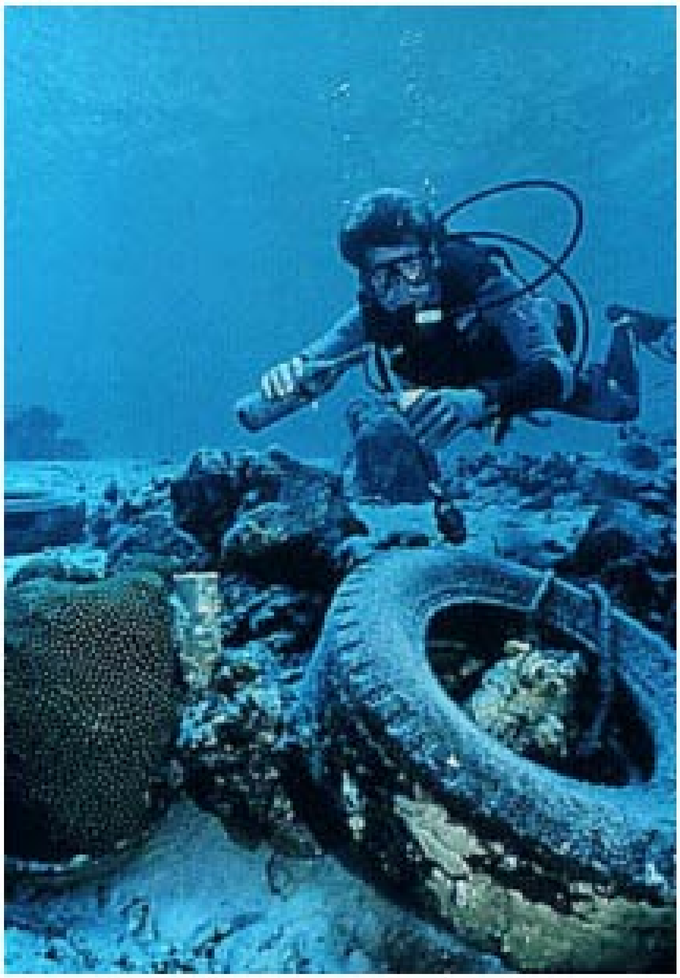
The Marine Debris Research, Prevention and Reduction Act: A Policy Analysis



The Marine Debris Team • Columbia University
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Table of Contents

Executive Summary

The coastal and pelagic oceans are fundamentally important regions of biological productivity, geochemical cycling, and human utility. As providers of food, recreation, and transportation to the global human community, they represent a significant part of the world's economy. Unfortunately, certain human activities are imperiling the health of the oceans. The wide scale dumping of waste, primarily plastics, is one of these threats. Marine debris is generally understood to be discarded anthropogenic, solid waste present in marine waterways. Composed largely of plastics, marine debris can include cigarette filters, baby diapers, automobiles, six-pack rings, beverage bottles and cans, disposable syringes, plastic bags, bottle caps, fishing line and gear, and thousands of other objects. The major sources of this debris are storm water discharges, sewer overflows, litter, solid waste disposal and landfills, offshore mineral and oil exploration, industrial activities, and illegal dumping. The debris poses a growing and direct threat to ocean life, marine habitats, human health, and navigational safety, with potentially serious economic and social ramifications.

Applying the scientific approach towards an understanding of the causes, effects, and cures of marine debris presents a challenging set of variables. The amount and type of debris in the ocean is difficult to measure, and the specific origin of debris and routes by which it travels while at sea are topics that require further research. A fair amount of evidence is accumulating, however, regarding the effects marine debris on marine life. From suffocation to starvation to strangulation, marine debris has lead to thousands of marine animal deaths. Coral reefs are destroyed as lost or abandoned fishing nets barrel across the sea floor. Marine vegetation, and thus important breeding and feeding habitat, is smothered under sheets of plastic that diminish sunlight. Despite these tragedies, conservation biologists are currently unable to fully evaluate how marine debris will affect the long-term survival of many species or the health of the marine ecosystem in general.

Current laws and other government actions do address the issue of marine debris and have for many years, but the inadequacy of these measures is confirmed by the preponderance and persistence of the problem. Insufficient data and research, as well as poor regional and international coordination, make marine debris a difficult problem to address and support. However, by increasing collaboration at all levels of government, improving research and information on the issue, and establishing education and outreach programs to facilitate prevention measures, the Marine Debris Research, Prevention and Reduction Act (the Act) addresses weaknesses in current efforts to mitigate the marine debris problem and has the potential to advance both understanding of and action against marine debris.

The Act mandates several steps within existing government agencies to mitigate the marine debris problem. First, it establishes the Marine Debris Prevention and Removal Program (the Program) within the National Oceanic and Atmospheric Administration (NOAA) to increase public education and awareness, to build strategies among maritime stakeholders to reduce the amount of lost or abandoned fishing gear, and to gather information about the sources, types and effects of marine debris. Second, in order to

increase the base of scientific knowledge surrounding marine debris, NOAA will administer a grant program through which the government will provide funding assistance for relevant research. Third, the Interagency Marine Debris Committee (the Committee) will be expanded to increase support and awareness regarding marine debris across numerous Federal agencies, act as a consulting group for the administering of the grant program, facilitate international collaboration, and make further recommendations to the Congress based on the acquired knowledge and experience. By bringing parties from the public and private sectors together, the Committee has the potential to be a powerful engine of change in addressing the systemic causes of marine debris. Finally, the U.S. Coast Guard is mandated to reduce marine debris infractions both by amending and enlarging upon existing regulations and by developing whistle-blowing programs.

Measuring the success of the Act will be challenging. Due to the lack of scientific research invested into this area, there are many uncertainties surrounding the topic of marine debris. The amount of debris in the seas, its specific affects on animals and ecosystems, and the amount of international dumping are all areas that need further study. The Act may also be evaluated by its ability to stimulate conclusions on these uncertainties, as well as its ability to foster policy-making and further research. The ultimate success of the Act, as measured by the quantifiable reduction of marine debris, will ultimately depend on the degree to which NOAA, the Committee, and the Coast Guard are able to fund and execute their respective functions, and the degree to which the Congress supports the recommendations of the Committee.

The Marine Debris Team
Columbia University
August 17, 2005

Introduction

Marine debris is a classic "tragedy of the commons" environmental problem. As the ocean is a vast commons, individuals can pollute without an immediate negative consequence. The lack of oceanic property rights and the transnational mobility of debris results in a dearth of incentive for private firms to participate in marine debris prevention or clean-up as there is no direct economic incentive for doing so. As such, marine debris is an externality that is not captured by market forces, therefore government intervention and assistance is necessary.

Marine debris is very difficult to regulate because of its diverse origin. Much of the terrestrial marine debris is of indirect origin, such as street litter, runoff from storm drains, landfills, solid waste, and sewer overflows. Because marine waste travels across national borders, international cooperation to obtain data and enforce regulatory policies will be necessary to alleviate the effects of marine debris. There is a lack of research in the area of marine debris. Insufficient knowledge on the source, movement, and effects of marine debris on marine ecosystems hampers the development of effective approaches to addressing the problem.

Current legislation and government bodies address the issue of marine debris, but better coordination is needed on all fronts. Since the oceans are a public good, their protection demands government-aided action. To this end, the Marine Debris Research Reduction and Prevention Act is aimed at generating further research and coordination to mitigate the issues caused by marine debris.

History

The Marine Debris Research, Prevention and Reduction Act was not born in a political or scientific vacuum. Indeed, there has been growing momentum behind the issue of debris in the seas. The first international marine pollution treaty was signed in 1954. Since then, numerous laws and regulations have been passed affecting marine debris. A complete table of these enactments is included as Appendix A. Unfortunately, current laws and regulations have only just begun to address the immense problem of marine debris, a fact perhaps most evident in the Hawaiian Islands. Here, atmospheric conditions force surface currents to converge, bringing vast amounts of debris from throughout the Pacific to the shores and reefs of the Islands. In 2003 alone, 122 tons of debris was removed from coral reefs in the Northwestern Hawaiian Islands.[1]

Due to inadequate data, research on, poor attention to and coordination of the issue, marine debris remains a difficult problem to address. Senator Daniel K. Inouye of Hawaii, with several colleagues, has introduced the Marine Debris Research, and Prevention and Reduction Act to address weaknesses in current legislation. By increasing collaboration at all levels of government, improving research and information on the issue, and establishing outreach programs to facilitate prevention measures, the Marine Debris Research, Prevention and Removal Act has the potential to address the immense problem of marine debris.

