAAs work on this action plan. While there is an abundance of literature on plastics in the marine environment, this bibliography is focused on ship-based litter. Due to the nature of the issue and the evolution in regulations, technology, and management, there was no limitations set on publication date.

Section I – Analysis and Estimates

This section is focused on material which provides analysis and estimates of ship-based marine plastic litter. It includes articles on debris analysis from beach litter, ships' litter management behavior, identifying ship-based litter, and reports which provide analysis of other contributors such as hull scrapings and container loss.

Section II – Impact of Ghost Fishing Gear

On the topic of ship-based plastic litter, literature on issues surrounding abandoned, lost, or discarded fishing gear represents a large percent of the research. This section is focused on the literature that describes the effect of lost gear including ghost fishing, catch rate estimates, environmental and socioeconomic impacts.

Section III – Port Waste Reception

This section is focused on literature related to port waste management systems and the reception facilities that are required under MARPOL. Literature in this area is a mix of guidelines, analysis of trends, practices, and impact reports.

Section IV – Ship-based Plastic Waste Reduction Strategies

This section is focused on literature in which the author(s) have worked to develop a strategy to reduce ship-based plastic litter. These strategies range from legal strategies to incentives, planning, technologies, and general approaches.

Sources Reviewed

The following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded and Social Science Index; ProQuest's Science and Technology; JSTOR; EBSCO's Academic Search Complete, EconLit, and Environment Complete; NOAA's Institutional Repository; ASFA; and BioOne. A review of UNEP, NOAA, IMO, and other relevant organizations both governmental and NGO was also conducted identify relevant literature. Only English language materials were included.

Section I: Analysis and Estimates

Al-Shwafi, N. A. A., & Ahmed, A. M. (2011). Litter on the Beaches of the Red Sea of Yemen. *Russian Journal of General Chemistry, 81*(13), 2717-2723 https://doi.org/10.1134/S1070363211130135.

Distribution of litter: ropes, netting, lamb bulbs, foot wear, plastic bags, bottles, aluminum cans, cardboard, wood loges, rubber, polystyrene blocks and plastic sheets accumulating on Red Sea beaches of Yemen were examined. The results of the study reflected these wastes to be varied from a region to region but they were similar in almost all-coastal areas. Most of the litter were plastics including food bags, oil and water bottles, bait bags, and also vehicles tires. Most of pollution occurred from the sea, due to the heavy traffic and to the fishing vessels, which fish in the area.

Barnett, F. G. J. (1997). Shipping and Marine Debris in the Wider Caribbean: Answering a Difficult Challenge. In J. M. Coe & D. B. Rogers (Eds.), *Marine Debris: Sources, Impacts, and Solutions* (pp. 219-227). New York, NY: Springer New York https://doi.org/10.1007/978-1-4613-8486-1_18.

Marine debris, a global pollution problem, is especially serious for the Wider Caribbean, a region of more than three dozen diverse states and territories renowned for its fragile, natural beauty. In this developing region, already beset with a dense resident population (Table 14.1), beauty makes tourism the number-one source of foreign exchange. Fueled by the burgeoning coastal populations and exacerbated by booming tourism, the marine debris problem is magnified in the Wider Caribbean, with more and more people generating more and more garbage, much of it finding its way to the sea.

Blidberg, E., Bekken, A. L., Bäckström, A., Haaksi, H., Hansen, L.-M., Skogen, M. H., . . . Ångström, J. (2015). *Marine Littering and Sources in Nordic Waters.* TemaNord produced for: Nordic Council of Ministers. Copenhagen. https://doi.org/10.6027/TN2015-524

Marine litter is a global environmental problem that endangers wildlife and has great socio-economic and aesthetic impacts. To identify sources of marine litter is an important key in order to propose cost-effective measures. Pick analyses of beach litter have therefore been conducted in order to categorise litter items from a product perspective. The results confirm that plastic are the most common litter material found on beaches in the Nordic countries. Short life items and packaging are dominating, which is strongly linked to individual consumers. It is further concluded that the plastics and packaging industry has an important role to play to decrease the amount of marine litter.

Butt, N. (2007). The Impact of Cruise Ship Generated Waste on Home Ports and Ports of Call: A Study of Southampton. *Marine Policy, 31*(5), 591-598 https://doi.org/10.1016/j.marpol.2007.03.002.

Cruise ships represent less than 1% of the global merchant fleet yet it has been estimated that they are responsible for 25% of all waste generated by merchant vessels. This volume of waste produces pressures on the environment, particularly with respect to ship-generated waste disposal at home ports and ports of call. Southampton, home port for both Cunard and P&O, and a port of call for Royal Caribbean Cruises, is the focus of this study. This paper investigates current waste management and disposal options for cruise ship generated waste and the associated impacts of this waste for ports. It is concluded that all cruise vessels should vigorously pursue a waste reduction strategy and for ports to

provide adequate recycling, reduction and re-use facilities for cruise ship generated waste, optimising use of local facilities whenever possible.

Cantin, J., Eyraud, J., & Fenton, C. (1990). *Quantitative Estimates of Garbage Generated and Disposal in the U.S. Maritime Sectors before and after MARPOL Annex V.* NOAA-TM-NMFS-SWFSC-154. Retrieved from https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-154_P119.PDF

Annex V of MARPOL 73/78 is regarded as an important instrument for reducing the amounts of plastics and other debris discarded into the ocean. Estimates of the aggregate quantities of garbage discarded are outdated, however, and represent only order of magnitude efforts. In this paper, the authors present updated estimates of the amounts of plastics and other debris generated in the U.S. maritime sectors. The analysis covers both public and private sectors, including merchant marine vessels active in U.S. trade; commercial fishing vessels; recreational boats; research and industrial vessels; U.S. Navy, Coast Guard, and Army ships; and vessels and structures associated with offshore oil and gas operations. Current disposal practices as well as disposal practices under Annex V are analyzed and used to develop estimates of how the disposition of garbage generated at sea, i.e., the amounts dumped overboard, brought back to shore for disposal, and incinerated, will change under the new regulations.

Čulin, J., & Bielić, T. (2016). Plastic Pollution from Ships. *Pomorski zbornik, 51* Retrieved from https://hrcak.srce.hr/index.php?show=toc&id_broj=12426

The environmental impact of shipping on marine environment includes discharge of garbage. Plastic litter is of particular concern due to abundance, resistance to degradation and detrimental effect on marine biota. According to recently published studies, a further research is required to assess human health risk. Monitoring data indicate that despite banning plastic disposal at sea, shipping is still a source of plastic pollution. Some of the measures to combat the problem are discussed.

Driedger, A. G. J., Durr, H. H., Mitchell, K., & Van Cappellen, P. (2015). Plastic Debris in the Laurentian Great Lakes: A Review. *Journal of Great Lakes Research, 41*(1), 9-19 https://doi.org/10.1016/j.jglr.2014.12.020

Pollution by plastic debris is an increasing environmental concern in the Laurentian Great Lakes where it affects open-water, shoreline, and benthic environments. Open-water surveys reveal that in certain areas of the Great Lakes, surface water densities of plastics are as high as those reported for areas of litter accumulation within oceanic gyres. Data from volunteer beach cleanups show that typically more than 80% of anthropogenic litter along the shorelines of the Great Lakes is comprised of plastics. The distribution of plastics in bottom sediments of the Great Lakes is essentially unknown. Sources of plastic debris to the Great Lakes include microplastic beads from consumer products, pellets from the plastic manufacturing industry, and waste from beach-goers, shipping, and fishing activities. Many plastics degrade slowly in the environment and may have long-term adverse ecological and economic impacts, including the dispersal of persistent organic pollutants. Plans to combat and curtail plastic debris pollution in the Great Lakes will come at a significant economic cost, likely in excess of $400 million annually. Here, we review the current state of knowledge on plastic pollution in the Great Lakes, identify knowledge gaps, and suggest future research directions.

Earl, R. C., Williams, A. T., & Tudor, D. T. (2000). *Pilot Project to Establish Methodologies and Guidelines to Identrify Marine Litter from Shipping.* Coastal Management for Sustainability, produced for: The Maritime and Coastguard Agency. Retrieved from www.globalgarbage.org/MALITA_6_ML_from_Shipping_2000_by_UKMCA.pdf

The overall aims of the Maritime and Coastguard Agency (MCA) are to developm promote and enforce high standards of maritime safety and pollution prevention; to minimise the loss of life among seafarers and coastal users, and to minimise pollution from ships to sea and coastline. One of its supporting objectives is "to develop, monitor, review and enforce pollution prevention policies and standards". The aim of this project was to produce a pragmatic robust methodology to assest the prevention of litter pollution from shipping.

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*(11-12), 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.

Fleet, D. M., Dau, K., Gutow, L., Schulz, M., Unger, B., & Franeker, J. A. v. (2017). *Marine Litter.* Common Wadden Sea Secretariat, Retrieved from https://qsr.waddensea-worldheritage.org/reports/marine-litter

The results from the various investigations and monitoring programmes presented in this report demonstrate the continuous and widespread occurrence of litter in the Wadden Sea and adjacent offshore waters. Marine litter of different sizes and from diverse sources occurs on dunes and beaches, in and on inter- to subtidal sediments and in marine organisms, including protected seabirds and mammals. The OSPAR Beach Litter Monitoring and Monitoring on Litter in Fulmars' Stomachs provide an evaluation of the temporal development of litter abundance in the southern North Sea. Both programmes clearly show that litter densities have not declined since the last Wadden Sea QSR in 2009, indicating that large amounts of litter are still entering the marine environment either directly within the Wadden Sea or from adjacent waters. The amount of litter entering the marine environment is continuously increasing

Franeker, J. A. v., Meijboom, A., Jong, M. d., & Verdaat, H. (2009). *Fulmar Litter Ecoqo Monitoring in the Netherlands 1979 2007 in Relation to EU Directive 2000/59/Ec on Port Reception Facilities.* IMARES Report number C032/09. Retrieved from http://edepot.wur.nl/143301

Operational and cargo related wastes from ships are an important source of litter in the marine environment in the southern North Sea and cause serious economical and ecological damage. Inadequacies in the ship to shore waste delivery procedures are considered a major factor in illegal discharges. The European Union therefore addressed the problem with the Directive on Port Reception Facilities (Directive 2000/59/EC). Obligatory waste delivery to shore and indirect financing of the costs are key elements of the Directive to stimulate and enforce proper disposal of shipwaste in harbours. Monitoring the effect of the EU Directive is required.

Golik, A. (1997). Debris in the Mediterranean Sea: Types, Quantities, and Behavior. In J. M. Coe & D. B. Rogers (Eds.), *Marine Debris: Sources, Impacts, and Solutions* (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.

Hammer, J., Kraak, M. H. S., & Parsons, J. R. (2012). Plastics in the Marine Environment: The Dark Side of a Modern Gift. In D. M. Whitacre (Ed.), *Reviews of Environmental Contamination and Toxicology* (pp. 1-44). New York, NY: Springer New York https://doi.org/10.1007/978-1-4614-3414-6_1

Plastics are one of the most widely used materials in the world; they are broadly integrated into today's lifestyle and make a major contribution to almost all product areas. The typical characteristics that render them so useful relate primarily to the fact that they are both flexible and durable. These characteristics are very useful when plastics are used in everyday life. But when plastics are discarded into the environment they can persist for very long periods of time. Because of their nearly indestructible morphology and the toxins they contain, plastics can seriously affect ecosystems (UNEP 2005).

Hansen, L.-M., Skogen, M. H., Frandsen, B. L., Thernström, T., & Ångström, J. (2015). *Marine Littering and Sources in Nordic Waters.* TemaNord produced for: Nordic Council of Ministers https://doi.org/10.6027/TN2015-524

Marine litter is a global environmental problem that endangers wildlife and has great socio-economic and aesthetic impacts. To identify sources of marine litter is an important key in order to propose cost-effective measures. Pick analyses of beach litter have therefore been conducted in order to categorise litter items from a product perspective. The results confirm that plastic are the most common litter material found on beaches in the Nordic countries. Short life items and packaging are dominating, which is strongly linked to individual consumers. It is further concluded that the plastics and packaging industry has an important role to play to decrease the amount of marine litter.

Hardesty, B. D., Lawson, T., van der Velde, T., Lansdell, M., & Wilcox, C. (2017). Estimating Quantities and Sources of Marine Debris at a Continental Scale. *Frontiers in Ecology and the Environment, 15*(1), 18-25 https://doi.org/10.1002/fee.1447

Marine debris is recognized as an important global issue that can negatively affect wildlife, habitats, environmental processes, ecosystem services, and human activities including tourism, fishing, and navigation. To improve understanding of the sources and impacts of marine debris, we carried out a national litter survey at 175 sites around Australia using a stratified random sampling approach. Litter from land- and sea-based sources is ubiquitous, and sampling effects related to coastline shape, substrate characteristics, gradient, and backshore type were highly significant. Source effects related to land-based sources (eg population density and distance to road) were also highly significant. Of the total debris sampled, approximately 75% was plastic; 2% was related to recreational fishing. Litter density significantly increased with proximity to urban areas, suggesting a domestic origin; statistical patterns suggest that illegal rubbish disposal is a major driver. By quantifying debris at a large scales and distinguishing potential litter sources, we can better develop scale-appropriate solutions to reduce debris inputs to the environment.

Horsman, P. V. (1982). The Amount of Garbage Pollution from Merchant Ships. *Marine Pollution Bulletin, 13*(5), 167-169 https://doi.org/10.1016/0025-326x(82)90088-1

The content of ships' waste was analysed on two merchant vessels. The results show a large amount of unnecessary garbage pollution by ships. The disposal at sea of plastic materials, and of all garbage except food waste in certain special areas, is against the Inter-Governmental Marine Consultative

Organization (IMCO) 1973 regulations. Ships are ignoring these regulations. The garbage can be a hazard to man and wildlife, apart from being aesthetically displeasing. It is recommended that more responsibility be put with the shipping companies, owners and suppliers to stop this pollution.

International Maritime Organization. (2016). *Review of the Current State of Knowledge Regarding Marine Litter in Wastes Dumped at Sea under the London Convention and Protocol.* Office for the London Convention/Protocol and Ocean Affairs. Retrieved from http://www.imo.org/en/OurWork/Environment/LCLP/newandemergingissues/Pages/default.aspx

As one of the partners in the UNEP-led Global Partnership for Marine Litter (GPML), IMO is co-leading efforts on sea-based sources of marine litter together with FAO. Within the framework of this partnership, the Secretariat was able to allocate GPML funding to commission a study on marine litter in relation to the various waste streams under the London Convention and Protocol. In January 2015, a consultant was contracted to carry out this study. A draft report, prepared by the consultant was reviewed by the Scientific Groups in May 2015. The main objective of the study is to provide an overview of the current state of knowledge regarding litter/plastics in wastes dumped at sea and their possible implication in relation to the London Convention and Protocol (LC/LP). It should be noted that the purpose of the report is to serve as a starting point for discussions on the nature and extent of litter (in particular plastics) in the waste streams under the LC/LP. It does not claim to be a complete review of these aspects, but will hopefully stimulate further discussions, both in relation to the LC/LP and within the wider global community.

International Maritime Organization. (2019). *Hull Scrapings and Marine Coatings as a Source of Microplastics.* Retrieved from http://www.imo.org/en/OurWork/Environment/LCLP/newandemergingissues/Pages/default.aspx

Through a recent report, the International Union for the Conservation of Nature (IUCN) identified hull scrapings, marine coatings and anti-fouling systems as potential sources of microplastics to the oceans. The impacts of marine plastics and microplastics upon species and communities are increasingly recognised with concomitant regulation and public attention. Accordingly, through its mandate on the protection of the marine environment from shipping operations, the International Maritime Organization (IMO) conducted a literature review to assess current knowledge and data regarding marine coatings as microplastics sources. This study identified important data gaps and made suggestions for subsequent research into whether ship coatings are an important source of microplastics to the ocean. If so, the overall relative contribution to ocean microplastics from ship coatings, as well as the individual contributions from the normal use, maintenance and cleaning of coatings, need to be determined as the first step in further research efforts with a view towards informed management.