Legislative Summary

The Marine Debris Prevention and Removal Program

The Marine Debris Research, Prevention and Reduction Act (the "Act") seeks to reduce the occurrence and adverse impact of marine debris on the marine environment and navigational safety through the establishment of a Marine Debris Prevention and Removal Program (the "Program"). The Program, which will fall under the responsibility of the National Oceanic and Atmospheric Administration (NOAA), will have an annual budget of $10 million for the fiscal years 2006 through 2010.[2] As Administrator of the Program, NOAA will be responsible for assessing the current state of marine debris while working towards generating effective prevention and reduction strategies. To accomplish these goals, NOAA will establish a grant program that will provide researchers and institutions with supplementary funds aimed at mapping debris, identifying inputs, and developing removal and prevention strategies. NOAA will also work towards preventing the loss of fishing gear, which is one of the most significant problems in marine debris.

An additional goal of the NOAA Program is to disseminate information on marine debris. Part of this task will be to create the Federal Information Clearinghouse, a database that will act as a clearinghouse of all pertinent information regarding the issue of marine debris. This database will increase knowledge at all levels of government, across all research entities working on this issue, and internationally so that greater collaboration can be reached in achieving effective prevention and reduction strategies. Finally, NOAA is responsible for increasing education and outreach to the public and other stakeholders in marine debris.

The Coast Guard Program

The Act establishes programs within the United States Coast Guard designed to help reduce violations of current marine debris policy. The Coast Guard will be allocated $5 million annually for the fiscal years 2006 though 2010 to work toward reducing these violations. The Commandant of the Coast Guard (the "Commandant") will be responsible for proposing recommendations for regulatory changes to current policies in an effort to address gaps in implementation. More specifically, the Commandant will undertake measures to increase compliance of Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL) (1973) and Section 6 of the Act to Prevent Pollution from Ships (33 U.S.C. 1905), which specifically relates to the disposal of sea-based garbage. Finally, the Coast Guard will develop voluntary programs encouraging boaters to report observed violations of existing regulations.

The Interagency Marine Debris Committee

The Act recognizes the current lack of coordination at both the federal and international level on the issue of Marine Debris. As part of the Program, the Interagency Marine

Debris Committee (the “Committee”) will be expanded[1] to utilize the collective expertise of variety of agencies to advise and coordinate with NOAA. The chairperson of the committee will be a senior official from NOAA. Other federal agencies that will be involved in the Committee include the United States Coast Guard, the Environmental Protection Agency, the United States Navy, the Maritime Administration of the Department of Transportation, the National Aeronautics and Space Administration, the United States Fish and Wildlife Service, the Department of State, the Marine Mammal Commission, and other federal agencies that have interest in the issue of marine debris as the NOAA Administrator deems appropriate . Non-federal entities that will be involved include state governments, Indian tribes, universities, research institutions, and non-government agencies.

The Committee will (i) work to increase coordination and collaboration among all levels of government as well as the private sector; (ii) identify potential and evaluate proposed prevention and removal programs and advise on their socio-economic feasibility; (iii) in cooperation with Federal and State agencies, submit recommendations for addressing source problems, design prevention strategies, attempt to identify an implementation infrastructure and launch public outreach activities. The Committee will meet at least twice annually will generate a proper definition of “marine debris.” In addition, it is responsible for generating a report to the United States Congress that will report on the progress of the Program to Congress on an annual basis that will identify sources, effects, prevention strategies, recommendations, and alternatives, as well as social and economic analysis of such alternatives. This report will be submitted to the Senate Committee on Commerce, Science, and Transportation and the House of Representatives Committee on Resources. Finally, the Committee will develop a strategy to improve international coordination on reducing marine debris. It will work to institute effective marine debris reduction strategies in international treaties, facilitate partnerships, and assist in multilateral negotiations related to marine debris, as required.

[1] The Interagency Marine Debris Committee currently consists of only three agencies.

Scope of the Problem

Marine debris, generally understood to be discarded anthropogenic solid waste present in marine bodies, poses a direct threat to ocean life, marine habitat, human health and navigational safety, thus resulting in serious economic and social losses. Marine debris is composed largely of plastics and may include cigar tips, baby diapers, six-pack rings, beverage bottles and cans, tires, disposable syringes, plastic bags, bottle caps, and fishing line and gear. Marine debris also comes in the form of toxic waste and organic compounds which have entered the ocean through leaking landfills, dumps, mines, and farms, and via rainfall which washes human waste, debris, and plastics into the ocean through run-off, flooding and sewage pipe overflow. The sheer amount and dispersal range of marine debris is daunting: 14 billion pounds of garbage is dumped annually into the oceans and travels across the globe.[3]

Sources and Transportation of Marine Debris

The accumulation of immense amounts of marine debris over recent decades, coupled with its exceptionally long persistence time within the marine ecosystems, compounds the negative impact marine debris has on marine habitats, flora and fauna, and humans.

Approximately 80% of marine debris is of terrestrial origin.[4] Stormwater runoff and ineffective sewage treatment facilities and landfills are a primary source of terrestrial debris. Because landfills must not retain water, they are created with extensive drainage systems which collect water and channel it to ditches located at the base of the landfill. Trash can also blow off inadequately covered landfills and be deposited directly into oceans.

Littering and illegal dumping are also sources of marine debris. In one year, the world's fishing fleets dumped approximately 135,400 tons of plastic fishing gear and 23,600 tons of synthetic packaging material into the sea.[5] Finally, while commercial vessels are responsible for a significant amount of debris discarded into the marine environment, the U.S. Coast Guard estimates recreational boaters and fishermen are the source of nearly 52% of domestically produced marine debris.[6]

Marine debris sinks to the coastal and ocean sea beds, is trapped by plants or animals, or floats along currents, traveling between continents until it is deposited on beaches. The currents in the North Pacific move in a clockwise spiral, or gyre, which traps debris in this region of the ocean. Referred to as the "eastern garbage patch," the area of debris is roughly the size of Texas and is located in the middle of the Pacific Ocean, near the northwestern Hawaiian Islands (see Figures 1- 3).[7] It is estimated that there are three million tons of debris in this part of the Ocean.[8] The North Pacific subtropical gyre, like the other four major gyres, is caused by monumental tides of air moving from the tropics toward the polar regions. Other ocean gyres include the South Pacific, North Atlantic, South Atlantic, and the South Indian. Air near the equator is heated and ascends high into the atmosphere due to its buoyancy within the cooler air masses that surround it. The rotation of the Earth causes heated air to move westward as it rises, then eastward as it cools and sinks – which creates the clockwise-circulating mass of air above the subtropical North Pacific. The air creates a high-pressure system above, which depresses the ocean's surface and pulls surface water in the same direction as the air above. Towards the center of the gyre, there is a "gentle maelstrom" wherein winds currents are calm. In this area, debris does not get mixed into the ocean but rather remains on the surface.[9]

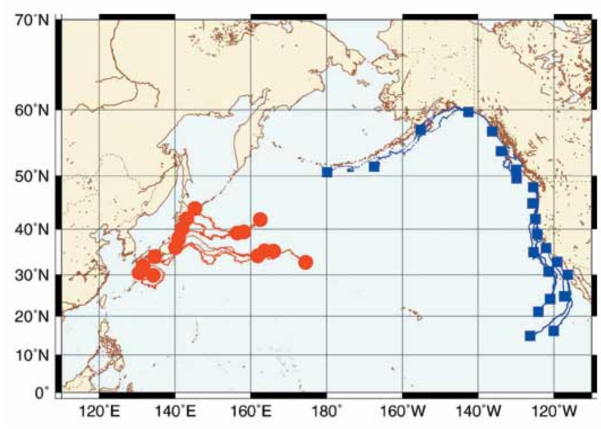


Figure 1: Floatable debris after 183 days

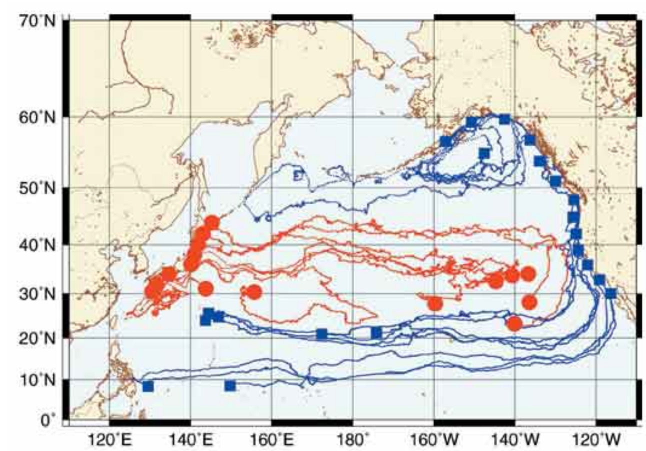


Figure 2: Floatable debris after three years

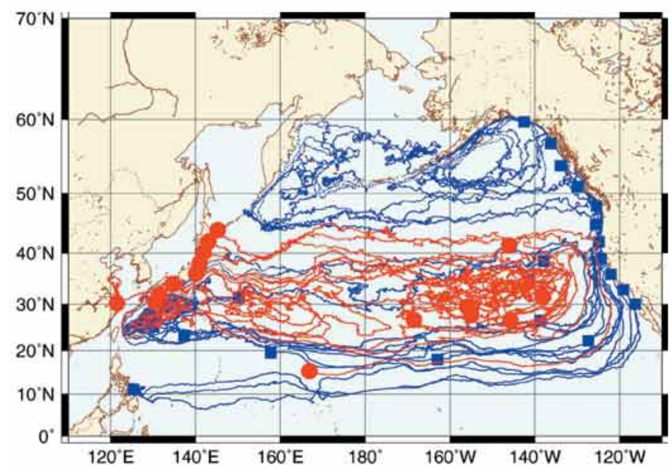


Figure 3: Floatable debris after ten years

Figures 1-3 from *Natural History Magazine* 2003 illustrate the far-reaching effects of marine debris in the oceans. In this map of the North Pacific Ocean, between Japan, Alaska, and the northwest coastline of the U.S., the red and blue dots represent the input points of debris into the ocean. The red and blue lines depict the movement of the debris over time. Figure 1 shows the movement after six months; Figure 2 shows the movement after three years; and Figure 3 displays the movement of the debris after 10 years in the ocean. These images illustrate the scope of marine debris and highlight the fact that international coordination is necessary to effectively address the problem.

Plastics

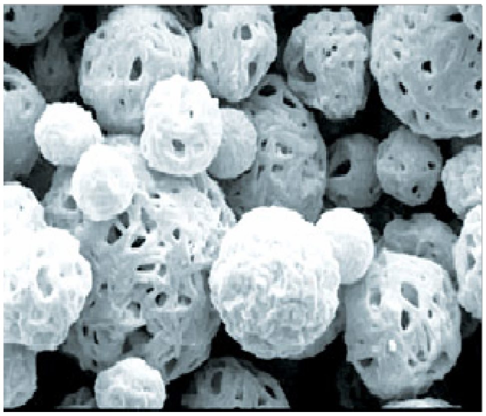
Plastics comprise the majority of marine debris worldwide.[10] Plastics are polymers composed of hydrocarbons bonded into long chains; carbon comprises the backbone of the molecule and hydrogen atoms are bonded along this backbone. Although the basic makeup of many polymers is carbon and hydrogen, other elements can also be involved. Oxygen, chlorine, fluorine, nitrogen, silicon, phosphorous, and sulfur are other elements that are found in the molecular makeup of polymers. Polyvinyl chloride (PVC) contains chlorine. Nylon contains nitrogen, while Teflon contains fluorine. There are also some polymers that, instead of having a carbon backbone, have a silicon or phosphorous backbone. These are considered inorganic polymers.

The chemical properties of plastics make plastics particularly dangerous to the marine environment. Plastics are man-made organic compounds, but unlike natural organic materials they are designed to biodegrade extremely slowly, often taking hundreds of years to break down into particulate matter. The lifetime of plastics at sea varies significantly depending of the material composition and the factors contributing to their breakdown. Lifespan depends on water temperature, abundance of UV-B radiation, and biotic potential of the environment. The primary factor affecting plastic degradation is actinic radiation, or radiation in the spectrum of about 290nm to 315nm (also known as UV-B radiation). Most manufacturers of plastics add a light-stabilizer which extends product life and reduces the rate of photodegradation. Oxidation is another factor in the breakdown of plastic. This process is comparable to the rate of photodegradation. Hydrolysis, or interaction with water, is also possible for some plastics, but not those frequently used for fishing equipment.[11] Seawater further slows the rate of degradation and thus increases the amount of time plastics can persist in the oceans. Cold temperatures stall degradation activity, and foulants in seawater coat the exterior of the object, deflecting UV-B radiation and interfering with the photodegradation process. [12]

The U.S. National Park Service developed an estimate of biodegradation times, which predict 600 years for monofilament fishing lines, 450 years for plastic beverage bottles and disposable diapers, and 10 to 20 years for plastic bags.[13] Biodegradation in this case is characterized by the embrittlement of plastic and not the breakdown of the composite polymers. The devastating effects of embrittlement on the marine environment are discussed in the following section.

Embrittlement of Plastics

Embrittlement is the breakdown of plastic into tiny plastic particulates. Plastics almost never fully degrade, instead forming plastic “dust” which can then be picked up by marine filter feeders and passed up the food chain to accumulate in larger, more toxic levels.[14] Plastic polymers, even as single molecules, are indigestible by all known organisms. Those single molecules require degradation by sunlight or slow oxidation before their constituent parts can truly be recycled into the building blocks of life. There is no data on how long such recycling takes in the ocean – some ecologists estimate 500 years or more.[15]



Embrittled plastic magnified by a microscope.
Source:http://sacoast.uwc.ac.za/education/resources/marinedebris/index.htm

Depending on the buoyancy of the original composite, these particulates can float, suspend, or sink to the bottom. One study found that in the coastal waters off of California as much as 60% of the mass of floating particulate matter smaller than 4.75mm consisted of plastic particulates.[16] Another study of nine remote beaches in the Hawaiian Islands found that 72% of all debris between 1mm and 15mm in size was made of plastic.[17] Miniscule pieces of plastics can also be directly dumped into marine bodies. Plastic scrubbers are tiny pieces of plastic (usually up to 0.5 mm across) found in cosmetic preparations, air- blast cleaning products and hand cleaners and are also roughly the same size as plastic "dust."[18,19]

Plastics as Carriers of Invasive Species and Toxic Chemicals

Plastics are subject to fouling, a process by which algae and other organisms use the plastic as a habitat substrate.[20] Studies have shown that many types of bacterial activity thrive on floating plastics, including harmful algal bloom species.[21] For this reason, plastics serve as vectors for invasive species transport across great distances and to great depths.[22] Plastics can also carry DDE (Dichlorodiphenyldicholorethylene), a breakdown of the pesticide DDT (Dichlorodiphenyltrichloroethane), Nonylphenol[23], and polychlorinated biphenyls (PCBs), which may be transferred to ocean life. Plastics are a known source of polychlorinated biphenyls PCBs in some seabirds and sea turtles.

Impacts of Marine Debris

It has been estimated that hundreds of thousands of pounds of lost or discarded fishing gear now foul the marine environment.[24] The impacts of marine debris on marine life are far-reaching, including entanglement in lost or discarded fishing gear and ingestion of plastics and in many cases results in the mortality of the animals. In addition to being a severe hazard to marine life, human health and navigational safety are also at risk from marine debris. Human impacts range from disease caused by discarded medical waste to navigational hazards for both recreational and commercial boaters.

Ecological Impacts of Marine Debris

Entanglement

Marine debris can become entangled around the neck, flippers, tails, or flukes of animals and can lead to infection, lower mobility, amputation of limbs, and even death. One example of such debris is monofilament, a type of thin, clear fishing line that is very difficult to see. Monofilament is not only a problem for fishermen or others attempting recover lost or discarded line but also for wildlife such as sea birds, mammals or turtles that are unable to detect it before becoming entangled. A second example are ghost nets, which are large trails of discarded or lost nylon fishing net that can form balls weighing a ton and can drift sixty feet below the ocean's surface. When drifting in the sea, ghost nets trap marine wildlife including whales, fish, birds and turtles.[25]

Source:http://www.coastal.ca.gov/publiced/marinedebris.html

According to the Marine Mammal Commission, seabirds and marine mammals have particularly high records of entanglement.[26] Fifty-one species of seabirds, thirty-four species of fish, nineteen species of seal and sea lion, eleven whale and dolphin species and six of the seven turtle species are common victims of entanglement in nylon fishing nets, plastic bags and six-pack rings.[27] NOAA found that fishing gear has accounted for 84% of all tissue abrasions in sponges and cnidarians in coral reefs, leading to partial individual or colony mortality. This is a grave problem because coral reefs provide habitat, food, and safe-holds from predation for many other species.[28]

Ingestion

Marine debris can also be harmful to marine life if it is ingested. Animals often confuse the debris for food, or accidentally swallow debris when it is in the vicinity of their food source. Debris can cause a physical blockage in the digestive system and/or infection, when sharp objects such as fish hooks pierce of the stomach or esophagus.[29] Ingestion of marine debris can also lead to starvation if no vital nutrients are able to pass through the body. Animals may not even realize they need to eat when the ingested debris gives the false sensation of satiation. Turtles are known to ingest plastic bags thinking they are jellyfish, which then block their digestive tract and cause starvation. [30] At least fifty-six species of seabirds are documented to consume polystyrene balls and plastic buoys, likely confusing the debris for dietary items such as fish eggs and crustaceans.[31]

On the island of Maui, 90% of the albatross had ingested plastics in their systems. Other species that have been known to eat plastics and other marine debris include dolphins, whales, and sharks.[32]