Jones, M. M. (1995). Fishing Debris in the Australian Marine Environment. *Marine Pollution Bulletin, 30*(1), 25-33 https://doi.org/10.1016/0025-326X(94)00108-L

The loss and disposal of fishing gear has been recognized internationally as a major environmental issue for several decades. This paper reviews the available data on fishing debris in the Australian marine environment. In some regions debris from deep-water trawl, longline and rock lobster fisheries has

harmed marine wildlife and littered beaches. The highest documented incidence of wildlife entanglement by fishing debris is for the Australian fur seal in Bass Strait and off southern Tasmania, where over the period 1989–1993 approximately 1.5-2% of seals were found with neck collars. Data collected by Australian observers on board foreign vessels fishing within the Australian Fishing Zone, indicate that in 1992 and 1993 at least one-third of these vessels did not comply with the MARPOL regulations on the disposal of plastics. Approaches used to reduce debris have included education programmes, development of plastic-free gear, and clean-up programmes.

Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., . . . Reisser, J. (2018). Evidence That the Great Pacific Garbage Patch Is Rapidly Accumulating Plastic. *Scientific Reports, 8*(1), 4666 https://doi.org/10.1038/s41598-018-22939-w

Ocean plastic can persist in sea surface waters, eventually accumulating in remote areas of the world's oceans. Here we characterise and quantify a major ocean plastic accumulation zone formed in subtropical waters between California and Hawaii: The Great Pacific Garbage Patch (GPGP). Our model, calibrated with data from multi-vessel and aircraft surveys, predicted at least 79 (45–129) thousand tonnes of ocean plastic are floating inside an area of 1.6 million km2; a figure four to sixteen times higher than previously reported. We explain this difference through the use of more robust methods to quantify larger debris. Over three-quarters of the GPGP mass was carried by debris larger than 5 cm and at least 46% was comprised of fishing nets. Microplastics accounted for 8% of the total mass but 94% of the estimated 1.8 (1.1–3.6) trillion pieces floating in the area. Plastic collected during our study has specific characteristics such as small surface-to-volume ratio, indicating that only certain types of debris have the capacity to persist and accumulate at the surface of the GPGP. Finally, our results suggest that ocean plastic pollution within the GPGP is increasing exponentially and at a faster rate than in surrounding waters.

Maes, T., Barry, J., Leslie, H. A., Vethaak, A. D., Nicolaus, E. E. M., Law, R. J., . . . Thain, J. E. (2018). Below the Surface: Twenty-Five Years of Seafloor Litter Monitoring in Coastal Seas of North West Europe (1992–2017). *Science of the Total Environment, 630*, 790-798 https://doi.org/10.1016/j.scitotenv.2018.02.245

Marine litter presents a global problem, with increasing quantities documented in recent decades. The distribution and abundance of marine litter on the seafloor off the United Kingdom's (UK) coasts were quantified during 39 independent scientific surveys conducted between 1992 and 2017. Widespread distribution of litter items, especially plastics, were found on the seabed of the North Sea, English Channel, Celtic Sea and Irish Sea. High variation in abundance of litter items, ranging from 0 to 1835 pieces km−2 of seafloor, was observed. Plastic tems such as bags, bottles and fishing related debris were commonly observed across all areas. Over the entire 25-year period (1992–2017), 63% of the 2461 trawls contained at least one plastic litter item. There was no significant temporal trend in the percentage of trawls containing any or total plastic litter items across the long-term datasets. Statistically significant trends, however, were observed in specific plastic litter categories only. These trends were all positive except for a negative trend in plastic bags in the Greater North Sea - suggesting that behavioural and legislative changes could reduce the problem of marine litter within decades.

Marine Environmental Emergency Preparedness and Response Regional Activity Centre. (2009). *Regional Report on Sea-Based Marine Litter in the Nowpap Region.* Retrieved from https://wedocs.unep.org/handle/20.500.11822/26200

Marine litter is now recognized as one of the major problems of marine pollution that destroys the ecological, economical and cultural values of the marine environment. Marine litter can be found in the water column and on the seafloor as well as on beaches in the Northwest Pacific region. It degrades very slowly and causes injury or death of human and other living things as well as accident or damage of the vessels. MERRAC, one of four Regional Activity Centres of NOWPAP, has been designated to implement activities related to sea-based marine litter. The 9th MERRAC Focal Points Meeting decided to develop the National Reports on sea-based marine litter in NOWPAP region for understanding general situation (5-7 June 2006). Based upon the National Reports, MERRAC has developed a regional report titled "Regional Report on Sea-based Marine Litter in the NOWPAP Region," as background information for further works on sea-based marine litter issue. This report aims to provide such general information on sea-based marine litter in the NOWPAP region.

Marine Environmental Emergency Preparedness and Response Regional Activity Centre. (2017). *Understanding of Floating Marine Litter Distribution in the Nowpap Region.* Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/26239/understand_floating_ML.pdf?sequence=1&isAllowed=y

This publication aims to gather information on the distribution of the floating marine litter in the NOWPAP region. The main objective is to understand the current status of floating marine litter in order to identify prospects for effective management and find solution to floating marine litter problems, by analyzing the marine litter distribution by amounts, types and sources (origins) and also by mapping hotspots in the NOWPAP region.

Mobilik, J. M., Ling, T. Y., Husain, M. L., & Hassan, R. (2016). Type and Quantity of Shipborne Garbage at Selected Tropical Beaches. *The Scientific World Journal, 2016*, 1-11 https://doi.org/10.1155/2016/5126951

Marine debris is widely distributed at the coastal area of the global oceans; however, shipborne garbage source studies are still lacking to document the pollution in Malaysia Territorial Water. Thus, this study has adopted a standard method of beach marine debris survey at five beaches and inspected 115 vessels to assess the type and amount of debris from shipping source stranded on the beach. This study found that vessel visiting Malaysian ports observed the MARPOL 73/78 Annex V requirements; however, identified objects from shipping activity (1.3%; 2 items/km) found on the beaches indicate that there are vessels disposing of garbage illegally at sea. Therefore, there is a need to promote the use of biodegradable material and introduce environmental education to increase awareness on the vessel.

National Ocean Service Office of National Marine Sanctuaries. (2014). *The Containerized Shipping Industry and the Phenomenon of Containers Lost at Sea.* Retrieved from https://repository.library.noaa.gov/view/noaa/17410

During a transit from San Francisco Bay to the Port of Los Angeles on February 26, 2004, the M/V Med Taipei encountered a storm and lost 15 forty-foot shipping containers in the Monterey Bay National Marine Sanctuary (MBNMS), and another nine south of the Sanctuary. One of these containers was

discovered by the Monterey Bay Aquarium Research Institute (MBARI) on June 9, 2004 on Smooth Ridge at a depth of 1,281 meters, 17.5 nm NW of Point Pinos. This was not an isolated incident. Containerized maritime trade grew eight-fold from 1985 to 2007, and worldwide there are now approximately 5 to 6 million containers in transit at any given moment. Thousands of shipping containers are lost at sea every year, often due to the nexus of rough seas, inadequate or faulty securing mechanisms, and failure to weigh all containers at the time of loading. On March 8-10, 2011, we conducted a research expedition to the container on Smooth Ridge using MBARI's R/V Western Flyer. The cruise aimed to assess the container's current condition, describe habitat and ecosystem impacts, and to bring public attention to this deep-sea phenomenon that has been increasing with economic globalization. Given the potentially severe ecological, economic, and navigational safety consequences associated with container loss, the issue has led to a range of responses from industry and the consideration of additional preventative measures at the international level.

National Research Council. (1995). *Clean Ships, Clean Ports, Clean Oceans: Controlling Garbage and Plastic Wastes at Sea*. Washington, DC: The National Academies Press. https://doi.org/10.17226/4769

Marine debris is a serious environmental problem. To do its part, the United States has agreed to abide by the international treaty for garbage control at sea, known as MARPOL 73/78 Annex V.Clean Ships, Clean Ports, Clean Oceans explores the challenge of translating Annex V into workable laws and regulations for all kinds of ships and boats, from cruise ships to fishing crafts and recreational boats. The volume examines how existing resources can be leveraged into a comprehensive strategy for compliance, including integrated waste management systems and effective enforcement.Clean Ships, Clean Ports, Clean Oceans describes both progress toward and obstacles to Annex V compliance. The book coversHow shipborne garbage orignates and what happens to garbage discharged into the seas.Effects of discharge on human health, wildlife safety, and aesthetics.Differences in perspective among military, industrial, and recreational seafarers and shoreside facilities.Clean Ships, Clean Ports, Clean Oceans will be important to marine policymakers, port administrators, ship operations officers, maritime engineers, and marine ecologists.

National Research Council. (1996). *Shipboard Pollution Control: U.S. Navy Compliance with MARPOL Annex V*. Washington, DC: The National Academies Press. https://doi.org/10.17226/9190

The Committee on Shipboard Pollution Control was formed under the auspices of the Naval Studies Board, based on discussions between U.S. Navy and National Research Council representatives. The issues involved in shipboard pollution control are a complex mixture of Navy management, congressional mandate, international agreements, environmental community concerns, and technology. The committee as a whole was chosen for its expertise in technology. The first term of reference for the study poses the following question: "What is the technical feasibility of eliminating, by 2000 for surface ships and 2008 for submarines, nonfood solid waste discharge from Navy ships operating in Special Areas?" The Special Areas referred to are defined in the international agreement on Marine Pollution, MARPOL, with specific reference to Annex V, which covers nonfood marine pollution solid waste. Naval ships are exempt from MARPOL, but the U.S. Congress required compliance by the U.S. Navy in the Marine Plastic Pollution Research and Control Act of 1987 as modified by the National Defense Authorization Act for Fiscal Year 1994. Various deadlines and extensions have been applied, with the latest deadlines those given in the above question. Special Areas already designated include the Baltic

Sea, the North Sea, and the Antarctic Ocean. Special Areas expected to be designated in the future include the Mediterranean Sea, the Persian Gulf, the Gulf of Mexico, and the Caribbean Sea.

Pruter, A. T. (1987). Sources, Quantities and Distribution of Persistent Plastics in the Marine-Environment. *Marine Pollution Bulletin, 18*(6b), 305-310 https://doi.org/10.1016/S0025-326x(87)80016-4

Persistent plastics are widely distributed at the surface and coastal margins of the global oceans, but many uncertainties remain about their specific sources, quantities and distribution. Awareness of the problem of plastic pollution has grown only recently. Thus, systematic observations have not been either extensive enough or long enough to document the situation adequately. Major sources of these materials are from land, vessels and beachgoers. This paper reviews recent literature on the sources, amounts and distribution of various types of plastics in the marine environment.

SCS Engineers. (1989). *An Investigation of Using Burn Barrel Technology to Dispose of Shipboard-Generated (MARPOL V) Wastes.* Produced for: National Marine Fisheries Service Marine Entanglement Research Program Retrieved from https://repository.library.noaa.gov/view/noaa/5870

With the advent of MARPOL Annex V, most ships must find an alternate to ocean dumping of their wastes. Marine incinerators, compactors, and grinders (comminutors) may not be economically viable for a particular vessel, or there may be inadequate space for their installation. One method of dealing with ships' wastes that has been used and may receive greater attention in the future is the "burn barrel". An example of a burn barrel is a 55-gallon drum with holes cut in the side to allow combustion air to enter, similar to those in widespread use in the 1950s to burn residential garbage. The National Oceanic and Atmospheric Administration (NOAA) has sponsored this study to evaluate the safety and feasibility of the burn barrel method of at-sea disposal. It was the intent of this study to provide vessel operators with clear information on the operation, safety and effectiveness of this disposal method.

Smith, S. D. A., Banister, K., Fraser, N., & Edgar, R. J. (2018). Tracing the Source of Marine Debris on the Beaches of Northern New South Wales, Australia: The Bottles on Beaches Program. *Marine Pollution Bulletin, 126*, 304-307 https://doi.org/10.1016/j.marpolbul.2017.11.022

Identifying the source of marine plastic pollution accumulating on ocean beaches is often difficult as unidentifiable fragments of plastic usually predominate. In this study, we surveyed plastic bottles as a relatively identifiable subset of plastics on 30km of beach along a 200-km section of the north coast of New South Wales, Australia. Source and product type (contents) were determined using barcodes, inscriptions/embossing, or bottle shape and characteristics. Country of origin and product type could be determined for two-thirds of the 694 bottles found. Just over half (51%) of these were of domestic origin with the remainder dominated by bottles from China (24%) and south-east Asian countries (21%). As most of the foreign bottles lacked marine growth, and are unavailable for purchase in the region, passing ships are hypothesised as the primary source.

Storrier, K. L., McGlashan, D. J., Bonellie, S., & Velander, K. (2007). Beach Litter Deposition at a Selection of Beaches in the Firth of Forth, Scotland. *Journal of Coastal Research, 23*(4), 813-822 https://doi.org/10.2112/04-0251.1

Beach litter deposition at a selection of beaches in the Firth of Forth, Scotland, was studied between July 2001 and December 2003. The amount and types of beach litter is relatively consistent among beaches and over time, with an increased abundance of certain litter types at irregular intervals. Plastic is the most common litter type recorded. The amount of litter items per square metre is affected by Local Authority beach cleaning, community beach cleanings, and the presence of sewerage structures and takeaway facilities. Litter from fishing and shipping was relatively low compared with litter from recreation and sewage-related debris. It is likely that climatic conditions and tidal patterns are the greatest influence on the abundance of beach litter. Management actions are required to effect a reduction in beach litter. A combination of education, provision of adequate waste reception facilities, and enforcement of legislation is needed to tackle beach litter.

Strand, J., Tairova, Z., Danielsen, J., Hansen, J. W., Magnusson, K., Naustvoll, L.-J., & Sørensen, T. K. (2015). *Marine Litter in Nordic Waters.* TemaNord produced for: Nordic Council of Ministers https://doi.org/10.6027/TN2015521

This report is one of the outcomes of a Nordic project called "Marine litter in the Nordic waters" funded by The Marine Group (HAV) under The Nordic Council of Ministers in 2013–2014. The main aim of the project was to establish a Nordic forum for collaboration and exchange of knowledge on status for methodologies and available data for marine litter between Nordic experts, environmental managers and stakeholders, due to the common environmental concerns in our shared seas. This report compiles information that can be used as a contribution to facilitate the framing of this environmental problem in a Nordic perspective. This report includes also input from two workshops on I) Common knowledge status on marine litter in the Nordic countries, and indicators relevant for EU Marine Strategy Framework Directive (November 14, 2013 in Gothenburg, Sweden) and II) Status for monitoring and Future actions (November 6–7, 2014 in Oslo, Norway).

Tekman, M. B., Krumpen, T., & Bergmann, M. (2017). Marine Litter on Deep Arctic Seafloor Continues to Increase and Spreads to the North at the Hausgarten Observatory. *Deep Sea Research Part I: Oceanographic Research Papers, 120*, 88-99 https://doi.org/10.1016/j.dsr.2016.12.011

The increased global production of plastics has been mirrored by greater accumulations of plastic litter in marine environments worldwide. Global plastic litter estimates based on field observations account only for 1% of the total volumes of plastic assumed to enter the marine ecosystem from land, raising again the question 'Where is all the plastic? '. Scant information exists on temporal trends on litter transport and litter accumulation on the deep seafloor. Here, we present the results of photographic time-series surveys indicating a strong increase in marine litter over the period of 2002–2014 at two stations of the HAUSGARTEN observatory in the Arctic (2500m depth). Plastic accounted for the highest proportion (47%) of litter recorded at HAUSGARTEN for the whole study period. When the most southern station was considered separately, the proportion of plastic items was even higher (65%). Increasing quantities of small plastics raise concerns about fragmentation and future microplastic contamination. Analysis of litter types and sizes indicate temporal and spatial differences in the transport pathways to the deep sea for different categories of litter. Litter densities were positively correlated with the counts of ship entering harbour at Longyearbyen, the number of active fishing vessels and extent of summer sea ice. Sea ice may act as a transport vehicle for entrained litter, being released during periods of melting. The receding sea ice coverage associated with global change has opened hitherto largely inaccessible environments to humans and the impacts of tourism, industrial activities including shipping and fisheries, all of which are potential sources of marine litter.

Topçu, E. N., Tonay, A. M., Dede, A., Öztürk, A. A., & Öztürk, B. (2013). Origin and Abundance of Marine Litter Along Sandy Beaches of the Turkish Western Black Sea Coast. *Marine Environmental Research, 85*, 21-28 https://doi.org/10.1016/j.marenvres.2012.12.006

Beach debris abundance was estimated from surveys on 10 beaches of the Turkish Western Black Sea Coast. Debris was collected from 20 m long transects during four different seasons; sorted and categorized by type, usage and origin. Litter density varied from 0.085 to 5.058 items m−2. Debris was mainly composed of unidentifiable small size (2–7 cm) plastic pieces and beverage-related litter such as bottles and bottle caps. About half of the labeled litter was of foreign origin, including 25 different countries, 23% of which are in the Black Sea region. The south-western Black Sea Coast seems to receive foreign litter from two main sources: land-based debris from the neighboring countries and seaborne debris due to international shipping. Standardized methodology and indicators need to be designated all over the Black Sea basin in order to quantify and qualify coastal litter pollution, monitor compliance with MARPOL and develop regionally effective mitigation measures.

Topping, P., Morantz, D., & Lang, G. (1997). Waste Disposal Practices of Fishing Vessels: Canada's East Coast, 1990–1991. In J. M. Coe & D. B. Rogers (Eds.), *Marine Debris: Sources, Impacts, and Solutions* (pp. 253-262). New York, NY https://doi.org/10.1007/978-1-4613-8486-1_22

There is a growing awareness that persistent plastic debris in the marine environment threatens marine life and reduces economic potential. Data from beach surveys and high seas observations collected over the years demonstrate a long-term problem and identify a common source of debris: offshore fishing fleets (Buxton 1990; Lucas 1992). An extensive fleet of both foreign and domestic vessels operates in the Atlantic Ocean within the 200-mile economic zone off Canada's east coast. Before this project, formal data concerning waste disposal practices of fishing vessels or of other vessels at sea were scarce.

Tutor, D., & Williams, A. (2004). Development of a 'Matrix Scoring Technique' to Determine Litter Sources at a Bristol Channel Beach. *Journal of Coastal Conservation, 10*(1-2), 119-127 Retrieved from https://link.springer.com/article/10.1652/1400-0350(2004)010[0119:DOAMST]2.0.CO;2

Litter at beaches can come from more than one source and determining the proportions to assign pollution to different sources is very complex. There is no widely accepted methodology at present that links litter items to their source. The aim of this study was to create a method of assigning a source to litter found on beaches of the Bristol Channel but which could equally be used on any beach. Various methods that attempt to establish the source of beach litter were evaluated; their strengths, weaknesses, applicability and reliability for use on Bristol Channel, UK beaches were considered. Elements of existing methods coupled with new ideas were utilized in the production of a 'refined' methodology: consequently a new method of assigning a source to beach litter was developed. The developed 'Matrix Scoring Technique' was applied to data collected at Minehead beach on the Bristol Channel, UK. Several numerical and nomenclature variations were used to produce a system that reflected the various sources and eliminated as much bias as possible. This cross-tabulated matrix scoring system can produce an insight into the contribution of different source groups to litter found on beaches. This novel approach requires further testing with emphasis on a control data set.

United Nations Environment Programme. (2005). *Marine Litter: An Analytitcal Overview.* Retrieved from http://wedocs.unep.org/handle/20.500.11822/8348

It is estimated that about 6.4 million tons of marine litter are disposed in the oceans and seas each year. According to other estimates and calculations, some 8 million items of marine litter are dumped in oceans and seas every day, approximately 5 million of which (solid waste) are thrown overboard or lost from ships. Furthermore, it has been estimated that over 13,000 pieces of plastic litter are floating on every square kilometre of ocean today. Considering the magnitude and the severity of the marine litter problem, UNEP's Regional Seas Programme, in cooperation with the GPA, initiated a "Feasibility Study on Sustainable Management of Marine Litter" to assess the global threat posed by marine litter worldwide and to examine the efficacy of current instruments, programmes and initiatives. This study, summarized in the analytical review before you, proposes a series of global and regional activities aimed at controlling, reducing and abating the problem.

United Nations Environment Programme. (2009). *Marine Litter: A Global Challenge.* Nairobi. Retrieved from http://wedocs.unep.org/handle/20.500.11822/7787

Marine litter is a global concern affecting all the oceans of the world. It poses environmental, economic, health and aesthetic problems that are rooted in poor solid waste management practices, lack of infrastructure, indiscriminate human activities and behaviours and an inadequate understanding on the part of the public of the potential consequences of their actions. The UNEP Global Initiative on Marine Litter has provided an effective framework for conducting regional activities addressing marine litter around the world, including those of the 12 participating Regional Seas programmes. The objective of this document is (1) to present and analyse available information on marine litter discussed in documents produced by the 12 regional programmes with the help of regional consultants and technical experts and (2) to propose recommendations for addressing the problems associated with marine litter worldwide.

United States Environmental Protection Agency. (2008). *Cruise Ship Discharge Assessment Report.* Oceans and Coastal Protection Division Office of Wetlands, Oceans, and Watersheds EPA842-R-07-005. Washington, DC. Retrieved from https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1002SVS.TXT

This Cruise Ship Discharge Assessment Report (Assessment Report) concludes EPA's response to the petition from Bluewater Network. This Assessment Report examines five primary cruise ship waste streams -- sewage, graywater, oily bilge water, solid waste, and hazardous waste. For each waste stream, the Assessment Report discusses (1) what the waste stream is and how much is generated; (2) what laws apply to the waste stream; (3) how the waste stream is managed; (4) potential environmental impacts of the waste stream; (5) on-going actions by the federal government to address the waste stream; and (6) a wide range of options and alternatives to address the waste stream from cruise ships in the future. Though this report includes discussion of some proprietary treatment technologies for the abatement of pollution from cruise ships, that discussion in no way constitutes an endorsement by EPA of any non-federal entity, its products, or its services.

Urban-Malinga, B., Wodzinowski, T., Witalis, B., Zalewski, M., Radtke, K., & Grygiel, W. (2018). Marine Litter on the Seafloor of the Southern Baltic. *Marine Pollution Bulletin, 127*, 612-617 https://doi.org/10.1016/j.marpolbul.2017.12.052

Marine litter occurrence and composition were investigated during routine bottom trawl fish surveys type BITS performed in the Polish Maritime Areas (the southern Baltic Sea). Sampling covered a distance of 325km and an area of 16km(2) at a depth range of 19-110m. Litter densities varying between 0 items/ha (34% of tows) and 2.23items/ha with a mean of 0.20items/ha (SD=0.30) are at the bottom range of densities reported from other shelf habitats worldwide at similar water depths. The majority of the items (40%) were found at a depth range of 51-60m. Overall, plastic was the most common litter type (67% of all items) found in all tows with litter. The results of this study indicate that despite the Baltic being a semi-enclosed basin, with a densely populated coastline and extensive shipping, marine litter pollution of the southern Baltic seafloor is low compared to other coastal areas.

Vauk, G. J. M., & Schrey, E. (1987). Litter Pollution from Ships in the German Bight. *Marine Pollution Bulletin, 18*(6, Supplement B), 316-319 https://doi.org/10.1016/S0025-326X(87)80018-8

A 60 m length of beach at Helgoland was sampled approximately every third day for a year to determine the composition of litter deposited there. A total of 8473 items with a total weight of 1320 kg were identified as shipping wastes in the 106 samples. Plastics of all types composed 75% of the items, whereas wood represented 65% of the total weight. Ships' waste from along the main shipping routes in the southern German Bight may be a dominant source of the litter. The objects found were originally manufactured in 26 different nations. The study provides an estimation of the dimensions of litter pollution in the area of the inner German Bight.

Veiga, J. M., Fleet, D., Kinsey, S., Nilsson, P., Vlachogianni, T., Werner, S., . . . Cronin, R. (2016). *Identifying Sources of Marine Litter.* Joint Research Centre, European Commission's Science and Knowledge Service, JRC 104038 EUR 28309. https://doi.org/10.2788/956934

A wide variety of methods have been used over the years to determine the sources of marine litter, from simple counts of items believed to originate from a given source to more complex statistical methods. This report provides a brief overview of the main methods used and outlines one of the most promising approaches for determining sources – a Matrix Score Technique based on likelihoods, which considers the possibility that specific items originate from more than one source. Furthermore, it presents a series of other parameters that can be used to analyse data-sets, with regard to the use, origin and risk of items recorded in the marine or coastal environments. These can further support decision-making when considering preventive measures. Finally, recommendations to help the process of identification of sources are given, from the early stage of data collection and site characterization to bringing in the knowledge of local stakeholders to better determine where litter is coming from and what needs to be done to prevent it.

Wade, B. A. (1997). The Challenges of Ship-Generated Garbage in the Caribbean. In J. M. Coe & D. B. Rogers (Eds.), *Marine Debris: Sources, Impacts, and Solutions* (pp. 229-237). New York, NY https://doi.org/10.1007/978-1-4613-8486-1_19

The ratification of Annex V of the MARPOL Convention marks an important step forward in the protection of the oceans. However, many countries have failed to fully understand its significance, and the leaders of Caribbean States do not seem to have paid sufficient attention to this development. One reason may be that in the area of marine pollution, ship-generated garbage is considered less significant than oil spills or spills of hazardous substances. At the local level, ship-generated garbage has not

evoked society-wide responses. Nonetheless, if left unaddressed ship-generated garbage could have damaging environmental and public health consequences.

Waller, C. L., Griffiths, H. J., Waluda, C. M., Thorpe, S. E., Loaiza, I., Moreno, B., . . . Hughes, K. A. (2017). Microplastics in the Antarctic Marine System: An Emerging Area of Research. *Science of the Total Environment, 598*, 220-227 https://doi.org/10.1016/j.scitotenv.2017.03.283

It was thought that the Southern Ocean was relatively free of microplastic contamination; however, recent studies and citizen science projects in the Southern Ocean have reported microplastics in deep-sea sediments and surface waters. Here we reviewed available information on microplastics (including macroplastics as a source of microplastics) in the Southern Ocean. We estimated primary microplastic concentrations from personal care products and laundry, and identified potential sources and routes of transmission into the region. Estimates showed the levels of microplastic pollution released into the region from ships and scientific research stations were likely to be negligible at the scale of the Southern Ocean, but may be significant on a local scale. This was demonstrated by the detection of the first microplastics in shallow benthic sediments close to a number of research stations on King George Island. Furthermore, our predictions of primary microplastic concentrations from local sources were five orders of magnitude lower than levels reported in published sampling surveys (assuming an even dispersal at the ocean surface). Sea surface transfer from lower latitudes may contribute, at an as yet unknown level, to Southern Ocean plastic concentrations. Acknowledging the lack of data describing microplastic origins, concentrations, distribution and impacts in the Southern Ocean, we highlight the urgent need for research, and call for routine, standardised monitoring in the Antarctic marine system.

Watters, D. L., Yoklavich, M. M., Love, M. S., & Schroeder, D. M. (2010). Assessing Marine Debris in Deep Seafloor Habitats Off California. *Marine Pollution Bulletin, 60*(1), 131-138 https://doi.org/10.1016/j.marpolbul.2009.08.019

Marine debris is a global concern that pollutes the world's oceans, including deep benthic habitats where little is known about the extent of the problem. We provide the first quantitative assessment of debris on the seafloor (20-365 m depth) in submarine canyons and the continental shelf off California, using the Delta submersible. Fishing activities were the most common contributors of debris. Highest densities occurred close to ports off central California and increased significantly over the 15-year study period. Recreational monofilament fishing line dominated this debris. Debris was less dense and more diverse off southern than central California. Plastic was the most abundant material and will likely persist for centuries. Disturbance to habitat and organisms was low, and debris was used as habitat by some fishes and macroinvertebrates. Future trends in human activities on land and at sea will determine the type and magnitude of debris that accumulates in deep water.

Whiting, S. D. (1998). Types and Sources of Marine Debris in Fog Bay, Northern Australia. *Marine Pollution Bulletin, 36*(11), 904-910 https://doi.org/10.1016/S0025-326x(98)00066-6

Marine debris items were collected and categorized during surveys of beaches in Fog Bay, northern Australia in 1996 and 1997, Synthetic items (45%) were the most numerous followed by metal (35%) and glass (16%). Drink containers contributed 53% of the total items, while fishing gear and foreign material contributed only 4% and 3%, respectively, Scores were given to each possible source of marine debris according to their likelihood of contributing to each group of debris items. Using this method, commercial fishing, merchant shipping and recreational boaters were likely to contribute to over 85% of

all debris items. Composition of debris items varied between beach orientation within the same year and within beach orientation between years, which suggests that a number of beaches and locations should be sampled to obtain an unbiased estimate of marine debris for annual comparisons. (C) 1998 Elsevier Science Ltd. All rights reserved.

Williams, A. T., Tudor, D. T., & Randerson, P. (2003). Beach Litter Sourcing in the Bristol Channel and Wales, UK. *Water Air and Soil Pollution, 143*(1-4), 387-408 https://doi.org/10.1023/A:1022808908500

Principal component analysis (PCA) and cluster analysis were carried out on beach litter found primarily along the Bristol Channel, U. K., together with beaches located around the Principality of Wales. Both techniques indicated three beach survey sites as outliers, with distinctive beach litter profiles. PCA distinguished between riverine, sewage related, fishing and shipping sourced items, but did not produce a coherent grouping for beach user litter. This was attributed to a difference in modes of transport. Beaches from mid and north Wales, which had small litter amounts, were not differentiated from the central grouping. The western edge of the Channel was more heavily influenced by shipping and fishing inputs than was the eastern portion. Cluster analysis showed a discrete group of beaches located mainly on the southern side of the Bristol Channel.

World Shipping Council. (2017). *Containers Lost at Sea 2017 Update.* Retrieved from http://www.worldshipping.org/industry-issues/safety/Containers_Lost_at_Sea_-_2017_Update_FINAL_July_10.pdf

In 2016, the international liner shipping industry transported approximately 130 million containers packed with cargo, with an estimated value of more than $4 trillion. Proper packing, stowage and securing of containers and reporting of correct weight is very important to the safety of a container ship, its crew and its cargo, to shore-based workers and equipment, and to the environment. However, even with proper packing of the cargo into the container, correct container weight declaration, and proper stowage and securing aboard ship, a number of factors ranging from severe weather and rough seas to more catastrophic and rare events like ship groundings, structural failures, and collisions can result in containers being lost at sea. In the past, obtaining an accurate assessment of how many containers actually are lost at sea was a highly speculative process. For many years, there were widely circulated, but unsupported and grossly inaccurate claims that the industry might lose as many as 10,000 containers a year at sea. Ocean carriers operating the containerships, which the World Shipping Council (WSC) represents, remain the best sources for accurate information on this subject. Therefore, in an effort to provide greater clarity and a more accurate assessment of the number of containers lost at sea on an annual basis, WSC undertook the first survey of its member companies in 2011, with updates in 2014 and 2017, and has published the results to make the information readily available to all interested parties.

Zuin, S., Radonjic, G., Logozar, K., Belac, E., & Marzi, B. (2010). Life Cycle Assessment of Ship-Generated Waste Management of Luka Koper (Vol 29, Pg 3036, 2009). *Waste Management, 30*(5), 3036-3046 https://doi.org/10.1016/j.wasman.2010.01.013

Sea ports and the related maritime activities (e.g. shipping, shipbuilding, etc.) are one of the main driver of Europe's growth, jobs, competitiveness and prosperity. The continuously growth of shipping sectors has however introduced some environmental concerns, particularly with respect to ship-generated

waste management. The port of Koper, one of the major ports on the northern Adriatic Coast, is the focus of this study. In this paper, a life cycle assessment was performed to identify and quantify the environmental impacts caused by the ship-generated waste management of port of Koper. Carcinogens substance (e.g. dioxins) and inorganic emissions, especially heavy metals, resulted to be the most critical environmental issues, while the fossil fuels consumption is reduced by recovery of ship-generated oils. Moreover, the final treatment of ship waste was found to be critical phase of the management, and the landfill have a significant contribute to the overall environmental load. These results can be useful in the identification of the best practices and in the implementation of waste management plans in ports.