Albatross that ingested cigarette lighters.
Source:http://www.coastal.ca.gov/publiced/marinedebris.html

Table 1 shows the wide range animals that are documented to have ingested or become entangled in marine debris. Degraded plastic particles can also be ingested by both detritivores and filter feeders. When other species feed on these smaller animals, the plastic particulates accumulate in animals' stomachs.[33]

Species Group	Total No. of Species Worldwide	Entanglement Records, No. (%)	Ingestion Records, No. (%)	One or Both Types of Records, No. (%)
Sea Turtles	7	6 (86%)	6 (86%)	6 (86%)
Seabirds	312	51 (16%)	111 (36%)	138 (44%)
Sphenisciformes (Penguins)	16	6 (38%)	1 (6%)	6 (38%)
Podicipediformes (Grebes)	19	2 (10%)	0 (0%)	2 (10%)
Procellariiformes (Albatrosses, Petrels, and Shearwaters)	99	10 (10%)	62 (63%)	63 (64%)
Pelicaniformes (Pelicans, Boobies, Gannets, Cormorants, Frigatebirds, and Tropicbirds)	51	11 (22%)	8 (16%)	17 (33%)
Charadriiformes (Shorebirds, Skuas, Gulls, Terns, and Auks)	122	22 (18%)	40 (33%)	50 (41%)
Other Birds	-	5	0	5
Marine Mammals	115	32 (28%)	26 (23%)	49 (43%)
Mysticeti (Baleen Whales)	10	6 (60%)	2 (20%)	6 (60%)
Odontoceti (Toothed Whales)	65	5 (8%)	21 (32%)	22 (34%)
Otariidae (Fur Seals and Sea Lions)	14	11 (79%)	1 (7%)	11 (79%)
Phocidae (True Seals)	19	8 (42%)	1 (5%)	8 (42%)
Sirenia (Manatees and Dugongs)	4	1 (25%)	1 (25%)	1 (25%)
Mustellidae (Sea Otter)	1	1 (100%)	0 (0%)	1 (100%)
Fish	-	34	33	60
Crustaceans	-	8	0	8
Squid	-	0	1	1
Species Total	-	136	177	267

Table 1. Entanglement and ingestion of debris by marine animals. From the Marine Mammal Commission.

Loss of Biodiversity & Habitat

Marine debris also threatens the biodiversity of the oceans through habitat destruction. Coral reefs are damaged by ghost nets that steamroll through sensitive centers of biodiversity. Habitat destruction also occurs when plastic sheeting covers sea grass beds or other bottom-dwelling species, deadening important feeding and breeding grounds.[34]

Fatality caused by debris has a particularly damaging effect on endangered species. Some species, such as turtles, have long life spans and delayed onset of reproductive maturity, which increases the difficulty of the population's recovery from fatality events. By increasing the fatality rate of already vulnerable populations, marine debris may increase the risk of extinction.

Human Impacts of Marine Debris

Marine debris has the potential to cause many different public health and safety problems. Discarded chemicals, medical waste, radioactive waste, and sewage threatens fishermen, recreational boaters and beachgoers alike. Sewage contains nitrates, phosphates and toxic metal compounds known to cause human health problems. Plastic debris from sewer sludge can include tampon applicators, condoms, and disposable diapers, which are a particular problem because they can transmit a variety of gastrointestinal diseases to swimmers.[35] Although sewage-related plastic and other floatable material should be disposed of at treatment sites, these materials enter the ocean when not properly filtered.

Medical Waste

The amount of medical debris in our oceans has increased with the cost of properly disposing such waste.[36] In 1988, the EPA recorded 477 wash-up incidents, with 3,487 medical waste items in six east coast states. [37] Medical debris can include syringes, blood vials, bandages, specimen cups, and blood bars, many of which are now made of plastic and can become floatable debris. The New York State Department of Commerce estimated losses of over 1 billion dollars when medical waste washed ashore along the state's coast in 1988.[38]

Sharps, such as needles, glass, or metal are a serious threat for human health. They can cause lacerations, particularly if washed up on beaches. In addition, needles and other medical sharps have the potential to carry diseases, such as Hepatitis B and HIV, although transfer of these diseases through sharps is currently relatively low. Sharps injuries can also cause local or systematic infections.[39] Discarded vials of blood, old urine samples and syringes could potentially still carry disease; however, the effects of medical waste found in the ocean are still largely unknown.

Medical waste, Coney Island, NY, 1988

© Michael Baytoff

Needles and syringes suspected to have originated from New York City streets and sewer systems after heavy rain storms, washed up onto Long Island and New Jersey beaches during the summer of 1988. Estimated costs from lost tourism and recreation that year were as high as $3 billion.

Source: http://seawifs.gsfc.nasa.gov/ocean_planet_scripts/search.pl

Navigational Hazards

Although human health problems are a major concern, marine debris also poses serious navigational and physical safety hazards. Marine debris can clog cooling water intake valves or become entwined in the propellers of boats. One danger for human health is the collision risk between vessels and large floating objects. Human safety can be endangered if power or steering is lost. For example, it is believed that some loss of lives during storms in the Bering Sea resulted from a loss of ship engine power. Submarines are also susceptible to entanglement in marine debris, particularly in gill nets. Divers can be tangled in marine debris, particularly monofilament line and nets, resulting in injuries or fatalities.[40]

Marine Debris Traps Russian Submarine 625 ft below the Ocean's Surface

A notable example of the navigational hazards posed by marine debris is the entanglement of the Russian mini submarine in August of 2005. The submarine's propeller is believed to have snagged on a fishing net some 625 feet below the ocean's surface. The crew was rescued by a Remotely Operated Vehicle.

Source: http://news.yahoo.com/photos/sm/events/wl/080505russianminisub/p:97

Clearly, marine debris poses a serious threat to marine life, human health and navigational safety. The Marine Debris Research, Prevention and Reduction Act proposes a number of solutions to address weaknesses in current legislation as well as serve as a springboard for future efforts to combat the problem of marine debris.

Analysis of the Proposed Solutions

In order to identify, determine sources of, assess, reduce, and prevent marine debris, the Marine Debris Research, Prevention and Reduction Act establishes the NOAA Marine Debris Prevention and Removal Program and the Coast Guard Program and expands the Interagency Marine Debris Committee. While the framework established by the Act is specific, the government agencies involved are allowed significant flexibility in the implementation of the Act's stated goals. This latitude generates important concerns regarding the effectiveness of the proposed solutions.

NOAA and the Marine Debris Prevention and Removal Program

NOAA is required to map marine debris, conduct an impact assessment of debris, and research ways to prevent debris from contaminating oceans and waterways. Specific mention is made to identify the material, location, age, and origin of debris, as well as further understand its impacts on living marine flora and fauna and their habitat. To better understand the solutions proposed by the legislation, it is helpful to examine the science behind each component of the NOAA Program.

Assessing and Identifying Marine Debris

Although there is still substantial speculation as to the specific sources of marine debris, as previously mentioned, it is estimated that approximately 80% of marine debris comes from terrestrial sources.[41] The waste stream, which includes stormwater runoff, landfills, and sewers, is a principle source of land-based marine debris.[42]

Landfills are a primary source of terrestrial debris. Because landfills must not retain water, they are created with extensive drainage systems which collect water and channel it to ditches located at the base of the landfill. Trash can also blow off inadequately covered landfills and be deposited directly into oceans. To reduce the amount of debris entering stormwater drains, landfill operators must follow regulations placed upon them to cover over landfills daily with six inches of compacted soil. However, this soil can be costly; therefore, many landfill operators are experimenting with other means of covering such as using spray covers of paper or paper/cement

In 1990, the Environmental Protection Agency developed the National Pollutant Discharge Elimination System Stormwater Program to address the negative impact of stormwater runoff. Under the program, operators of stormwater facilities must obtain permits for stormwater discharges. Operators must also implement stormwater pollution prevention plans or stormwater management programs to reduce or prevent the discharge of pollutants into receiving waters.[43] In assessing the problem of marine debris, NOAA will therefore need to examine how inefficiencies in current waste management procedures and programs are contributing to the problem.

Current technologies to ameliorate stormwater runoff problems include a variety of storm filters, including home filters for roof drains, grates for storm drain entrances, rice straw wattles (filters) and sandbags for construction sites, which control sediment runoff and channel debris to filtration systems.[44] Straw and coconut wattles can also be used for water main maintenance and erosion control around hills and construction sites. These devices are particularly important when street-sweeping efforts are suspended and in times of heavy rain when the amount of water entering the system is likely to overflow directly into waterways.

Mapping, Modeling and Tracing Marine Debris

Sophisticated mapping, modeling and tracing technologies are key to assessing the impact of marine debris as well as identifying its sources. These tools allow environmental managers and policymakers to understand the specific point sources of debris, how quickly and where marine debris travels, and finally which regions are most threatened by the problem. Thus, the detailed information provided by mapping technologies may potentially lead to more efficient remediation efforts.