Section II: Impact of Ghost Fishing Gear

Al-Masroori, H., Al-Oufi, H., McIlwain, J. L., & McLean, E. (2004). Catches of Lost Fish Traps (Ghost Fishing) from Fishing Grounds near Muscat, Sultanate of Oman. *Fisheries Research, 69*(3), 407-414 https://doi.org/10.1016/j.fishres.2004.05.014

A field study was undertaken to quantify the catch rate of simulated lost fish traps at five traditional fishing grounds near Muscat and Mutrah, Sultanate of Oman. Twenty-five traps were set at depths between 16 and 36m during the period late November 2000 to mid-July 2001. Ghost fishing mortality was estimated at 1.34kg/trap per day, decreasing over time. An exponential model, to estimate trap ghost fishing mortality, predicted a mortality rate of 67.27 and 78.36kg/trap during 3 and 6 months respectively, with trapped fish having a value of 55.565RO/trap (~US$145) and 64.725RO/trap (~US$168) respectively.111 Rial Omani (RO) equals 2.604 US$. To reduce the negative impacts of ghost trap fishing here and elsewhere, it is recommended that future traps be better marked, equipped with timed-release or degradable sections or panels, and that openings be included in the traps to release undersized animals.

Anderson, J. A., & Alford, A. B. (2014). Ghost Fishing Activity in Derelict Blue Crab Traps in Louisiana. *Marine Pollution Bulletin, 79*(1), 261-267 https://doi.org/10.1016/j.marpolbul.2013.12.002

Derelict crab traps impact the coastal ecosystem through continued catch of target species and species of conservation, economic, or recreational importance. During volunteer-supported crab trap cleanups in 2012 and 2013, we quantified ghost fishing activity in derelict crab traps in coastal Louisiana through a citizen scientist program. Volunteers removed 3607 derelict traps during these events, and over 65% of traps analyzed by citizen scientists were actively ghost fishing. Additionally, volunteers identified 19 species enmeshed in derelict traps, including a combination of fresh and saltwater species. We also detected a significant difference in the number of blue crab in actively ghost fishing derelict traps across removal locations with estimated catches varying between 2.4 and 3.5 crabs/trap. Our instantaneous estimates of ghost fishing activity are greater than those previously thought in Louisiana, further justifying current derelict crab trap prevention and removal extension and outreach programs in Louisiana and throughout the Gulf of Mexico.

Arthur, C., Sutton-Grier, A. E., Murphy, P., & Bamford, H. (2014). Out of Sight but Not out of Mind: Harmful Effects of Derelict Traps in Selected U.S. Coastal Waters. *Marine Pollution Bulletin, 86*(1), 19-28 https://doi.org/10.1016/j.marpolbul.2014.06.050

There is a paucity of data in the published literature on the ecological and economic impacts of derelict fishing traps (DFTs) in coastal ecosystems. We synthesized results from seven NOAA-funded trap fisheries studies around the United States and determined that DFT-caused losses to habitat and harvestable annual catch are pervasive, persistent, and largely preventable. Based on this synthesis, we identified key gaps to fill in order to better manage and prevent DFTs. We conclude with suggestions for developing a U.S. DFT management strategy including: (1) targeting studies to estimate mortality of fishery stocks, (2) assessing the economic impacts of DFTs on fisheries, (3) collaborating with the fishing industry to develop solutions to ghost fishing, and (4) examining the regional context and challenges resulting in DFTs to find effective policy solutions to manage, reduce, and prevent gear loss.

Baeta, F., Costa, M. J., & Cabral, H. (2009). Trammel Nets' Ghost Fishing Off the Portuguese Central Coast. *Fisheries Research, 98*(1), 33-39 https://doi.org/10.1016/j.fishres.2009.03.009

The loss of fishing gear has negative consequences to marine communities if the gear preserves its catching abilities for a significant period, a phenomenon called "ghost fishing". The present study assessed the impact of lost trammel nets in both sandy and rocky bottoms in the central area of the Portuguese coast. Ten trammel nets, each 50m long and corresponding to the most common type used by the local commercial fleet, were allowed to fish continually for 285 days. During this time, changes in the structure and catching ability of each net were monitored by scuba divers in regular time intervals (1, 5, 10, 15, 20, 30, 40, 60, 80, 120, 250 and 285 days). Three control nets were also set in each bottom type the day before each monitoring dive. Irrespective of bottom type, nets' fishing area decreased to about 40% during the first 30 days, and then gradually (rocky bottoms) or sharply (sandy bottoms). It was estimated that during the experiment 541 and 257 individuals were caught per 100m of net in rocky and sandy bottoms, respectively. Catching efficiency decreased in a negative exponential manner in parallel with the nets deterioration. The nets' effective fishing lifetime, when catching efficiency became lower than 1%, was 10–11 months in the rocky bottom and 8 months in the sandy bottom.

Ballesteros, L. V., Matthews, J. L., & Hoeksema, B. W. (2018). Pollution and Coral Damage Caused by Derelict Fishing Gear on Coral Reefs around Koh Tao, Gulf of Thailand. *Marine Pollution Bulletin, 135*, 1107-1116 https://doi.org/10.1016/j.marpolbul.2018.08.033

Most lost fishing gear is made of non-biodegradable plastics that may sink to the sea floor or drift around in currents. It may remain unnoticed until it shows up on coral reefs, beaches and in other coastal habitats. Stony corals have fragile skeletons and soft tissues that can easily become damaged when they get in contact with lost fishing gear. During a dive survey around Koh Tao, a small island in the Gulf of Thailand, the impact of lost fishing gear (nets, ropes, cages, lines) was studied on corals representing six different growth forms: branching, encrusting, foliaceous, free-living, laminar, and massive. Most gear (> 95%) contained plastic. Besides absence of damage (ND), three categories of coral damage were assessed: fresh tissue loss (FTL), tissue loss with algal growth (TLAG), and fragmentation (FR). The position of the corals in relation to the fishing gear was recorded as either growing underneath (Un) or on top (On), whereas corals adjacent to the gear (Ad) were used as controls. Nets formed the dominant type of lost gear, followed by ropes, lines and cages, respectively. Branching corals were most commonly found in contact with the gear and also around it. Tubastraea micranthus was the most commonly encountered coral species, either Un, On, or Ad. Corals underneath gear showed most damage, which predominantly consisted of tissue loss. Fragmentation was less common than expected, which may be related to the low fragility of T. micranthus as dominant branching species. Even if nets serve as substrate for corals, it is recommended to remove them from

reefs, where they form a major component of the plastic pollution and cause damage to corals and other reef organisms.

Brown, J., & Macfadyen, G. (2007). Ghost Fishing in European Waters: Impacts and Management Responses. *Marine Policy, 31*(4), 488-504 https://doi.org/10.1016/j.marpol.2006.10.007

In this paper we review levels of net loss, what happens to the gear once it has been lost, and the resulting levels of 'ghost catches' made in passive net fisheries in the EU. We also consider ghost catches resulting from lost gear in other types of fisheries, and the extent to which the value of ghost catches has been quantified. We consider why fishing gear is lost, and profile common management responses. We present a cost benefit model to assess the relative cost effectiveness of different management measures, and suggest that gear retrieval programmes may provide less value for money than other management responses. (c) 2007 Elsevier Ltd. All rights reserved.

Brown, J. G., Macfadyen, G., Huntington, T., Magnus, J., & Tumilty, J. (2005). *Ghost Fishing by Lost Fishing Gear.* Institute for European Environmental Policy, Poseidon Aquatic Resource Management DG FISH/2004/20. Retrieved from https://ieep.eu/uploads/articles/attachments/4a24b509-013d-44ca-b26e-47c8f52e29c4/ghostfishing.pdf?v=63664509699

'Ghost fishing' is the term given to the continued fishing by fishing gear that has been lost or abandoned. It is largely confined to 'passive gears' such as gillnets, trammel nets, wreck nets, and traps. It is a phenomenon that has attracted attention over the past two decades given the sometimes graphic images of fish and other marine life entangled in lost nets, illustrating the potentially wasteful and destructive impacts of lost fishing gear. However, the real extent of the problem is not well known at the present time. This report is the output of a six-month research project funded by the Environment Unit of DG Fisheries and Maritime Affairs of the European Commission. Evidence suggests that ghost fishing from 'active' fishing gears such as trawl nets and from 'static' pot fishing is not significant in European Union (EU) waters, and the focus of this project is therefore on ghost fishing in static set-net fisheries.

Chiappone, M., Dienes, H., Swanson, D. W., & Miller, S. L. (2005). Impacts of Lost Fishing Gear on Coral Reef Sessile Invertebrates in the Florida Keys National Marine Sanctuary. *Biological Conservation, 121*(2), 221-230 https://doi.org/10.1016/j.biocon.2004.04.023

The Florida Keys coral reef ecosystem supports multimillion-dollar commercial and recreational fisheries. The ecological effects caused by fishing gear that is lost when cut or broken after snagging on the bottom is a growing concern to managers and scientists. Few data exist, however, to assess the impacts of lost fishing gear to benthic organisms and habitat structure. In this study, 63 offshore coral reef and hard-bottom sites were surveyed during 2001 to quantify the impacts of lost fishing gear to coral reef sessile invertebrates. Lost hook-and-line fishing gear accounted for 87% of all debris (N = 298 incidences) encountered and was responsible for 84% of the 321 documented impacts to sponges and benthic cnidarians, predominantly consisting of tissue abrasion causing partial individual or colony mortality. Branching gorgonians (Octocorallia) were the most frequently affected (56%), followed by milleporid hydrocorals (19%) and sponges (13%). Factors affecting the impacts of lost fishing gear include sessile invertebrate density, the density of lost fishing gear, and gear length. While lost hook-and-line fishing gear is ubiquitous in the Florida Keys, less than 0.2% of the available milleporid hydrocorals, stony corals, and gorgonians in the habitats studied are adversely affected in terms of colony abrasions and partial mortality.

Cho, D.-O. (2011). Removing Derelict Fishing Gear from the Deep Seabed of the East Sea. *Marine Policy, 35*(5), 610-614 https://doi.org/10.1016/j.marpol.2011.01.022

The East Sea, with an average depth of 1700m, has long been subject to heavy fishing pressure, resulting in derelict fishing gear. Most derelict fishing gears, such as fishing nets, fishing ropes, and crab pots, sink to the seabed and do not degrade. This gear results in “ghost fishing,” which has adverse impacts on deep benthic habitats. Recently, the Korean government has started to remove derelict fishing gears from the deep seabed of the East Sea by bottom trawling with heavy hooks (50–80kg) and ropes. A total of 207.8 and 252.2tons of marine debris in 2009 and 2010, respectively, were removed from the seabed, most of which were derelict fishing gears. Contrary to monitoring surveys and clean-up in shallow waters, removal of marine debris from remote deep habitats is much more difficult and dangerous for removal crews.

Erzini, K., Monteiro, C., & Ribeiro, J. (1998). An Experimental Study of Gill Net and Trammel Net Ghost Fishing Off the Algarve (Southern Portugal). *Marine Ecology Progress Series, 6*(45), 1049-1050 Retrieved from https://www.jstor.org/stable/24858816

Four 100 m lengths of both monofilament gill nets and trammel nets were deployed at depths between 15 and 18 m off the coast of the Algarve (south of Portugal) between April 1995 and June 1996. The nets were set on a natural rocky bottom with one end cut loose to simulate lost nets. Changes in net structure (net height, effective fishing area, movement, colonisation, wear and tear) and their catches (species, sizes, numbers, and biomass) were monitored by divers. Similar patterns were observed in all the nets, with a sharp decrease in net height and effective fishmg area, and an increase in visibility within the first few weeks. Net movement was negligible except in the case of interference from other fishing gears. Catch rates were initially comparable to normally fished gd.l nets and trammel nets in this area, but decreased steadily over time. No sea birds, reptiles or mammals were caught in any of the 8 nets. Catches were dominated by fish (89% by number, at least 27 species), in particular by sea breams (Sparidae) and wrasscs (Labridae). Under the conditions experienced throughout the study the fishlng hfetime of a 'lost' net is between 15 and 20 wk. Based on an exponential model, we estimated that 100 m lengths of gill net and trammel net will catch 314 and 221 fish respectively over a 17 wk period. However, we consider this to be an underestimate due to high rates of predation and scavenging by octopuses, cuttlefish, moray eels, conger eels, and other fish such as the wrasse Coris julis. When the nets were surveyed in the following spring. 8 to 11 mo after being deployed, they were found to be completely destroyed or heavily colonised by algae and had become incorporated into the reef.

Gilardi, K. V. K., Carlson-Bremer, D., June, J. A., Antonelis, K., Broadhurst, G., & Cowan, T. (2010). Marine Species Mortality in Derelict Fishing Nets in Puget Sound, WA and the Cost/Benefits of Derelict Net Removal. *Marine Pollution Bulletin, 60*(3), 376-382 https://doi.org/10.1016/j.marpolbul.2009.10.016

Derelict fishing gear persists for decades and impacts marine species and underwater habitats. Agencies and organizations are removing significant amounts of derelict gear from marine waters in the United States. Using data collected from repeated survey dives on derelict gillnets in Puget Sound, Washington, we estimated the daily catch rate of a given derelict gillnet, and developed a model to predict expected total mortality caused by a given net based on entanglement data collected upon its removal. We also generated a cost:benefit ratio for derelict gear removal utilizing known true costs compared to known market values of the resources benefiting from derelict gear removal. For one study net, we calculated

4368 crab entangled during the impact lifetime of the net, at a loss of $19,656 of Dungeness crab to the commercial fishery, compared to $1358 in costs to remove a given gillnet, yielding a cost:benefit ratio of 1:14.5.

Gilman, E. (2015). Status of International Monitoring and Management of Abandoned, Lost and Discarded Fishing Gear and Ghost Fishing. *Marine Policy, 60*, 225-239 https://doi.org/10.1016/j.marpol.2015.06.016

Abandoned, lost and discarded fishing gear (ALDFG) can pose substantial ecological and socioeconomic problems. Over the past decade there has been increasing international recognition of the need for multilateral efforts to address transboundary problems resulting from ALDFG, including ghost fishing. To benchmark the status of international monitoring and mitigation of ALDFG and ghost fishing, an assessment was made of data collection protocols and management measures to prevent and remediate ALDFG and ghost fishing by 19 global and regional bodies and arrangements with the competence to establish binding controls for marine capture fisheries. Four organizations were explicitly mandated by their convention or agreement text to monitor and control ALDFG and ghost fishing. Modifying mandates of the other organizations might augment members' political will to monitor, prevent and remediate ALDFG and ghost fishing. Ten organizations collected logbook or observer data on ALDFG. Harmonizing data collection protocols where they are in place, and filling gaps where they are lacking, would improve regional monitoring of ALDFG. Twelve organizations have adopted binding measures that contribute to avoiding or remediating ALDFG. The organizations, however, make use of a small subset of available tools: Only half of 18 categories of methods identified as having the potential to prevent and remediate ALDFG and ghost fishing were used by the organizations. Organizations lacking relevant binding measures could begin to fill this gap and organizations can tap a broader suite of complimentary management methods.

Gilman, E., Chopin, F., Suuronen, P., & Kuemlangan, B. (2009). *Abandoned, Lost or Otherwise Discarded Gillnets and Trammel Nets.* Food and Agriculture Organization of the United Nations (FAO) FAO technical paper no. 600. Rome. Retrieved from http://www.fao.org/3/a-i5051e.pdf

The ecological and socio-economic problems caused by abandoned, lost and discarded fishing gear (ALDFG) are increasingly of concern. Used primarily by coastal, artisanal, small-scale fisheries worldwide, marine gillnets and trammel nets, which have relatively high ghost fishing potential, account for about one-fifth of global marine fisheries landings. FAO and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, hosted by the United Nations Environment Programme, as Secretariat for the Global Partnership on Marine Litter, commissioned this study to identify best practices to estimate ghost fishing mortality rates and levels, priority research needs, and the status of international monitoring and management of ALDFG and ghost fishing by marine gillnet and trammel net fisheries. Accurate estimates of total ghost fishing mortality levels can be made given quality data on the density of ALDFG retaining fishing efficiency, duration of ghost fishing efficiency, and total ghost fishing mortality level of a unit of effort of ALDFG over the full period that the derelict gear retains fishing efficiency. Recommendations to improve estimates of regional and global rates and levels of ghost fishing from ALDFG from marine gillnet and trammel net fisheries were made. An assessment was made and opportunities were identified to improve intergovernmental organizations' data collection protocols and management measures to prevent and remediate ALDFG and ghost fishing by marine gillnets and trammel nets.