A network of base stations is already in existence and is currently maintained by the United States Coast Guard. The Coast Guard uses a Global Positioning System (GPS) to provide information in real-time to researchers. The database consists of geographical coordinate fields, a description of each surveyed site and the type of marine debris found. One available method for collecting data regarding near-shore habitats and existing marine debris is through the use of acoustic seafloor mapping systems. This technique involves utilizing digital depth sounders and sidescan sonar in conjunction with video surveys.[45] Acoustic seabed classification gathers data on roughness and hardness of bottom reflections from depth sounder echoes. These characteristics are classified by "Hypack" software and are confirmed by diver or video surveys. A second mapping technique is a Remotely Operated Vehicle (ROV) that uses video and acoustics to produce underwater maps. A recent mapping expedition off the coast of Antarctica used the Super Phantom S2 ROV, property of NOAA's National Underwater Research Program. The ROV equipment provided continuous geo-referenced data of seafloor debris fields.[46]

Drawbacks to these techniques include the time-consuming nature of analyzing hours of video footage and the fact that they are restricted in the area of ocean they can cover. Finally, while there are allegedly ten Federal agencies involved in ocean-mapping, lack of coordination and overlap in regions of study have left approximately 90% of the nation's maritime territory unmapped.

The use of complex models that predict pathways of debris based upon wind driven currents will also assist NOAA in its efforts to map marine debris. One such model is the Ocean Surface Currents Simulation (OSCURS), which was developed by NOAA in conjunction with the Alaska Fisheries Science Center to measure the movement of surface currents over time.[47] The model is based on long-term knowledge of ocean currents and the daily affects of wind movement. Although the model was not developed to monitor the movement of marine debris, several accidental spills of floatable cargo have proved fortuitous for this model, allowing fine-tuning of the models components. In 1990, 80,000 pairs of Nikes fell overboard mid-ocean, followed by a spill of 29,000 plastic bathtub toys in 1992, and 1,100 logs in 1996. The spills have allowed OSCURS to develop a simulation for the drift and diffusion trajectories of similar floating objects in the ocean.[48] One uses the model by choosing a start location and a date anytime between 1901 and the present. The model then compiles the daily sea level pressure grid for the chosen criteria. The sea level pressure is converted into east-west velocity components and east-west ocean currents grid. Long-term mean geostrophic currents are factored into the model to yield the total velocity field, or in other words, the speed and direction of the surface waters.[49] Technological advancements such as these make it feasible to track marine debris to its source, an imperative step in marine debris prevention and reduction.

OSCURS has limitations as it only models northern Pacific Ocean surface currents in a 90-km ocean-wide grid from Baja California to China and from 10°N to the Bering Strait from 1901 to the present. In order to improve mapping of marine debris, models must be developed that cover more of the oceans, both vertically throughout the water column and horizontally across the surface of all oceans. There are also uncertainties involved in such research models as they can over and under estimate the input locations. In addition, the ocean system is quite complex; weather changes have the potential to alter trajectories of debris on short time scales. Furthermore, the reliability of determining a source of input from degraded plastics lower in the water column would again create another inconsistency in locating the source of marine debris. Lastly, if models such as OSCURS were to be used, they would need to be modified to give a more accurate location of marine debris input. Only then would it be known whether the Act and its proposed programs are being effective in mitigating the problem of marine debris.

NOAA may also want to utilize programs such as the National Marine Debris Monitoring Program (NMDMP), one of the nation's most comprehensive land-based studies on debris monitoring. Created by the EPA and the Ocean Conservancy, the goal of the NMDMP is to address the lack of information regarding the extent and nature of the problem, with the main focus on tracing the source of marine debris. The program divides U.S. coastline into nine regions based on prevailing ocean currents. Surveys and cleanups are conducted on a 28-day interval, during which time volunteers survey the same 500-meter stretch of beach.[50] The data is analyzed by the Ocean Conservancy and made available to the public on the organization's website. The NMDMP is one example of land-based marine monitoring, and grant funding as part of the proposed NOAA Program.

The cost of utilizing the above technologies (as well as developing new technologies) regarding the mapping of marine debris may be prohibitive. Mapping is time consuming and difficult, considering that much debris is small (monofilament lines and nets, cigarette butts, bottle caps, etc.) and does not float along the water's surface. Of equal concern is the ability to track debris to its exact origin. Because marine debris is a global issue, carried by both oceanic and wind currents, debris that ends up in the U.S. exclusive economic zone may have originated thousands of miles away. As such, the goal of identifying the sources of marine debris may be a difficult and costly one to achieve.

Environmental impact assessments for marine debris may take much longer than the scope of the original funding as outlined in the legislation. With the current dearth of research conducted in this area, many resource and habitat programs may find they are at the edge of current scientific understanding of these issues- and may thus require more time, money and resources than that which is provided under the Act.

Regardless of their drawbacks, mapping technology and research expeditions will remain critical to furthering knowledge of the impact of marine debris and will continue to play an essential role in debris remediation procedures. It is essential that new models be developed which are capable of covering more of the world's oceans, both geographically and vertically throughout the water column. Such models would not only allow scientists to more accurately identify the regions most impacted by marine debris but also allow for retrospective analysis and the tracing of debris back to its point of input into the system. Finally, as marine debris is a global issue, better tracing technologies are needed to effectively inform international coordination efforts.

Reducing and Preventing Loss of Fishing Gear

A second aim of NOAA is to reduce and prevent the loss of fishing gear. Discarded fishing gear accounts for much of the destructive qualities of marine debris. As such, the Act mandates NOAA engage the fishing and maritime industries to reduce marine debris' adverse impacts on navigational safety and marine resources. Specifically, the Act requires efforts be made to prevent and reduce the loss of fishing gear as well as implementation of voluntary or mandatory measures (incentive programs, observer programs, toll-free reporting hotlines, computer-based notification programs) to reduce gear loss and assist in its recovery. As previously stated, most lost or discarded fishing gear is difficult to see and thus costly to remove. To aid in this process, as well as to remove other types of debris, various techniques and technologies can be used.

Currently, the most effective method for removing marine debris is to skim it off the surface. One example is the TrashCat™ debris-collecting vessel, produced by United Marine International. The TrashCat™ skims floatable debris from the surface using a hydrologically powered system of conveyors that can reach to the depth of 2 to 2.5 feet below the surface. The vessel is able to store up to 12,000 pounds of material. Originally commissioned in the early 1980s by the New York City Department of Sanitation to skim polluted waterways near Fresh Kills landfill on Staten Island, NY, today there are over 50 TrashCat™ vessels in use.[51] Most often, they operate at polluted ports and harbors of major cities such as New York, Chicago, and Washington D.C. They are also in use at several U.S. and international hydroelectric and flood control dams, such as Tennessee Valley Authority's Wilson Dam and Appalachian Power Company hydroelectric dam in Roanoke, Virginia.[52]

However, surface-skimming devices are not able to reduce the amount of subsurface marine debris. Unfortunately, few current technologies exist that provide a cost-effective method of collecting submerged and suspended debris. As these devices are necessary for the removal of debris on a large scale, the question of funding is raised. There is currently little economic incentive for the private sector to build and operate such debris-catching machines. This is yet another area where support from the NOAA grant program can influence the science and economics of marine debris.

Education and Outreach

The education and outreach component of the NOAA Program is directed at the public and other stakeholders, and is designed to increase the understanding and awareness of the problem of marine debris and its negative effects. Outreach is to be accomplished through collaborative efforts with current activities conducted under the Marine Plastics Pollution Research and Control Act of 1987, and via the coordination of international marine clean-up programs. As Administrator, NOAA is required under the Act to target fishing firms, gear manufacturers along with other marine-dependant industries to identify the sources of waste, reduce its presence in marine environments, and assess its impacts. The Act also requires NOAA to coordinate these activities with relevant programs included under Section 2204 of the Marine Plastic Pollution Research and Control Act of 1987.[53]

Education programs are of vital importance to the consensus-building process, and can also serve as the basis for behavioral changes. Such programs can work to highlight areas of concern and share information with parties that may be unaware of the extent of the marine debris problem. However, without incentives to encourage participation and more responsible behavior, changing current practices and attitudes may prove difficult. The Marine Plastic Pollution Research and Control Act already requires NOAA to initiate workshops, public service announcements, and the distribution of printed material to achieve these same objectives. Yet it is unknown whether NOAA's activities to date have been sufficient, and if education and outreach efforts are effectively changing behaviors and attitudes towards marine debris. The Marine Debris Research, Prevention and Reduction Act does not delineate specific programs to initiate; outlining only the relevant parties to which activities should be aimed. This may encourage NOAA to simply continue current education and outreach efforts as defined in the 1987 Marine Pollution Act, without re-analyzing their effectiveness or creating new initiatives.