Gilman, E., Chopin, F., Suuronen, P., & Kuemlangan, B. (2016). *Methods to Estimate Ghost Fishing Mortality, and the Status of Regional Monitoring and Management.* Food and Agriculture Organization of the United Nations, FAO Fisheries and Aquaculture Technical Paper No. 600. Rome. Retrieved from http://www.fao.org/3/a-i5051e.pdf

The ecological and socio-economic problems caused by abandoned, lost and discarded fishing gear (ALDFG) are increasingly of concern. Used primarily by coastal, artisanal, small-scale fisheries worldwide, marine gillnets and trammel nets, which have relatively high ghost fishing potential, account for about one-fifth of global marine fisheries landings. FAO and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, hosted by the United Nations Environment Programme, as Secretariat for the Global Partnership on Marine Litter, commissioned this study to identify best practices to estimate ghost fishing mortality rates and levels, priority research needs, and the status of international monitoring and management of ALDFG and ghost fishing by marine gillnet and trammel net fisheries. Accurate estimates of total ghost fishing mortality levels can be made given quality data on the density of ALDFG retaining fishing efficiency, duration of ghost fishing efficiency, and total ghost fishing mortality level of a unit of effort of ALDFG over the full period that the derelict gear retains fishing efficiency. Recommendations to improve estimates of regional and global rates and levels of ghost fishing from ALDFG from marine gillnet and trammel net fisheries were made. An assessment was made and opportunities were identified to improve intergovernmental organizations' data collection protocols and management measures to prevent and remediate ALDFG and ghost fishing by marine gillnets and trammel nets.

Good, T. P., June, J. A., Etnier, M. A., & Broadhurst, G. (2010). Derelict Fishing Nets in Puget Sound and the Northwest Straits: Patterns and Threats to Marine Fauna. *Marine Pollution Bulletin, 60*(1), 39-50 https://doi.org/10.1016/j.marpolbul.2009.09.005

Derelict fishing gear remains in the marine environment for years, entangling, and killing marine organisms worldwide. Since 2002, hundreds of derelict nets containing over 32,000 marine animals have been recovered from Washington's inland waters. Analysis of 870 gillnets found many were derelict for years; most were recovered from northern Puget Sound and high-relief rocky habitats and were relatively small, of recent construction, in good condition, stretched open, and in relatively shallow water. Marine organisms documented in recovered gillnets included 31,278 invertebrates (76 species), 1036 fishes (22 species), 514 birds (16 species), and 23 mammals (4 species); 56% of invertebrates, 93% of fish, and 100% of birds and mammals were dead when recovered. For all taxa, mortality was generally associated with gillnet effectiveness (total area, age and condition, and suspension in the water). Mortality from derelict fishing gear is underestimated at recovery and may be important for species of economic and conservation concern.

Hong, S., Lee, J., & Lim, S. (2017). Navigational Threats by Derelict Fishing Gear to Navy Ships in the Korean Seas. *Marine Pollution Bulletin, 119*(2), 100-105 https://doi.org/10.1016/j.marpolbul.2017.04.006

This study assessed the impact of derelict fishing gear (DFG) on navigation. The Republic of Korea's navy (ROKN) recorded every case of approximately 170 naval ships associated with propeller entanglement by DFG from January 2010 to December 2015. The frequency of cases was 2.3 per ship and 397.7 (±37.5) per year. The amount of DFG disentangled was 0.025tons per ship and 10.0 (±1.7) tons per year. The frequency temporally decreased whereas the amount increased over these six years. To disentangle propellers, 3.1 divers were needed on average per case. Propeller entanglement occurred in all local seas and some of these areas showed increases over time. Our study highlights that the impact of DFG

on navigational threats has been persistent and ubiquitous and can potentially be reduced by preventing DFG in fishing areas, with a focus on improved management by fishermen and government and with more efficient retrieval of DFG.

Humborstad, O.-B., Løkkeborg, S., Hareide, N.-R., & Furevik, D. M. (2003). Catches of Greenland Halibut (Reinhardtius Hippoglossoides) in Deepwater Ghost-Fishing Gillnets on the Norwegian Continental Slope. *Fisheries Research, 64*(2), 163-170 https://doi.org/10.1016/S0165-7836(03)00215-7

Fishing gear may continue to fish after it has been lost. Large catches have been observed during cruises to retrieve lost gillnets in Norwegian waters, especially in the fishery for Greenland halibut (Reinhardtius hippoglossoides). The Norwegian Greenland halibut is overexploited, and there is serious concern about the effect of lost nets on this stock. Catches in deliberately lost gillnets were studied in the fishery for Greenland halibut off the coast of mid-Norway in July 2000 and June 2001. Gillnet fleets were deployed at depths of between 537 and 851m, and the soak time ranged from 1 to 68 days. Most of the catch consisted of the target species, and the proportions of different species did not change with soak time. All individuals caught were categorized in terms of seven condition states. A gradual shift from fresh to decomposed individuals over time was evident. The catching efficiency of gillnets decreased with soak time, presumably due to the weight of the catch causing the headline height to decrease, and after 45 days was only about 20–30% of that of nets used in the commercial fishery. Catch rates were estimated after stabilization at 67–100 and 28–43kg per day per gillnet fleet in 2000 and 2001, respectively. The results indicated that gillnets lost in this area continue to fish for long periods of time. Annual losses of nets need to be quantified in order to estimate the effects of ghost fishing on stock levels, a figure that is currently lacking.

Johnson, S. W. (1989). Deposition, Fate, and Characteristics of Derelict Trawl Web on an Alaskan Beach. *Marine Pollution Bulletin, 20*(4), 164-168 https://doi.org/10.1016/0025-326X(89)90486-4

Derelict trawl web washed ashore on an 8 km beach near Yakutat, Alaska was counted, weighed, measured for mesh size, and tagged periodically from September 1985 to September 1987 to determine deposition rate, fate, and net characteristics. Approximately nine fragments of trawl web were deposited per km of beach per year. Significantly more fragments were washed ashore during the fall and winter than during the spring and summer. A total of 165 fragments of trawl web were tagged of which 72 (44%) were recovered during the last survey in September 1987; most (73%) fragments recovered remained near their original tagging location. Fragments not recovered probably were either washed inland or buried by sand during storms. The average weight of a fragment of trawl web was 4.0 kg and one-third of the fragments sampled had mesh sizes (≥ 15 cm) with the potential, while adrift at sea, to entangle northern fur seals.

Kaiser, M. J., Bullimore, B., Newman, P., Lock, K., & Gilbert, S. (1996). Catches in 'Ghost Fishing'' Set Nets. *Marine Ecology Progress Series, 145*(1-3), 11-16 https://doi.org/10.3354/meps145011

Both trammel and gill. nets are used to catch marine fishes and crustaceans around the British Isles. Their use is controversial in areas where there is a risk of incidental catches of seabirds or marine mammals. An additional concern is the fate and fishing capabilities of nets when they are lost either as a result of bad weather or when they are damaged by mobile fishing gear. Few, if any, studies have ascertained for how long or effectively these lost nets continue to fish, more commonly termed 'ghost fishing'. Two types of fixed gear, a gill and trammel net, were set by a commercial fisherman ca 1000 m

offshore from a rocky coastal area in southwest Wales, UK. One end of each net was cut free to simulate net loss. The nets were then allowed to fish continually for 9 mo, during which time they were surveyed by divers recording catches by direct observation, still photography and video camera survey. Several hours after both nets had been set, a large number of dogfishes were caught, causing the nets to collapse. Within 1 d, 2 commercial crustacean species, spider crabs Maja squinado and brown crabs Cancer pagurus, were attracted to the dead and decomposing fishes. Many of these animals also became trapped in the netting and were fed upon by their conspecifics and other scavengers. Some of these crustaceans also became entangled and died, producing a sequence of captures throughout the observation period. Catch rate began to decline within a few days of the initial deployment, probably related to a decline in the effective fishing area. The results indicate that lost nets could continue to catch commercial crustacean species for at least 9 mo after initial loss.

Macfadyen, G., Huntington, T., & Cappell, R. (2009). *Abandoned, Lost or Otherwise Discarded Fishing Gear.* United Nations Environment Programme FAO Technical Paper No. 523 UNEP Regional Seas Reports and Studies No. 185. Rome. Retrieved from http://www.fao.org/docrep/011/i0620e/i0620e00.htm

This report reviews the magnitude and composition of ALDFG, and while noting that information is not comprehensive and does not allow for any global estimates, suggests that gillnets and fishing traps/pots may be the most common type of ALDFG, although netting fragments may also be common in some locations. The impacts of ALDFG are also considered and include: continued catching of target and non-target species (such as turtles, seabirds and marine mammals); alterations to the benthic environment; navigational hazards; beach debris/litter; introduction of synthetic material into the marine food web; introduction of alien species transported by ALDFG; and a variety of costs related to clean-up operations and impacts on business activities. In general, gillnets and pots/traps are most likely to “ghost fish” while other gear, such as trawls and longlines, are more likely to cause entanglement of marine organisms, including protected species, and habitat damage.

Morishige, C., & McElwee, K. (2012). At-Sea Detection of Derelict Fishing Gear in the North Pacific: An Overview. *Marine Pollution Bulletin, 65*(1), 1-6 https://doi.org/10.1016/j.marpolbul.2011.05.017

There are numerous known impacts of derelict fishing gear (DFG) to marine ecosystems and safe navigation around the world. To mitigate these impacts, the preemptive detection and removal of DFG at sea are being pursued. This special issue focuses on the North Pacific Ocean because of historic and ongoing research on DFG in the area, particularly as it relates to the Hawaiian Archipelago. In order to develop an effective detection strategy, information and expertise from three disciplines must be integrated: marine debris, oceanography, and remote sensing technology. Building upon results and discussions during a workshop held in December 2008, this special issue provides both results of original research and review papers, pursuing each discipline as it relates to DFG and outlining a multi-faceted strategy to effectively detect DFG at sea. This strategy serves as a roadmap, taking us closer to realizing the goal of detecting and removing DFG at sea.

Nash, A. D. (1992). Impacts of Marine Debris on Subsistence Fishermen an Exploratory Study. *Marine Pollution Bulletin, 24*(3), 150-156 https://doi.org/10.1016/0025-326X(92)90243-Y

As a first step, the study investigates two beaches close to Jayapura, Irian Jaya province, Indonesia, for types and amounts of waste. The source of litter is a municipal dumpsite on the coastline in a nearby bay. In that bay lives a small community of traditional fishermen. These fisherfolk mainly use gill nets, hook and line, or

gather shellfish and molluscs by hand. The respondents described impacts such as propeller entanglements, foulings of gill nets and hooks, damage to the fishing gear, and injuries. These problems were viewed by some as serious enough to cause modifications to their fishing behaviour (sometimes against their best economic interest) such as avoidance of some fishing areas, and use of different types of gear. Plastic bags are the most common type of debris reported by the fishermen. More than half of gill net fishing expeditions had debris fouling the nets.

Pawson, M. G. (2003). The Catching Capacity of Lost Static Fishing Gears: Introduction. *Fisheries Research, 64*(2), 101-105 https://doi.org/10.1016/S0165-7836(03)00208-X

Concern over the ability of synthetic nets and traps to continue fishing after they are lost, and the resulting additional mortality of target and non-target species, lead to an international project to quantify the catching capacity of such gears in commercial fishing situations. This special section of Fisheries Research presents eight case study investigations, ranging from gill nets set for hake in coastal waters off Portugal, to traps set for red king crabs in deep water off Norway.

Phillips, C. (2017). Ghostly Encounters: Dealing with Ghost Gear in the Gulf of Carpentaria. *Geoforum, 78*, 33-42 https://doi.org/10.1016/j.geoforum.2016.11.010

Ghost gear-abandoned, lost, or otherwise discarded fishing gear-has been recognised as a global environmental challenge since the mid-1980s, and yet little social science attention has fallen on the phenomenon. This paper explores how the burden of global fisheries, materialised through its gear, is experienced and managed. How is ghost gear encountered? How is it understood? What influence does it have, and what responses does it provoke? To consider these questions, the paper begins with detailing of an encounter with ghost gear and Aboriginal rangers on the eastern coast of the Gulf of Carpentaria, northern Australia. Understanding encounters as tangles of interlaced threads, rather than isolated intimacies, the paper also follows ghost gear beyond the expetience of beach clean-up. How ghost gear journeys to this beach, and the mobilities and meetings that occur during its travels is explored, as well as the policy responses to ghost gear that figure it primarily as marine debris to be managed through territorial control as isolated 'waste'. These more-than-human stories offer insights into the distributed agencies, complex relations, and differential responsibilities involved in the phenomenon of ghost gear, and efforts to deal with it as part of land-sea assemblies.

Richardson, K., Gunn, R., Wilcox, C., & Hardesty, B. D. (2018). Understanding Causes of Gear Loss Provides a Sound Basis for Fisheries Management. *Marine Policy, 96*, 278-284 https://doi.org/10.1016/j.marpol.2018.02.021

Derelict fishing nets comprise a significant amount of the marine debris in the world's oceans and on its shorelines. These ‘ghost nets’ result in economic losses for the fishing industry, pose hazards to navigation at sea, and can entangle marine and terrestrial wildlife. Ghost nets are an acute problem along Australia's northern coastline, with most nets originating from Southeast Asian fishing vessels outside Australia's Exclusive Economic Zone (EEZ). To understand the causes of gear loss and identify tractable solutions to this transboundary problem, Australian and Indonesian fishers (N = 54) were asked why, when and in what circumstances and conditions they are likely to lose gear. Fishers identified snagging of nets (78%) and gear conflicts (19%) as the main causes of gear loss. These interviews informed the development of a fault tree, as a tool to identify the chain of events that result in gear loss or abandonment. The fault tree analysis provides recommendations for interventions and improvements in regional fisheries management to reduce fishing gear loss ultimately resulting from overcrowding, overcapacity and illegal, unreported and unregulated Fishing (IUU).

Richardson, K., Haynes, D., Talouli, A., & Donoghue, M. (2017). Marine Pollution Originating from Purse Seine and Longline Fishing Vessel Operations in the Western and Central Pacific Ocean, 2003-2015. *Ambio, 46*(2), 190-200 https://doi.org/10.1007/s13280-016-0811-8

Fisheries observer data recorded between 2003 and 2015 on-board purse seine and longline vessels operating in the Western and Central Pacific Ocean reported more than 10 000 pollution incidents within the exclusive economic zones (EEZs) of 25 Pacific countries and territories, and in international waters. A majority of the reported purse seine pollution incidents related to dumping of plastics waste. Other common pollution incidents related to oil spillages and to abandoned, lost or dumped fishing gear. Data analysis highlighted the need for increased monitoring, reporting, and enforcement of pollution violations by all types of fishing vessels operating in the Pacific region; a regional outreach and compliance assistance programme on marine pollution prevention and improvements in Pacific port waste reception facilities.

Saldanha, H. J., Sancho, G., Santos, M. N., Puente, E., Gaspar, M. B., Bilbao, A., . . . Arregi, L. (2003). The Use of Biofouling for Ageing Lost Nets: A Case Study. *Fisheries Research, 64*(2-3), 141-150 https://doi.org/10.1016/S0165-7836(03)00213-3

The use of biofouling for estimating the age of lost nets was investigated by means of net loss simulations and sequential retrieval, conducted in the Bay of Biscay (northern Spain) and off the Algarve (southern Portugal). Two trials were conducted in each location at different seasons. At both study sites, heavier colonisation was observed on the upper parts of the retrieved nets than in the bottom sections, irrespective of season. The biomass of fouling organisms was subject to geographical and seasonal variation, being considerably higher in the Algarve and throughout the spring/summer trials. Three bivalve species were selected as key species for net ageing: Anomia sp., Hiatella artica and Pteria hirundo. Bivalve abundance increased over time, until the 7th month of the trials in the Bay of Biscay and the 3rd month off the Algarve, and decreased thereafter. Analyses of the specimens' size evolution over time indicated that the shell length of Anomia sp. could be used for ageing abandoned nets in the Bay of Biscay and that of P. hirundo off the Algarve. However, the use of these particular organisms for estimating soaking times of fishing gear is limited to a specific set of environmental conditions.