Though the source of the marine debris is global, the problem of debris removal is dealt with on a local and/or regional scale. The remedial efforts of beach cleanup and litter disposal in particular are costs that local authorities and, therefore, taxpayers must incur. These efforts often depend on volunteers, and are often initiated by volunteers. One successful example of such efforts is the International Coastal Clean-up, a global volunteer program organized by the Ocean Conservancy. The International Coastal Clean-up, which takes place once a year, encourages people to visit their local beaches and clean up debris that has washed ashore. The International Coastal Clean-up removed almost 4 million pounds of marine debris from U.S. beaches and involved 160,000 Americans and close to 500,000 volunteers around the globe.

Finally, given the nature of most industry-related marine debris, recovery of discarded fishing gear is difficult and expensive. While an important problem in need of immediate attention, finding and removing these items will require substantial effort and funds. Despite the large participation for beach clean-up events, relying on volunteer efforts to report wrong doings or sea based dumping is not as reliable. There is always someone who has something to lose or a close connection to an industry who is dumping illegally. People may even feel that they have no right to report the information as they do not know the laws or feel such participation does not contribute to a real solution. One way that the legislation could address this misconception is by targeting educational and public outreach programs to convey the severity of the problem and encourage participation.

The Grant Program

The final program requirement for NOAA under the proposed Act is the creation of a 50% matching grant program to outside organizations interested in conducting research relevant to the marine debris issue. While the program provides matching federal funding for projects that have been able to raise partial funds, some research groups may be unable to raise even the first half of funding. The Act does include an exception to this requirement: in the case of research deemed by the Administrator to be of substantial value, a waiver can be made and NOAA is then allowed to fund the entire project. The 50% matching stipulation risks that some projects, unable to source outside funding, will be unable to commence- but gives the program Administrator at NOAA the flexibility to identify important projects and fund them accordingly.

It is crucial that the grants administered under the jurisdiction of the Act investigate how to measure and trace marine debris more efficiently, re-assess the efficiency of existing programs related to marine debris, and locate areas of greatest impact so funding for clean-up efforts may be properly allocated. Most importantly, the grant program under the direction of the NOAA must pursue research efforts that expand the knowledge of marine debris and inform efforts to resolve the problem.

While the legislation itself gives NOAA the authority to develop the guidelines to determine who receives grants, NOAA is expected to coordinate these actions with the Interagency Marine Debris Committee. However, the legislation does not clearly identify the limits of this interaction. Much of the structure of the grant program is up to NOAA; the legislation does provide some criteria regarding areas or potential study, however it lacks clarification of any prioritization among these areas of research. The interagency marine Debris Committee also has some say in the matter although they do not make the final decision. The legislation does state who makes the decisions in awarding grants as well as provide criteria on who is eligible, however the legislation fails to produce clear criteria on which programs should be prioritized. Should prevention measures be a top priority or should they take a back seat to reduction technologies, or mapping techniques? This of course could create some potential problems or conflicts between Committee members and NOAA given the difference in the missions of various agencies. Furthermore, given the amount of money that is allocated to NOAA for grants it is questionable as to whether it will be enough to make a difference in research or whether it will significantly limit the choices on who receives grants.

Federal Information Clearinghouse

NOAA will also be required to establish a Federal information clearinghouse. The purpose of the clearinghouse is to make information about marine debris available to researchers and other interested parties. By encouraging further research, the legislation promotes both interest and participation in the work against this currently little-understood environmental and economic problem.

The Coast Guard Program

Enforcement of Existing Regulations

The Coast Guard is instructed to ensure that ship ports and terminals maintain proper receptacles for the disposal of garbage and plastics, such as to make certain that an adequate number of facilities exist, and to ensure requirements for logging the waste received are being maintained. The Coast Guard will also be responsible for comparing vessel and port logs to determine compliance with the established regulations. The Coast Guard will be required to try and close record keeping gaps that exist within the current system. The gaps are usually found in the details in which ships are instructed to record relating to their debris activities. These records are being inadequately maintained and often exclude details such as time, date, type of garbage, quantity, and location of discharge; data which are required by law. The more stringent record-keeping process outlined by the legislation will also be extended to include a number of vessels previously unmonitored in an effort to reduce overall illegal dumping. In addition to enforcement of the existing laws, the Coast Guard can also provide recommendations for statutory and/or regulatory changes that they believe would improve compliance with those laws, also the Coast Guard will also expand on-board waste management requirements. The framework suggests that this could include expanding existing requirements for maintaining ship-board receptacles to smaller vessels and requiring all vessels to have viable waste management plans in effect.

On advantage of this framework is that the Coast Guard is already an established agency with the resources and experience to carry out the necessary enforcement of the legislation; however, the drawbacks of the solution piggyback on the advantages. The fact that the Coast Guard is already an established agency means that it already has many other responsibilities, which may impede the effectiveness of enforcing regulations pertaining to marine debris. The staff of the Coast Guard is already responsible for a host of other programs; therefore the enforcement of marine debris violations may end up being of low priority to the Coast Guard due to their stratified focus on other important responsibilities. In addition, the required enforcement necessary for this bill to be effective may overextend the Coast Guard's limited capabilities due to the fact that the program is not highly funded, which makes thorough enforcement contingent on very limited resources.

It has also been recognized that the Coast Guard's information collection system is burdensome and inefficient. Data input times can take up to 10 hours for one case, and the time spent completing these reports takes away from the time the Coast Guard can spend actually enforcing the Act. Their task is also daunting due the sheer number of recreational and fishing boats. Enforcement of each violation through inspection and patrolling is nearly impossible. Finally, the typical standard checklist pertaining to inspection of vessels has not been established in the case of the marine debris legislation. This small oversight makes it hard for inspectors to know what they are supposed to be looking for and therefore enforcing.

Voluntary Programs

A second component of the proposed solution is that the creation and implementation of voluntary reporting programs targeting commercial vessel operators and recreational boaters. More specifically, one program will involve reporting damage caused by marine debris; another will involve reporting violations witnessed by other boaters and a third program will encourage United States flag vessels to report foreign ports with inadequate facilities for garbage disposal.

A concern regarding the above initiatives is the effectiveness of voluntary reporting and compliance programs. Without a concrete reward/fine system in place, incentive to participate in these programs may be minimal. The burden of proof in these cases is of note as well. In many cases, the violation of regulations appears to be too difficult to prove because the burden of proof is placed on the party making the report, not the party acting illegally. Within the current system, very few cases make it through all the red tape and actually incur penalties for their actions. For example, in February of 1995, out of 725 MARPOL V cases reported, only 10% resulted in assessment of a penalty against the violators, and the average fine was only $6,200 per case.[54]

Finally, one of the most important weaknesses within the proposed solution is that the Coast Guard can only enforce legislation on vessels within the United States exclusive economic zone, which does not apply to foreign licensed ships. The requirement of ships to maintain garbage discharge records do not apply to foreign licensed vessels. This required log is one of the main sources of evidence used by the Coast Guard in illegal dumping cases. In addition, any debris dumped in foreign countries without legislation such as this, will drift into the oceans of the United States and exacerbate the problem.

Interagency Marine Debris Committee

A third solution outlined by the Act is the expansion of the Interagency Marine Debris Committee in order to better coordinate marine debris research and activities among Federal agencies and non-federal entities. Within twelve months of the enactment of the Act, the Committee is required to submit a report to Congress that identifies the sources of marine debris. The report will examine the ecological and economic impacts of marine debris, alternatives for reducing, mitigating, preventing, and controlling the harmful affects of marine debris, the social and economic costs and benefits of such alternatives, and recommendations regarding both domestic and international marine debris issues.[55] The Committee will also be required to submit annual progress reports to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Resources of the House of Representatives.

Although collaboration between agencies is ideal, there are many issues that may hinder the effectiveness and success of the Committee. The issue of sharing power is important because partners rarely come to the table equal in power.[56] NOAA has the ultimate authority to develop the guidelines to determine who receives grants. NOAA is expected to coordinate these actions with the Interagency Marine Debris Committee. However, the legislation does not clearly identify the limits of this interaction. While the Committee has some say in the matter, it does not make the final decision about prioritizing grants. Because the legislation fails to produce clear criteria on which programs should be prioritized, conflicts may arise between Committee members and NOAA given the differences in the missions of member agencies. Therefore, it is vital that a skilled management system is created in order for these agencies and entities to define shared goals and priorities and to work together in an effective and efficient manner.

Measuring the Success of the Marine Debris Research, Prevention and Reduction Act

The Marine Debris Research, Prevention and Reduction Act establishes a framework in which NOAA, the Coast Guard, and other federal and non-federal entities may increase coordination, collaboration, and research on marine debris issues. Other goals of the Act include identifying the sources of marine debris, assessing the magnitude of the problem, and reducing and preventing loss of fishing gear. Thus, measuring the success of the Act will involve evaluating the effectiveness of the NOAA Program, the Federal Information Clearinghouse, the United States Coast Guard Program, and the Interagency Marine Debris Committee as well as whether the stated goals in the legislation are being achieved. Finally, while a reduction in the overall amount of marine debris in U.S. waters would certainly constitute success, such a measurement is extremely difficult to quantify. However, there exist scientific indicators which are able to quantify reductions in debris, and such tools, although limited, may also be utilized in measuring the success of the Act.

The NOAA Prevention and Removal Program

The grant program is an important component of the NOAA Program because it will provide the foundation for much-needed research on marine debris. Effective implementation of the grant program will be essential in ensuring that the scientific community views it as a viable source of funds to supplement their research. A tangible way of monitoring the program's success is to look at changes in grant proposals as a proxy for gauging the marine debris community's respect of the program. Efficient management of the program by NOAA may be reflected in the development of guidelines, clear definitions of priority research areas, and responsible management of grant awards.

The Federal Information Clearinghouse

NOAA's development of the Federal Information Clearinghouse will help achieve the goal of disseminating information and research on marine debris. As there is currently no centralized database regarding marine debris, the Clearinghouse is a valuable component of the Act and has the potential to mitigate the paucity of current, easily-accessible data on marine debris. Measurements of success may include the scope and depth of information uploaded, credibility of data sources, ease of accessibility, and number of access requests and responses.

The Coast Guard Program

The Coast Guard program will help achieve the goal of reducing violations of existing law and regulations relating to marine debris. The program may be evaluated on whether an increase in the frequency of reported violations of MARPOL Annex V occurs after the Act is implemented. The establishment of additional on-board and port waste receptacles will also be an important indicator.

Success of voluntary reporting programs established by the Coast Guard will be demonstrated by the number of responses to reported violations as well as the outcomes of such responses, which include evaluating the severity of violations, the promptness of the Coast Guard response, and the revenue generated from imposed fines.

The Interagency Marine Debris Committee

The expanded Interagency Committee will play an important role in achieving the goal of increasing the coordination and collaboration of efforts to address marine debris issues. The Committee will be collectively evaluated on its ability to coordinate across federal agencies by producing a clear definition of marine debris, defining priority areas for research, and compiling annual progress reports and recommendations for Congress. The Committee will also be evaluated on its ability to foster international collaboration through effective coordination with the International Maritime Organization as well as its participation in potential multilateral treaty negotiations concerning marine debris.

Scientific Indicators of Success: A Reduction in Marine Debris

A performance measurement system will likely be created during the implementation phase of the Act, and will therefore utilize a variety of scientific measurements to quantify a reduction of marine debris within U.S. waters and from U.S. sources. One way to measure reductions in marine debris is through the use of survey techniques, such as debris-related underwater mapping, which are eventually logged with Global Positioning Systems (GPS) software and analyzed with Geographic Information Systems (GIS).[57] This software is able to determine changes in debris density of the surveyed area, and ultimately provides information regarding the density, distribution, and type of debris within a specific region. The use of statistical methods in analyzing these data may allow one to infer the effect the Act is having on reducing marine debris.

While surveys are the most accurate tool for measuring reductions in marine debris, they have limitations, and thus must be supplemented with indirect measurements as proxies of debris volumes. Proxies include the number of debris-related beach closings, animal entanglements/mortality, and boat damage insurance claims. A reduction in debris-related beach closings or boat damage-related insurance claims are particularly telling statistics as they are concrete values that can be located quickly and correlate directly to the amount of debris within U.S. waters.

Well-defined measurements of success are crucial to assessing the effectiveness of the Marine Debris Research, Prevention and Reduction Act. The development of a performance measurement system will be key in evaluating the overall success of the Act. Choosing among the myriad of possible indicators and indirect measurements will likely prove to be a challenging task. Because the Act exclusively covers domestic sources of debris and marine systems, the measurements utilized therein must focus solely on domestic regions. Although the global nature of the problem makes such a narrow focus seem limited, it is an important step in addressing the problem.

Conclusion

The Marine Debris Research, Prevention and Reduction Act addresses the problem of marine debris from several angles: its origin, composition, and effects. The Act similarly established a framework for increasing collaboration among stakeholders with the goal of promoting the overall understanding of the problem while encouraging the expansion of scientific and economic research.

Measuring the success of the Act will be challenging. Due to the lack of scientific research addressing this issue, there are many uncertainties surrounding the topic of marine debris. The amount of debris in the oceans, its specific affects on ecosystems, the level of acceptable marine debris, the best policies or measures to reduce and remove waste and even the appropriate level of funding for the Act are issues that must be addressed before one can determine if the legislation has been successful. Many of these issues are left to NOAA, the Committee and the Coast Guard to decide. Their conclusions, and how they implement their decisions, will play an integral role in mitigating the problem of marine debris.

Above all, marine debris is a global issue, therefore new policy and regulation within U.S. waters is inherently limited in its effectiveness. Marine debris will continue to travel across national boundaries and affect marine life, public health and maritime transportation. Thus, increasing international collaboration on the issue will be absolutely essential to successful implementation of the Marine Debris Research, Prevention and Reduction Act.

APPENDIX A
Legislative History

International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, London, 1972 [London Convention (LDC)] (26 UST 2403)	Prohibits dumping plastics and other persistent synthetic material into the oceans, which may float or remain in suspension so as to materially interfere with uses of the ocean. Excludes wastes disposed during normal vessel operations, which instead are regulated by MARPOL Annex V.
Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972 (Ocean Dumping Act), amended in 1988 [Ocean Dumping Ban Act (ODBA)L (33 USC 1401 et seq.)	Prohibits the transport of material for the purpose of ocean dumping unless authorized by permit. Implements the London Convention. Prohibits the ocean disposal of sewage sludge and industrial wastes, and ocean disposal of potentially infectious medical wastes.
Protocol of 1978 Relating to the International Convention for the Prevention of Pollution from Ships, 1973-1978 (MARPOL 73/78) (17 ILM 546, 1978)	Applies to ship-generated wastes. Annex V restricts the at-sea disposal of garbage, and prohibits the at-sea disposal of plastic materials. Requires adequate port waste-reception facilities. Entered into force in the United States on December 31, 1988, but Canada is not a party.
Act to Prevent Pollution from Ships (APPS) of 1982 (33 USC 1901 et seq.)	Regulates disposal of wastes, including oil or other hazardous substances, generated during normal operation of vessels. Implements MARPOL 73/78 legislation, and was amended in 1987 by MPPRCA to implement MARPOL Annex V specifically.
Marine Plastic Pollution Research and Control Act (MPPRCA) of 1987 (PL 100-220)	Implements MARPOL Annex V by amending APPS. Calls for federal agency Reports to Congress on methods to reduce plastic pollution and effects of plastics on the aquatic environment. Requires Coast Guard regulation of overboard disposal of plastics and other garbage under MARPOL Annex V. Calls for Citizen Pollution Patrols joint responsibility of NOAA, Coast Guard, and EPA) and public outreach and citizen awards for reported violations. Requires adequate port waste-reception facilities, and vessels 26 ft. in length or greater to display placards, and vessels 40 ft. in length or greater to provide waste management plans. Subtitle B requires EPA to study methods for reducing plastic pollution and requires the Department of Commerce to determine the effects of plastics on the aquatic environment.
Washington Declaration on Protection of the Marine Environment from Land-Based Activities (1996) (26 EP&L 37 et seq.)	A nonbinding international declaration that calls on nations to reduce land-based sources of pollution, including littering. Objectives include: the reduction of litter reaching the marine and coastal environments and