Sancho, G., Puente, E., Bilbao, A., Gomez, E., & Arregi, L. (2003). Catch Rates of Monkfish (Lophius Spp.) by Lost Tangle Nets in the Cantabrian Sea (Northern Spain). *Fisheries Research, 64*(2), 129-139 https://doi.org/10.1016/S0165-7836(03)00212-1

Commercial tangle nets used for capturing monkfish were employed in an experiment designed to study the fishing pattern by tangle nets that are lost at sea, a phenomenon commonly known as ‘ghost’ fishing. To simulate lost nets, 27 fleets of tangle nets were deployed on soft bottoms in the Cantabrian Sea shelf at depths between 117 and 135m. Nets were recovered at intervals of 1–12 months and their catches recorded (composition, abundance, size, biomass, preservation state) in two trials, measuring seasonal changes in catch rates. A fleet of tangle nets was operated following commercial procedures next to the abandoned nets, providing simultaneous estimates of commercial catch rates. Monkfish (Lophius budegassa and Lophius piscatorius) dominated the fish catches in abandoned tangle nets (81%). In summer–fall conditions, abandoned nets showed after 135 days catch rates similar to those simultaneously recorded for commercial nets (respectively, 0.18 and 0.22 specimens per 100m of netting), but ceased to capture monkfish after 224 days. In spring–summer conditions, monkfish catches were negligible in abandoned experimental nets and lower in the commercial nets than in the previous trial. The pattern of extended catch rates observed in tangle nets abandoned in deep water differed from studies using abandoned gill and trammel nets in shallow waters, which typically cease to capture fish much sooner. Total monkfish catches by abandoned tangle nets were estimated through a cumulative catch model to be 17.7kg (4.7 specimens) per 100m of netting. Multiplying this value by the estimated number of tangle nets lost annually by the Cantabrian Sea fishing

fleet, it was estimated that 18.1t of monkfish are captured annually by abandoned nets. This represents 1.46% of the commercial landings of these species in the Cantabrian Sea.

Scheld, A. M., Bilkovic, D. M., & Havens, K. J. (2016). The Dilemma of Derelict Gear. *Scientific Reports, 6*, 1-7 https://doi.org/10.1038/srep19671

Every year, millions of pots and traps are lost in crustacean fisheries around the world. Derelict fishing gear has been found to produce several harmful environmental and ecological effects, however socioeconomic consequences have been investigated less frequently. We analyze the economic effects of a substantial derelict pot removal program in the largest estuary of the United States, the Chesapeake Bay. By combining spatially resolved data on derelict pot removals with commercial blue crab (Callinectes sapidus) harvests and effort, we show that removing 34,408 derelict pots led to significant gains in gear efficiency and an additional 13,504 MT in harvest valued at US $21.3 million--a 27% increase above that which would have occurred without removals. Model results are extended to a global analysis where it is seen that US $831 million in landings could be recovered annually by removing less than 10% of the derelict pots and traps from major crustacean fisheries. An unfortunate common pool externality, the degradation of marine environments is detrimental not only to marine organisms and biota, but also to those individuals and communities whose livelihoods and culture depend on profitable and sustainable marine resource use.

Stelfox, M., Hudgins, J., & Sweet, M. (2016). A Review of Ghost Gear Entanglement Amongst Marine Mammals, Reptiles and Elasmobranchs. *Marine Pollution Bulletin, 111*(1), 6-17 https://doi.org/10.1016/j.marpolbul.2016.06.034

This review focuses on the effect that ghost gear entanglement has on marine megafauna, namely mammals, reptiles and elasmobranchs. A total of 76 publications and other sources of grey literature were assessed, and these highlighted that over 5400 individuals from 40 different species were recorded as entangled in, or associated with, ghost gear. Interestingly, there appeared to be a deficit of research in the Indian, Southern, and Arctic Oceans; and so, we recommend that future studies focus efforts on these areas. Furthermore, studies assessing the effects of ghost gear on elasmobranchs, manatees, and dugongs should also be prioritised, as these groups were underrepresented in the current literature. The development of regional databases, capable of recording entanglement incidences following a minimum global set of criteria, would be a logical next step in order to analyse the effect that ghost gear has on megafauna populations worldwide.

Taylor, J. R., DeVogelaere, A. P., Burton, E. J., Frey, O., Lundsten, L., Kuhnz, L. A., . . . Barry, J. P. (2014). Deep-Sea Faunal Communities Associated with a Lost Intermodal Shipping Container in the Monterey Bay National Marine Sanctuary, CA. *Marine Pollution Bulletin, 83*(1), 92-106 https://doi.org/10.1016/j.marpolbul.2014.04.014

Carrying assorted cargo and covered with paints of varying toxicity, lost intermodal containers may take centuries to degrade on the deep seafloor. In June 2004, scientists from Monterey Bay Aquarium Research Institute (MBARI) discovered a recently lost container during a Remotely Operated Vehicle (ROV) dive on a sediment-covered seabed at 1281 m depth in Monterey Bay National Marine Sanctuary (MBNMS). The site was revisited by ROV in March 2011. Analyses of sediment samples and high-definition video indicate that faunal assemblages on the container's exterior and the seabed within 10 m of the container differed significantly from those up to 500 m. The container surface provides hard substratum for colonization by taxa typically found in rocky habitats. However, some key taxa that dominate rocky areas were absent or rare on the container, perhaps related to its potential toxicity or limited time for colonization and growth. Ecological effects appear to be restricted to the container surface and the benthos within approximately 10 m.

Unger, A., & Harrison, N. (2016). Fisheries as a Source of Marine Debris on Beaches in the United Kingdom. *Marine Pollution Bulletin, 107*(1), 52-58 https://doi.org/10.1016/j.marpolbul.2016.04.024

Marine debris from ships has persisted and remains a concern despite international agreements such as MARPOL We report on an analysis of beach litter based on a data set established by the Marine Conservation Society (MSC) Beachwatch weekends. Debris collected around the UK was divided into three main types of debris: (1) plastic, (2) fishing, and (3) fishing related plastic and rubber. Correspondence analysis (CA) was used to examine patterns in the occurrence of debris types on a total of 1023 beaches and debris attributable to fishing was identified on clusters of beaches mainly located on the coasts of Scotland and along the English Channel. General Linear model (GLM) identified fishing as the highest explanatory factor when testing for relationships between litter and proximity to fishing ports and grounds. The results add to the growing body of evidence that the fishing industry is largely responsible for marine debris. Crown Copyright (C) 2016 Published by Elsevier Ltd. All rights reserved.

Section III: Port Waste Reception

Ball, I. (1999). Port Waste Reception Facilities in UK Ports Iwan Ball. *Marine Policy, 23*(4), 307-327 https://doi.org/10.1016/S0308-597X(98)00057-8

The ability to comply fully with the discharge requirements set out in the MARPOL 73/78 Convention depends upon the availability of adequate facilities on land for the reception of shipgenerated waste. This paper considers ways of ensuring adequate provision of reception facilities, and discusses the approach taken by the UK to reduce the amount of pollution entering the marine environment from the deliberate discharge of waste from ships. Arguably, the most significant of the measures adopted by the UK is the requirement for all ports and harbours to prepare port waste management plans. Disincentives to the use of port waste reception facilities are examined, together with the benefits and shortcomings of various financing arrangements, and compulsory discharge of waste in ports. The paper concludes that the statutory approach to improving the provision and use of waste facilities should be supported by an appropriate awareness campaign to educate shipowners about the need to discharge waste legally to port reception facilities.

Carpenter, A., & Macgill, S. M. (2005). The EU Directive on Port Reception Facilities for Ship-Generated Waste and Cargo Residues: The Results of a Second Survey on the Provision and Uptake of Facilities in North Sea Ports. *Marine Pollution Bulletin, 50*(12), 1541-1547 https://doi.org/10.1016/j.marpolbul.2005.06.021

The aim of this paper is to evaluate the results of a survey of the availability and uptake of port reception facilities within the North Sea area. The evaluation is based primarily on original survey data from the autumn of 2002 which followed on from a similar survey conducted in the summer of 2000. The EU Directive on port reception facilities for ship-generated waste etc. (Directive 2000/59/EC) was due to enter into force in December 2002, and required all EU ports to provide reception facilities to meet the needs of the vessels normally calling in at them. This paper examines the readiness of North Sea ports to meet that requirement and also considers the actual uptake levels of facilities, where ports were able to provide such information.

Commission of the European Communities. (2015). *Inception Impact Assessment: REFIT Revision of EU Directive 2000/59/EC on Port Reception Facilities for Ship-Generated Waste and Cargo Residues.* Retrieved from http://ec.europa.eu/smart-

regulation/roadmaps/docs/2017_move_001_refit_directive2000-59_port_reception_facilities_for_waste_en.pdf

Discharges from shipping are estimated to account for about 20% of global discharges at sea. The protection of the marine environment can be greatly enhanced by reducing these discharges of ship generated waste and cargo residues into the sea. Achieving zero-waste in maritime transport is one of the Commission's policy goals, as set out in the Commission Communication on strategic goals and recommended actions for the EU's maritime transport policy until 2018 (COM(2009) 8)1. Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues ("the PRF Directive") aims "to reduce the discharges of ship generated waste and cargo residues into the sea, especially illegal discharges from ships using ports in the EU, by improving the availability and use of facilities in ports for receiving the waste from ships – "port reception facilities" (Article 1 – Purpose). The Directive is based on the requirements contained in the International Convention for the Prevention of Pollution from Ships (the MARPOL Convention). MARPOL requires the Contracting Parties2 to provide for port reception facilities for waste from ships that is not allowed to be discharged into the sea. Those facilities must be adequate to meet the needs of ships using the port, without causing undue delay.

Hollin, D., & Shaw, D. F. (1997). Comparison of MARPOL Annex V Port Reception Facilities for Garbage in the U.S. Gulf of Mexico and the United Kingdom. In J. M. Coe & D. B. Rogers (Eds.), *Marine Debris: Sources, Impacts, and Solutions* (pp. 245-251). New York, NY: Springer New York https://doi.org/10.1007/978-1-4613-8486-1_21

Annex V of the International Convention for the Prevention of Pollution from Ships, as modified by the protocol of 1978 (MARPOL 73/78), entered into force on December 31, 1988, changing the way ships' wastes are managed. Ports, terminals, and marinas are required to provide adequate waste reception facilities for ships to offload waste generated onboard. Under Annex V, ship-generated garbage includes "all kinds of victual, domestic and operational waste excluding fresh fish and parts thereof, generated during the normal operation of the ship."

Kuznetsov, A., Dinwoodie, J., Gibbs, D., Sansom, M., & Knowles, H. (2015). Towards a Sustainability Management System for Smaller Ports. *Marine Policy, 54*, 59-68 https://doi.org/10.1016/j.marpol.2014.12.016

Larger ports routinely deploy environmental management tools but systematic sustainability management in smaller ports is rare. Accordingly, this paper assesses the sustainability needs of smaller ports in Cornwall and Devon, a case-study, and proposes a systematic method for identifying and managing them. The development and deployment of a Port Sustainability Management System for smaller ports in an environmentally sensitive but economically peripheral UK area is discussed. In-depth collaboration with Harbour Masters to identify sustainability management practice revealed few applications of the theoretical elements of triple bottom line accounting. Rather, semi-structured interviews unearthed the essential elements of port management and facilitated mapping of the forces which underpin port sustainability practices. A constructivist grounded theory approach identified emerging concepts, common patterns and sustainability themes, which were synthesised into a Sustainability Management System based on 11 indicators of knowledge criteria and a self-scoring mechanism. Adopters reported a more proactive stance towards sustainability and safeguarding of local communities, improved understanding, and more effective discourse with stakeholders. Benefits spanned port improvements; awareness of progress, performance, strengths and weaknesses; enhanced communication and reporting; and improved thought processes. Almost all reacted positively and identified multiple benefits, equating to two new jobs in each port.

Mohee, R., Surroop, D., Mudhoo, A., & Rughooputh, B. K. (2012). Inventory of Waste Streams in an Industrial Port and Planning for a Port Waste Management System as Per ISO14001. *Ocean & Coastal Management, 61*, 10-19 https://doi.org/10.1016/j.ocecoaman.2012.02.003

The Port Louis Harbour is the sole port in Mauritius and handles 99% of cargo entering the island. The port area is subject to a wide range of port installations handling, processing and storing a wide range of cargo ranging from petroleum products, coal, cement, edible oil, heavy oil, molasses, wheat, bitumen to fertiliser manufacturing. This study integrated procedures of ISO14001 and was carried out in the context of the UNEP GEF WIO–Lab Solid Wastes Demo Project during the period April 2009 to May 2010. An inventory of the wastes generation and flow from ships and within the industrial port area was conducted, and on basis of the results obtained, an environmental pollution prevention and protection program was developed to eventually assist in the setting up of a Port Waste Management System (PWMS) at the Port Louis Harbour. The PWMS identified the significant environmental aspects and impacts, structure of the organisation, distribution of responsibilities, needs for training, objectives and targets as well as the operational control measures. At the end of the study, suggestions on how to improve the port's environmental performance with regards to waste management were recommended.

National Marine Fisheries Service Northwest and Alaska Fisheries Center. (1988). *A Report to the Alaska Department of Environmental Conservation on the Effects of MARPOL, Annex V, on the Ports of Kodiak and Unalaska.* NWAFC Processed Report 88-26. Retrieved from https://repository.library.noaa.gov/view/noaa/5836

The practical effects of Annex Von U.S. sea ports and coastal communities are unknown. However, since Annex V places severe restrictions on the ability of sea going vessels to dump refuse in the ocean, it is assumed significant quantities of additional refuse from sea-going vessels will be returned to shore for disposal. This additional refuse poses potential problems for municipal waste management systems, particularly in remote Alaskan seaports. In order. to gage the impact of Annex von municipal waste management systems, the Alaska Department of Environmental Conservation, in concert with the National Marine Fisheries Service, contracted with Pacific Associates, a Juneau based consulting firm, to evaluate the waste management systems in Kodiak and Unalaska relative to their ability to handle the increased refuse expected to result from the implementation of Annex V. Specifically, Pacific Associates was asked to: (1) Review current laws and regulations to identify any potential interactions or conflicts with Annex V. (2) Characterize the vessel traffic in Kodiak and Unalaska by type, volume, seasonal patterns, duration of in-port stay, destination while in-port, crew size, etc. (3) Estimate the range of types and volumes of refuse that might be generated by each type of vessel category. (4)Discuss the impact of the delivery of the additional refuseinto Kodiak and Unalaska, and recommend possible solutions for those areas where present capaCity may be inadequate.

Neffa Gobbi, C., Lourenco Sanches, V. M., Acordi Vasques Pacheco, E. B., de Oliveira Cavalcanti Guimaraes, M. J., & Vasconcelos de Freitas, M. A. (2017). Management of Plastic Wastes at Brazilian Ports and Diagnosis of Their Generation. *Marine Pollution Bulletin, 124*(1), 67-73 https://doi.org/10.1016/j.marpolbul.2017.07.004

This study evaluated the management of plastic wastes at 20 Brazilian maritime ports, from three sources: vessels, leased and non-leased areas. The data were obtained from documents on port wastes organized in a relational database with defined protocols (closed form). Analysis of the spreadsheets

prepared and field visits revealed that the main bottleneck in managing plastic wastes at ports is their segregation. In general, more material is segregated and sent for recycling from leased areas than non-leased ones (administered by the government). This relatively better performance in managing the wastes generated in leased areas is probably due to the need for private operators to comply with the international standards such as the Code of Environmental Practice to satisfy the international market.

Ninaber, E. (1997). MARPOL Annex V, Commercial Ships, and Port Reception Facilities: Making It Work. In J. M. Coe & D. B. Rogers (Eds.), *Marine Debris: Sources, Impacts, and Solutions* (pp. 239-243). New York, NY: Springer New York https://doi.org/10.1007/978-1-4613-8486-1_20

Annex V of MARPOL (73/78) is the key international authority for controlling ship sources of marine debris. States representing nearly 70% of the world's registered shipping tonnage have ratified Annex V and presumably are striving toward its full implementation. Annex V requires states "to ensure the provision of facilities at ports and terminals for the reception of garbage, without causing undue delay to ships, and according to the needs of the ships using them." Interestingly, while Annex Y prohibits the discharge of plastics, ships are generally allowed to discharge all their other garbage at sea, at specified minimum distances from shore. In Annex V Special Areas, the discharge norm is far more strict: only food wastes may be discharged outside 12 nautical miles from shore; all other disposal into the sea is prohibited. However, the International Maritime Organization (IMO) Guidelines for the Implementation of Annex V (1988) recommend that, regardless of location, ships should endeavor to use port reception facilities as the primary means for disposal of their wastes. In the context of commercial shipping, this paper briefly examines some institutional factors relevant to the ability of ships and ports to meet these challenges. In particular, we consider whether it is possible to use port reception facilities as the primary means to dispose of ships' wastes.

Øhlenschlæger, J. P., & Gordiani, G. (2012). *The Final Report of the Study on the Delivery of Ship-Generated Waste and Cargo Residues to Port Reception Facilities in EU Ports.* Ramboll produced for: European Maritime Safety Agency, EMSA/OP/06/2011. Retrieved from http://emsa.europa.eu/implementation-tasks/environment/147-port-reception-facilities/1607-study-on-the-delivery-of-ship-generated-waste-and-cargo-residues-to-port-reception-facilities-in-eu-ports.html

This study, carried out by consultants following a public tender, is based on the information received from 40 EU ports. The aim of the study was threefold: to update the data on the delivered ship-generated waste and cargo residue volumes to port reception facilities; to describe the systems in place; to analyse the impact of these systems on the delivery of ship-generated waste and cargo residues.

Oosterhuis, F. (2006). *Free Plastic Waste Disposal in the Ports of Rotterdam and Amsterdam.* Institute for European Environmental Policy, Institute for Environmental Studies Retrieved from https://ieep.eu/uploads/articles/attachments/552a9429-b172-44da-b311-121a8d4623f0/NL%20Port%20Plastic%20Waste%20final.pdf?v=63680923242

Since 1 January 2016, sea-going vessels visiting the ports of Rotterdam and Amsterdam can dispose of their plastic waste without paying a fee. This price incentive is only effective for amounts of garbage that exceed 6 m3 , since for smaller amounts the disposal fee is already included in the port dues and is unrelated to the amount of garbage. The effectiveness of this instrument is not yet known, but it fits well in the framework of the multi-stakeholder 'Green Deal' on ship waste. This Green Deal aims at closing the maritime waste cycle by means of waste prevention and delivering waste in harbours, and at

contributing to the closing of the plastic cycle by collecting plastic waste separately and making it suitable for recycling. The instrument is accepted by all stakeholders and is considered to be suitable for application in other sea ports. Harmonisation of the waste disposal rate structure provisions in the port reception facilities Directive (2000/59/EC) could be helpful to enhance the effectiveness of the instrument.

Pallis, A. A., Papachristou, A. A., & Platias, C. (2017). Environmental Policies and Practices in Cruise Ports: Waste Reception Facilities in the Med. *SPOUDAI Journal of Economics and Business, 67*(1), 54-70 Retrieved from http://hdl.handle.net/10419/169194

With cruise activities continuing to grow, the cruise world and related decision makers take initiatives aiming to handle the produced externalities. Among the key environmental issues is the handling of the various wastes produced on cruise ships. In recent times, cruise lines and ports have put efforts into reducing, selecting and managing generated wastes implementing the requirements of the international regulatory framework (MARPOL 73/78), as well as those imposed by the European legislation. This study focuses on the state port reception facilities (PRF) in the case of the second biggest cruise region of the world, the Mediterranean and its adjoining seas. In particular, it sheds light on the extent that the current practices of cruise ports have achieved a satisfactory level of compliance to the emerging environmental related international regulatory framework. The paper does so via a survey that maps the existing conditions and port based practices followed by 40 port entities that manage 52 cruise ports in the region. The findings record the available facilities, technologies and services suggesting a widespread effective correspondence to required adjustment. It also details a variation as regards the charging practices, that might affect the level playing field. The analysis generates knowledge on the emphasis given by cruise ports in addressing environment challenges. Given that the European Directive governing PRF is currently (2016) under review, the study provides practical recommendations to decision makers and practitioners on what can be done so as to further secure a sustainable cruise future.

Recht, F. (1988). *Dealing with Annex V : Reference Guide for Ports.* National Marine Fisheries Service Marine Entanglement Research Program, NMFS F/NWR-23. Retrieved from https://repository.library.noaa.gov/view/noaa/5856

This reference guide has been assBnbled based on experiences gained in Newport, Orego~during a 15 month pilot project. The project improved refuse reception facilities at the Port of Newport and encouraged the return of refuse to port through an educational campaign. The Port of Newport serves a large and diversified commercial fishing fleet, numerous recreational vessels, and operates a small non-containerized international shipping terminal. The purpose of this project was to assist other ports in meeting Annex V requirements efficiently while promoting a positive image of the Port and its clients. While there are larger and smaller ports it is felt that many of the lessons learned in Newport are generally applicable to the various types of port operations. This guide provides ideas as well as resources. It begins with a summary of the information contained in this report. A short introduction to the marine debris problem, and a description of the Port of Newport and the pilot project are included in the part called "Background". Each section of the "Guidelines" is designed to stand alone, so redundancies may exist in the points made. Section 1 contains recommendations for the port or terminal manager and an outline for a marine debris progrrun. Subsequent sections contain information pertaining to forming and using an advisory group, defining refuse system needs and options, anticipating and recovering costs, refuse system operation and evaluation, and education and promotion. The appendices provide resources and supplemental informatton. Appendix 1 contains

information about the changes made in the Port of Newport refuse reception system. Appendix 2 contains lists of available resources. Appendix 3 provides information on the recycling of plastics and references to other waste management information. The other appendices contain sample surveys, notices, press releases, activity ideas, and other items which can be used or adapted.

Sarinas, B., Docto, D., Dumaicos, M., & Flores, J. (2012). Solid Waste Management: Compliance, Practices, Destination and Impact among Merchant Vessels Docking in Iloilo Ports, Philippines. *Journal of Maritime Research, 9*(2), 73-76 Retrieved from https://www.jmr.unican.es/index.php/jmr/article/view/184

There are no or few existing studies exist on the solid waste management of ships in Fort San Pedro port (FSPP) and Dumangas port (DP), Iloilo, Philippines. Thus, this descriptive-survey determines the compliance and practices on ship's solid waste management, its impact to crew members on board the vessel and the fate of these solid wastes during docking. Nine ships served as samples, six of which are Ro-Ro from DP and three passenger-cargo vessels from FSPP. There were 141 crews were interviewd which comprise of six masters (four masters from DP and two from FSPP), three chief officers (two from DP and one from FSPP), 50 crew from Ro-Ro vessels at DP and 82 crew from passenger vessels in FSPP were interviewed on the impacts of solid waste management. The results showed a 100% compliance to solid waste management among vessels in both ports while in wastes practices' on board, specific garbage bins where used by these vessels. Consequently, these vessels upon reaching the receiving port, relinquish their solid wastes to the "Golden Dragon" that collects solid wastes. The present study showed that vessels in both ports observe the Annex V of the MARPOL 73/78 and reveals an eco-friendly shipping.

Svaetichin, I., & Inkinen, T. (2017). Port Waste Management in the Baltic Sea Area: A Four Port Study on the Legal Requirements, Processes and Collaboration. *Sustainability, 9*(5), 17 https://doi.org/10.3390/su9050699

The cruise ship industry has become a well-implemented industry in the Baltic Sea area, and each year, the number of cruise ship passengers rises steadily. Efficient waste management in cruising ports around the Baltic Sea is a crucial element in minimizing environmental impacts. This research involves the four selected ports of Copenhagen, Helsinki, Stockholm and Tallinn. The study applies statistics and interview data to the analysis of waste management systems for cruise ship-generated waste. The interview data involves 12 executives and professionals responsible for environmental issues and decision making in their respective ports. The interviews highlighted the need for standardized environmental legislation and related procedures, which would result in coherent measurement systems. These systems would enable transparent environmental monitoring, thus maintaining the ports' competitiveness. A common environmental legislation would support the emerging waste management system for the whole Baltic Sea area. The study suggests that ports should focus on handling specific types of wastes and collaborate as a spatial network. Specialization to allow the discharge of certain fractions of waste is essential. The paper concludes by addressing demands for future research, particularly vessel-and customer behavior-focused studies.

Wallace, B., & Coe, J. M. (1998). *Guidelines for the Provision of Garbage Reception Facilities at Ports under MARPOL Annex V.* NOAA Technical Report NMFS 136. Retrieved from https://repository.library.noaa.gov/view/noaa/3049

This report offers guidelines for the provision of adequate port reception facilities for vessel-generated garbage under the requirements ofAnnex V ofthe International Convention for the Prevention of Pollution From Ships, 1973 (MARPOL 73/78), Regulations for the Prevention of Pollution by Garbage from Ships. MARPOL Annex V prohibits at-sea disposal of plastic materials from vessels, and specifies the distance from shore at which other materials may be dumped. Annex V also requires the provision ofport reception facilities for garbage, but it does not specify these facilities or how they are to be provided. Since the at-sea dumping restrictions apply to all vessels, the reception facility requirement applies to all ports, terminals, and marinas that serve vessels. These guidelines were prepared to assist port owners and operators in meeting their obligation to provide adequate reception facilities for garbage. The report synthesizes available information and draws upon experience from the first years ofimplementation ofMARPOL Annex V.

Section IV: Ship-based Plastic Waste Reduction Strategies

A.T. Kearney Inc. (1989). *Dealing with Garbage under MARPOL Annex V : Examples of Compliance Approaches Used by the Shipping Industry.* National Marine Fisheries Service Marine Entanglement Research Program Retrieved from https://repository.library.noaa.gov/view/noaa/9169

To identify the range of approaches and techniques used by the commercial shipping and cruise industries using U.S. waters and at U.S. ports to comply with MARPOL Annex V, telephone interviews with shipping company and port operations personnel were conducted. The interviews were conducted between May and November 1989. The purpose of the interviews was to find out how a cross section of companies with different types of vessels were complying with MARPOL Annex V. The results of the interviews are, therefore, not a comprehensive survey of the shipping industry'S response to MARPOL Annex V. The approach to MARPOL Annex V compliance used by the companies and at the ports was not known before the telephone contact was made. This report summarizes the interviews conducted. It describes the approach and techniques used to comply with MARPOL Annex V by six companies with ocean going commercial vessels, two cruise lines operating out of U.S. ports, seven ports, and one barge company operating on the inland waterways. In addition, activities by the U.S. Navy to manage plastic and other solid waste are summarized. Military vessels are not included in MARPOL Annex V, but under U.S. law, military and other public vessels have until December 31, 1993 to comply with the new at sea garbage disposal limitations. The results of a survey of vessel operators on their knowledge of MARPOL Annex V and their method of compliance by the U.S. Coast Guard in Honolulu, Hawaii are also presented. The report is organized around four headings: ocean going commercial vessels, cruise lines, ports, and other. This report was prepared as part of a shipping industry marine debris education program sponsored by the National Oceanic and Atmospheric Administration's (NOAA) Marine Entanglement Research Program.

A.T. Kearney Inc. (1989). *Model Plastics Refuse Control and Minimization Plan for Ships.* produced for: National Marine Fisheries Service Marine Entanglement Research Program. Seattle, WA. Retrieved from https://repository.library.noaa.gov/view/noaa/8997

On December 31, 1988, with the entry into force of MARPOL Annex V. tbe way the shipping industry handles garbage changed. Over the side is no longer tbe unquestioned practice for garbage disposal

MARPOL Annex V probibits disposal of plastics in the ocean and specifies the distance from shore that all other garbage may be dumped. It does not, however. specify how compliance is to be achieved. The appropriate approach to compliance varies and depends on a number of factors including route, type and size of vessel, on board garbage handling and processing equipment, storage space, and crew size. Plastics control and minimization are integral pans of MARPOL Annex V compliance. This document presents a model plastics control and minimization plan. It was developed based on guidance documents on MARPOL Annex V implementation, shipboard waste management plans, and actual practices and techniques used by shipping companies to comply with MARPOL Annex V. The plan is divided into three parts (1) Techniques to Control and Minimize Plastics on Vessels. This section presents examples of some of the techniques used by shipping companies to comply with MARPOL Annex V. (2) Model Plastics Refuse Control and Minimization Plans (or Ships. This section presents examples of plans to reduce and control plastic garbage on vessels. These model plans are also examples of different approaches to MARPOL Annex V compliance. (3) Marine Debris Education Program (or the Shipping Industry. This section organizes existing marine debris education techniques and malerials into a Cfe'N awareness training program on MARPOL Annex V and marine debris. This Model Plastics Refuse Control and Minimization Plan for Ships was prepared by the Kearney Centaur Division of AT. Kearney. Inc. for the National Oceanic and Atmospheric Administration under Contract Number 52ABNF800132. The plan outlines techniques being used by the shipping industry to comply with MARPOL Annex V requiremenu that prohibit at sea disposal of plastics and place restrictions on at sea disposal of other types of garbage. It includes examples of different formats for a plastics ooolrol and minimization plan. It also includes techniques (or use in crew education and training about MARPOL Annex V and the consequences of marine debris. This document is pan of a marine debris education program for the Shipping industry.

Bean, M. J. (1987). Legal Strategies for Reducing Persistent Plastics in the Marine-Environment. *Marine Pollution Bulletin, 18*(6b), 357-360 https://doi.org/10.1016/S0025-326x(87)80026-7

A variety of legal strategies could be employed to address aspects of the problem of persistent plastics in the marine environment. These include strategies based on international agreements, federal legislation, and state law. At the international level, plastic pollution from vessels is addressed by the International Convention Relating to Pollution from Ships (MARPOL), though its operative provisions are not yet in force. Vessel-source pollution can also be addressed, with varying degrees of effectiveness, through pollution laws, fishery and wildlife conservation laws, and fishing gear compensation programmes. These authorities provide a diverse set of opportunities for addressing the entanglement problem, though realizing such opportunities is likely to require an expanded perception on the part of their administrators of the types of hazards addressed by the pollution laws. Various state measures focus primarily on reducing or preventing the problem of generation of plastic pollution from land-based sources. These include several laws that impose degradability standards for certain plastic products or attempt to encourage recycling of plastic waste. The experiences of various states that have enacted such laws are described and recommendations are made with respect to needed measures for more effective implementation of such laws.

Chen, C.-L. (2015). Regulation and Management of Marine Litter. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine Anthropogenic Litter* (pp. 395-428): SpringerOpen https://doi.org/10.1007/978-3-319-16510-3_15

To minimize the negative impacts of marine litter, a plethora of instruments has been developed at international, regional and national levels to prevent, reduce and manage marine litter. They represent

a wide range of international, regional and national efforts devoted to combat marine litter. The goal of this article is to provide an overview of these instruments, to identify the potential gaps in the existing management body and suggest solutions. As it is impossible and impractical to cover the gamut of all relevant instruments in detail within the scope of this chapter, I will first consider the general mechanisms of the instruments and refer to specific ones as illustration when appropriate. This approach has the advantage of providing a general, snapshot picture of the management framework of marine litter, while also laying out the specifics of certain instruments, including the management measures contained therein. It should also be noted that marine litter is an issue of, or related to, broader topics, such as marine environmental protection, changes in biodiversity, rafting of invasive species, water quality and hazardous waste, waste and sewage water management as well as eco design and producer responsibility. The instruments addressing these broader issues would also be applicable to marine litter, although not specifically mentioned. However, as such instruments are large in scope and may not encompass the specifics of marine litter management, I will focus on those that specifically address marine litter.

Chen, C. L., & Liu, T. K. (2013). Fill the Gap: Developing Management Strategies to Control Garbage Pollution from Fishing Vessels. *Marine Policy, 40*, 34-40 https://doi.org/10.1016/j.marpol.2013.01.002

It is widely documented that marine debris is detrimental to the marine ecological environment. While there are various sources of marine debris, that generated by ships constitutes a significant proportion. Annex V of MARPOL 73/78 is to regulate the discharge of garbage from ships; in particular, it prohibits all kinds of plastics from being discharged into ocean. However, most fishing vessels are virtually exempt from such regulations due to their low gross tonnage, below 400 t. Given the great number of fishing vessels operating around the world, it can be argued that fishing vessels are a common source of marine debris. This paper aims to propose measures that will fill the gap in international regulations in addressing the problem of vessel-source garbage pollution. An understanding of what constitutes the underlying causes leading to fishers' decision on debris disposal is needed when designing effective measures to reduce garbage pollution from ships. Thus, this paper seeks to identify factors that have the potential to influence fishers' disposal behavior and investigate the association between factors and fishers' intention of bringing garbage back to port. Major factors of a well-developed recycling practice, adequate collection facilities placed at port, fishers' positive views towards marine environments and provision of rewards are identified, which have significant implications for management strategies. Finally, the papers offers suggestions regarding future efforts focusing on debris reduction strategies to further address the problem of garbage pollution from fishing vessels.

Cho, D. O. (2009). The Incentive Program for Fishermen to Collect Marine Debris in Korea. *Marine Pollution Bulletin, 58*(3), 415-417 https://doi.org/10.1016/j.marpolbul.2008.10.004

A significant amount of sea-based marine debris is generated and deposited in Korean coastal waters. The Korean government has removed 66,000 tons of deposited marine debris since 1999. However, to fully address the problem, the generation of marine debris needs to be prevented. As an alternative, Korean government has initiated an incentive program for fishermen, who collect fishing gear or other marine debris while fishing. Although a considerable amount of marine debris is collected and removed from major fishing grounds, the program may not incentivize long-term sustainable behavior, resulting in further discarding of marine debris when the program is completed.

Ellis, J., & Podlich, M. (1997). Recreational Boaters and Marine Debris: How We Can Effectively Reduce Littering. In J. M. Coe & D. B. Rogers (Eds.), *Marine Debris: Sources, Impacts, and Solutions* (pp. 271-276). New York, NY: Springer New York https://doi.org/10.1007/978-1-4613-8486-1_24

Historically, there has been considerable emphasis on identifying the sources of marine debris to narrow the focus of remediation. This has been a valuable exercise, principally because it has shown that every group using the water contributes to the trash problem. Recreational boaters, however, have earned the dubious distinction of being a major source of marine debris. There is no question that boaters have ample opportunity to contribute, because collectively they spend more time on the water than any other potential source group. However, the estimates of debris attributable to recreational boaters are based on assumptions about generation and dumping rates that have not been confirmed.

Hagen, P. E. (1990). The International Community Confronts Plastics Pollution from Ships: Marpol Annex V and the Problem That Won't Go Away. *American University International Law Review* Retrieved from https://digitalcommons.wcl.american.edu/auilr/vol5/iss2/9/

Part I of this Comment provides an overview of the primary sources and quantities of marine plastics pollution. The environmental and economic impacts of plastics in marine waters are also examined. Part II examines the regulation of plastic pollution from ships and analyzes the inadequacy of previous international and United States law governing vessel source plastics pollution. This section also surveys the role of the International Maritime Organization (IMO) and the evolution of the 1973 MARPOL Convention and Protocol of 1978. Part III discusses the enforcement regime of Annex V as well as United States implementing legislation and interim regulations. Part IV analyzes the limits of Annex V and United States implementing legislation in regulating plastic pollution from ships. This part also examines the problems likely to occur through increased and largely unregulated on-board incineration. The Comment .concludes with recommendations for strengthening both domestic and international prohibitions on the disposal of ship generated plastic and ash at sea.

Hartmann, N. B., Huffer, T., Thompson, R. C., Hassellov, M., Verschoor, A., Daugaard, A. E., . . . Wagner, M. (2019). Are We Speaking the Same Language? Recommendations for a Definition and Categorization Framework for Plastic Debris. *Environmental Science & Technology, 53*(3), 1039-1047 https://doi.org/10.1021/acs.est.8b05297

The accumulation of plastic litter in natural environments is a global issue. Concerns over potential negative impacts on the economy, wildlife, and human health provide strong incentives for improving the sustainable use of plastics. Despite the many voices raised on the issue, we lack a consensus on how to define and categorize plastic debris. This is evident for microplastics, where inconsistent size classes are used and where the materials to be included are under debate. While this is inherent in an emerging research field, an ambiguous terminology results in confusion and miscommunication that may compromise progress in research and mitigation measures. Therefore, we need to be explicit on what exactly we consider plastic debris. Thus, we critically discuss the advantages and disadvantages of a unified terminology, propose a definition and categorization framework, and highlight areas of uncertainty. Going beyond size classes, our framework includes physicochemical properties (polymer composition, solid state, solubility) as defining criteria and size, shape, color, and origin as classifiers for categorization. Acknowledging the rapid evolution of our knowledge on plastic pollution, our framework will promote consensus building within the scientific and regulatory community based on a solid scientific foundation.

He, P., & Suuronen, P. (2018). Technologies for the Marking of Fishing Gear to Identify Gear Components Entangled on Marine Animals and to Reduce Abandoned, Lost or Otherwise Discarded Fishing Gear. *Marine Pollution Bulletin, 129*(1), 253-261 https://doi.org/10.1016/j.marpolbul.2018.02.033

Fishing gears are marked to establish and inform origin, ownership and position. More recently, fishing gears are marked to aid in capacity control, reduce marine litter due to abandoned, lost or otherwise discarded fishing gear (ALDFG) and assist in its recovery, and to combat illegal, unreported and unregulated (IUU) fishing. Traditionally, physical marking, inscription, writing, color, shape, and tags have been used for ownership and capacity purposes. Buoys, lights, flags, and radar reflectors are used for marking of position. More recently, electronic devices have been installed on marker buoys to enable easier relocation of the gear by owner vessels. This paper reviews gear marking technologies with focus on coded wire tags, radio frequency identification tags, Automatic Identification Systems, advanced electronic buoys for pelagic longlines and fish aggregating devices, and re-location technology if the gear becomes lost.

International Maritime Organization. (2018). *(Revised) Consolidated Guidance for Port Reception Providers and Users.* IMO MEPC.1/Circ.834/Rev.1. Retrieved from http://www.imo.org/en/OurWork/Environment/PortReceptionFacilities/Documents/MEPC.1-Circ.834-Rev.1.pdf

In view of the need to tackle the long-standing problem of the inadequacy of port reception facilities, the Marine Environment Protection Committee (the Committee), having received valuable input from the Industry Port Reception Facilities Forum, adopted, at its fifty-fifth session (October 2006), the Action Plan on Tackling the Inadequacy of Port Reception Facilities and instructed the Sub-Committee on Flag State Implementation (FSI) to progress the Plan's work items. The Guide to good practice for port reception facility providers and users was developed as one of the work items of the Action Plan as a practical users' guide for ships' crew who seek to deliver MARPOL wastes/residues ashore and for port reception facility providers who seek to provide timely and efficient port reception services to ships.

Kim, S., Kim, P., Lim, J., An, H., & Suuronen, P. (2016). Use of Biodegradable Driftnets to Prevent Ghost Fishing: Physical Properties and Fishing Performance for Yellow Croaker. *Animal Conservation, 19*(4), 309-319 https://doi.org/10.1111/acv.12256

Abstract When synthetic non-biodegradable fishing nets are lost, abandoned or discarded at sea, they may continue to catch fish and other animals for a long period of time. This phenomenon is known as ‘ghost fishing’. Biodegradable fishing nets, on the other hand, are intended to degrade or decompose after a certain period of time under water and thereby lose their ghost fishing capacity more quickly than conventional gear. A biodegradable net material, a blend of 82% polybutylene succinate (PBS) and 18% polybutylene adipate-co-terephthalate (PBAT), was developed. We examined the physical properties and degradability of the biodegradable monofilament, and compared the fishing performance of driftnets made of conventional nylon and of the biodegradable material. When dry, conventional nylon monofilament exhibited a greater breaking strength and elongation than biodegradable monofilament of the same diameter. When wet, the biodegradable monofilament exhibited a stiffness of c. 1.5-fold than nylon monofilament. This suggests that a net made of the less flexible biodegradable monofilament would have lower fishing efficiency than conventional nets. The fishing performance comparisons between the biodegradable and conventional nylon nets, however,

revealed similar catch rates for yellow croaker Larimichthys polyactis. Biodegradable monofilament started to degrade after 24 months in seawater by marine organisms. We conclude that biodegradable netting may become a feasible alternative to conventional nylon netting and can contribute to reducing the duration of ghost fishing. Nonetheless, there remain many uncertainties, challenges and knowledge gaps that have to be solved before we are able to draw firm conclusions about the overall benefits of these materials in driftnet fisheries.

Koss, L. J. (1997). Dealing with Ship-Generated Plastics Waste on U.S. Navy Surface Ships. In J. M. Coe & D. B. Rogers (Eds.), *Marine Debris: Sources, Impacts, and Solutions* (pp. 263-270). New York, NY: Springer New York https://doi.org/10.1007/978-1-4613-8486-1_23

In the 1980s, the U.S. Navy began a long-term program to develop shipboard equipment to manage solid waste. The primary objectives were to improve the efficiency of shipboard waste handling, to reduce the security risks associated with a ship's "trash signature," and to comply with the potential ocean discharge restrictions on trash and garbage, even though the pending international agreements exempted military vessels. Plastics were considered a normal component of the solid waste stream. In 1987 when the U.S. Congress made the international ban on plastics discharge at sea applicable to Navy ships, the U.S. Navy was caught somewhat by surprise. International maritime regulations have always recognized the unique operating constraints of warships and have allowed navies to comply to the extent practicable. Nevertheless, the Navy responded to the challenge and undertook an aggressive program to achieve compliance. This paper summarizes the Navy's response to the unexpected plastics discharge limitations, the regulatory background, the Navy's program strategy, and the status of the Navy's efforts. The formal requirements and policies, adopted by the Navy for shipboard solid waste handling and. disposal, are detailed in OPNAVINST 5090. IB of 1 November 1994.

Lentz, S. A. (1987). Plastics in the Marine-Environment - Legal Approaches for International Action. *Marine Pollution Bulletin, 18*(6b), 361-365 https://doi.org/10.1016/S0025-326x(87)80027-9

Serious problems caused by the presence of plastics and other synthetic materials in the marine environment are well demonstrated. Legal regimes exist to address those problems internationally and regionally through the Law of the Sea Convention, the London Dumping Convention, an international agreement on vessel-source pollution, and regional conventions. This paper describes and compares those legal regimes. All provide appropriate forums for implementing specific mitigation measures and all should be fully utilized to regulate plastic pollution of the ocean.

McElwee, K., Donohue, M. J., Courtney, C. A., Morishige, C., & Rivera-Vicente, A. (2012). A Strategy for Detecting Derelict Fishing Gear at Sea. *Marine Pollution Bulletin, 65*(1), 7-15 https://doi.org/10.1016/j.marpolbul.2011.09.006

Derelict fishing gear (DFG) is a highly persistent form of marine pollution known to cause environmental and economic damage. At-sea detection of DFG would support pelagic removal of this gear to prevent and minimize impacts on marine environments and species. In 2008, experts in marine debris, oceanography, remote sensing, and marine policy outlined a strategy to develop the capability to detect and ultimately remove DFG from the open ocean. The strategy includes three interrelated components: understanding the characteristics of the targeted DFG, indirectly detecting DFG by modeling likely locations, and directly detecting pelagic DFG using remote sensing. Together, these components aim to refine the search area, increase the likelihood of detection, and decrease mitigation response time, thereby providing guidance for removal operations. Here, we present this at-sea detection strategy,

relate it to relevant extant research and technology, and identify gaps that currently prevent successful at-sea detection and removal of DFG.

Øhlenschlæger, J. P., Newman, S., & Farmer, A. (2013). *Reducing Ship Generated Marine Litter – Recommendations to Improve the EU Port Reception Facilities Directive.* Instituite for European Environmental Policy, London, UK. Retrieved from https://ieep.eu/publications/reducing-ship-generated-marine-litter

An important contributing EU law to address one source of marine litter, waste from shipping, is the Port Reception Facility Directive. The study provides an analysis of this Directive, discusses the situation in Member State ports regarding ship waste handling, and provides examples of ports with efficient systems and 'best practices'. The study makes recommendations for improvement of the implementation of the Directive. The study has been based on literature review, phone interviews and meetings.

Palabıyık, H. (2003). Waste Management Planning for Ship Generated Waste. *Journal of Naval Sciences Engineering, 1*(2) Retrieved from https://dergipark.org.tr/jnse/issue/9983/123402

The most considerable purpose of waste management plans and reception facilities is to reduce and eliminate dumping wastes illegally to the sea environment. Many examples have already demonstrated that unsatisfactory waste handling and/or even illegal dumping take place in many ports around the world due to inefficient waste management operations, lack of control, recovery systems and inefficient information flow [1]. Especially the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and European Council Directive on port reception facilities for ship generated waste and cargo residues, which requests ports to prepare and implement port waste management plans, provide on international framework on management of ship and port wastes.

Seas at Risk. (2011). *Ship Waste Dumping and the Clean Ship Concept: How an Improved EU PRF Directive Can Play a Key Role in Cleaning up the Seas.* Retrieved from https://seas-at-risk.org/images/pdf/Seas_At_Risk_Position_Paper160911.pdf

This paper intends to give further insight into the problem of ship-waste dumping and recommends some crucial reforms needed for the Port Reception Facilities Directive (to be acknowledged as the PRF Directive from here in) that can reduce the potential for illegal dumping of waste at sea and in turn facilitate a move towards making the Clean Ship concept a reality. The paper is broken down into 4 chapters: 1) Ship waste dumping, the problem; 2) The Clean Ship concept in relation to ship waste; 3) Problems associated with ship generated waste in Europe; 4) Detailed recommendations on the review of the PRF Directive (and other associated instruments)

Senarak, C. (2016). The Use of Seasons in Preventing Marine Pollution from Cargo Ships in Laemchabang Port, Thailand. *Environment and Natural Resources Journal, 14*(1) https://doi.org/10.14456/ennrj.2016.2

The success of marine pollution prevention relies on several managerial tools and knowledge from the interdisciplinary sciences. As the critical source of pollution, seaports need a variety of policies and practices for enhancing their environmental performance. This paper contributes to the existing literature and the implementation by analyzing the season of operational waste from maritime transportation. The seasonal regression analysis (SRA) was performed by using the data from Port

Authority of Thailand. The adjusted model provides a greater statistics for identifying the seasons than that of the original model which was impaired by the obsolete information. To ensure the correctness of the finding, the result of SRA was compared with the seasonal index, goodness-of-fit measure and model error obtained from times series analysis. The conclusion was mutually agreed by two approaches indicating the reliability of the research finding. As the vacillation of operational waste depends on time, port authority should pay a close attention during the high season. Thanks to the enormous amount of operational waste, the monitoring of ship and marine environment should be strictly implemented. However, the pollution-related concern can be alleviated during the interval of the low season due to the scarce demand for discharging operational waste at the port.

Spirkovski, Z., Ilik-Boeva, D., Ritterbusch, D., Peveling, R., & Pietrock, M. (2019). Ghost Net Removal in Ancient Lake Ohrid: A Pilot Study. *Fisheries Research, 211*, 46-50 https://doi.org/10.1016/j.fishres.2018.10.023

A pilot study on the occurrence of abandoned, lost or otherwise discarded fishing gear (ALDFG) was conducted in the Macedonian part of Lake Ohrid. Focussing on abandoned gill nets, different methods for detection and removal of these so-called ghost nets were tested and effects on biota assessed. As shown with the help of echo sounding, diving and creeping (i.e. towing of armed anchors and grapnels, respectively, over the ground), ghost nets were found to be widely present in this freshwater habitat. Altogether more than 12,000 m of nets were retrieved from water column and lake bottom. Free-floating nets were effectively detected using echo sounding, whereas masses of nets accumulated at underwater obstacles were easier to detect by diving. Creeping led to removal of less numerous but actively fishing ghost nets. Ghost nets contained fish at different stages of decomposition (in addition to birds and crustaceans) indicating that abandoned gear continues fishing over extended periods. Together, the results show that ghost nets are not only a marine problem but can significantly pollute freshwater lakes, too.

Wallace, B. (1997). A Strategy to Reduce, Control, and Minimize Vessel-Source Marine Debris. In J. M. Coe & D. B. Rogers (Eds.), *Marine Debris: Sources, Impacts, and Solutions* (pp. 277-286). New York, NY: Springer New York https://doi.org/10.1007/978-1-4613-8486-1_25

The principal focus of this paper is on commercial and publicly owned vessels, including commercial shipping, commercial fishing vessels, passenger cruise lines, mili-tary fleets, research vessels, passenger ferries, tugboats and barges, offshore oil and gas platforms, and offshore service industry vessels. There are few common elements among these categories of vessels. Some vessels are privately owned, others are public vessels. Some primarily use private ports and terminals, while others tend to use public ports and terminals. Some vessels move worldwide, while others have more regional or local movements. Some vessels carry a crew, while others carry crew and passengers. The crew on some vessels totals fewer than 5 persons, while on others the crew totals 500 persons or more. Nonetheless, every vessel generates wastes.