	the establishment of facilities for the disposal of litter in coastal environments. Encourages international, regional, and national-level activities including: (1) the implementation of regulatory measures or economic instruments to reduce solid waste generation; (2) local management and planning to avoid siting waste dumps near coastlines or waterways; (3) formulation and implementation of awareness and education campaigns; (4) participation in an international clearinghouse and exchange of information; among other things.
Federal Water Pollution Control Act (FWPCA) of 1972, as amended [Clean Water Act (CWA) (33 USC 1251, 1262, 1311 et seq.)	Establishes permitting and pollution control requirements for point source [including publicly owned treatment works (POTW), combined sewer overflows (CSO), and storm drains] for discharges into waters of the U.S. and the oceans. Establishes the NPDES permit program to control such discharges.
Federal Water Pollution Control Act (FWPCA) of 1972, as amended [Clean Water Act (CWA) (33 USC 1251, 1262, 1311 et seq.)	Establishes permitting and pollution control requirements for point source [including publicly owned treatment works (POTW), combined sewer overflows (CSO), and storm drains] for discharges into waters of the U.S. and the oceans. Establishes the NPDES permit program to control such discharges.
Marine Mammal Protection Act (MMPA) of 1972 (16 USC 1361 et seq.)	Places a moratorium on the taking and importing of aquatic mammals and aquatic mammal products from U.S. waters for any purpose other than scientific research or public display. Establishes the Marine Mammal Commission (MMC), which recommends protection and conservation policies on marine manuals for federal agencies.
Endangered Species Act of 1973 (ESA), as amended (16 USC 1531 et seq.)	Intended to conserve endangered and threatened species and protect the ecosystems in which they live. It calls for all necessary measures to improve condition of species so they can be delisted, and to support international treaties for the protection of wildlife and habitat. Among other things, it requires the listing of threatened and endangered species, designation of critical habitat of listed species, development of recovery plans, and provides for enforcement actions.
Resource Conservation and Recovery Act of 1976 (RCRA) (42 USC 6901 et seq.)	Amends the Solid Waste Disposal Act to better address the disposal of municipal and industrial wastes. Includes provisions to regulate the disposal of hazardous wastes by establishing a "cradle to grave" program. The goals set by RCRA are to: protect human health and the environment; reduce waste and conserve energy and natural resources; and reduce or eliminate

	the generation of hazardous waste as expeditiously as possible.
Medical Waste Tracking Act of 1988 (Subtitle J of RCRA; 42 USC 6992 et seq.)	Regulates generators and handlers of wastes and requires standards for separating, labeling, packaging, and tracking of certain types of medical wastes. EPA established a demonstration project in several states for the purpose of tracking medical wastes from generation through disposal.
The U.S. Public Vessel Medical Waste And-Dumping Act of 1988 (PL 100-699 Sections 3101-3105)	Requires that all public vessels have a management plan for medical wastes on board ship and prohibits the disposal of these wastes at sea except during national emergencies.
An Act to Study, Control, and Reduce the Pollution of Aquatic Environments from Plastic Materials and For Other Purposes of 1987 (Degradable Plastic Ring Carrier Law) (P.L. 100-556)	Directs EPA to develop regulations that require plastic ring carriers to be made of degradable materials. Many states have already enacted similar laws.
Driftnet Impact Monitoring, Assessment, and Control Act of 1987 (P.L. 100-220, Title IV)	Requires the study and creation of a driftnet marking, registry, and identification system. Directs the Secretary of Commerce to collect information on the numbers of U.S. marine resources killed, retrieved, discarded, or lost by foreign driftnet fishing vessels operating beyond the EEZ of any nation, to evaluate alternative driftnet materials that hasten decomposition of the netting, and evaluate the feasibility of a driftnet bounty system.
Shore Protection Act (SPA) of 1988 (PL 100-688, Sections 4001-4204)	Establishes a permitting scheme for vessels transporting municipal and commercial waste. Requires waste handlers to minimize the release of municipal or commercial wastes during onloading or offloading to vessels, or during vessel transport.
The National Beach Enhancement Act of 2000 (S 3036IS)	To assure that recreation and other economic benefits are weighted equally with hurricane and storm damage reduction benefits and environmental restoration benefits.

APPENDIX B
Biodegradable Plastics

Plastic constitutes roughly 80% of the debris that is currently in the oceans. Plastics that biodegrade, known as bioplastics, are a compelling solution to this problem. Bioplastics are created from natural plant polymers that break down through natural processes such as photodegradation, the interaction with UV radiation, hydrolysis, the interaction with water, and composting or compositing, interaction with oxygen or oxygenation.[58]

One such plant material used to make natural polymers is starch, a granular carbohydrate made by plants during photosynthesis that can be derived from potatoes, corn or wheat. Microorganisms are used to transform the starch into lactic acid monomers, or small molecules, to produce a more stable substance. However, these monomers are not stable enough to replace traditional plastics, and deform easily when moistened. Thus, they are chemically treated so that they bind to form polylactide (PLA), a stable polymer that has been available since 1990.[59] Another form of bioplastics is polyhydroxyalkanoate (PHA), which are polymers harvested from fermented bacteria cultures.[60] Typically biodegradable plastics are a combination of plant-derived and synthetic polymers and therefore are not entirely biodegradable. Bioplastics can substitute for traditional plastics in most forms. However, they cost two to ten times more than traditional plastics. Unfortunately, biodegradable plastics are unable to compete due to the high cost of production. Table 1 shows the average cost of common biodegradable and traditional plastics in U.S. dollars per pound.

Types of plastics	Average Cost ($/lb.)
Biodegradable	
Poly(lactic acid) (PLA)	1.50 – 3.00
Starch-based resins	1.60 – 2.90
Poly(hydroxyalkanoates) (PHA)	4.00 – 6.30
Traditional (petrochemical) plastics	
Poly(vinyl chloride) (PVC)	0.28
Poly(propylene) (PP)	0.33
Poly(styrene) (PS)	0.39

Table 1. Production Costs of Biodegradable and Traditional Plastics [61]

Biodegradation varies widely depending on the type of biodegradable material, the amount of biodegradable material in the product, and the environmental circumstances under which biodegradation will occur. To address this lack of knowledge, several scientists conducted a study to determine the percentage of ultimate biodegradability as well as the lag time of eight kinds of biodegradable plastics under highly controlled laboratory conditions.[62] The scientists mixed a thin piece of film of each plastic with composting materials and calculated the biodegradability by weight-loss and by creation of CO. The results are listed below in Table 2.

Type of biodegradable plastic	Thickness of film (μm)	Average degradability (%)	Composting time (day)
Poly(caprolactone)	50	81.4	8
Modified poly(caprolactone)	50	57.8	14
Hydroxybutyrate and hydroxyvalyrate	50	57.9	8
Polymer alloy of starch	30	91	14
1,4-butanediol, succinic acid	50	3.5	14
1,4 butanediol, succinic acid, adipic acid	25	83.9	14
Poly(lactic acid)	25	38.4	14
Poly(lactic acid) (alternative form)	100	0.4	14

Table 2. Degradability of Bioplastics [63]

Table 2 indicates the wide range of biodegradability of products considered "biodegradable" by our current definition. However, it is important to note that this study placed the biodegradable materials in an ideal composting scenario that will be highly unlikely to be found in landfills, oceans, or even in soil deposits. Furthermore, the study used microscopic pieces of plastics, which is a much smaller amount than would be present in a more realistic setting. The length of time required to compost the film was relatively long. The study also recognized that the biodegradation processes for some materials did not begin until several hours after the plastics were placed in the composting environments. These values are shown in Table 3.

Type	Ultimate degradability (%)	Lag time (hours)
Poly(caprolactone)	62	72
Modified poly(caprolactone)	25.5	84
Hydroxybutyrate and hydroxyvalyrate	3.8	-
Polymer alloy of starch	17.4	48
1,4-butanediol, succinic acid	3.3	-
1,4 butanediol, succinic acid, adipic acid	4.8	-
Poly(lactic acid)	38.8	84
Poly(lactic acid) (alternative form)	5.3	-

Table 3. Effectiveness and Duration of Degradation [64]

If bioplastics obtain widespread use, an alternative system of disposal would be necessary. Most bioplastics, such as those included in the biodegradability experiment, degrade through composting or compositing, which requires oxygen. The majority of solid waste is disposed of in landfills, which rely on microbes to break down the resident materials but often lack sufficient amounts of the oxygen to perform these actions.[65] Also, the chief benefit of biodegradable material is that the constituent parts of the plastic decompose into organic material that can be recycled rather than discarded. A separate disposal system for biodegradable materials, if feasible, would take time to implement. It is unclear what effect the presence of biodegradable plastics will have in marine ecosystems as it is not well understood how these materials break down in aquatic environments. Also, the duration of time required for complete degradation is still uncertain.[66] The presence of harmful byproducts must also be considered. Designing effective biodegradable materials will require more knowledge about material properties and performance as well as biodegradability. Finally, a standardized definition of 'biodegradable' must be established as well.[67]Research in this area is still in its early stages. It is uncertain whether biodegradable plastics will be an effective solution to the problem of marine debris. Specifically, there has been discussion about making fishing nets with plastics that degrade through photo degradation. However, since these plastics require light to break down, and plastics in the marine environment tend to become coated with algae and other insulating materials, it is uncertain if these nets will effectively degrade. Also, many bioplastics incorporate some percentage of synthetic material that does not break down. For these reasons, it is uncertain as to whether such plastics will have any less impact on marine life if they are lost or discarded.

REFERENCES

Agency for Toxic Substances and Disease Registry. 1990. The Public Health Implications of Medical Waste: A Report to Congress. U.S. Department of Health and Human Services, PB91-100271.

American Plastics Council. 2005. Plastics: The Basics of Polymer Chemistry. http://www.americanplasticscouncil.org/s_apc/sec.asp?TRACKID=&CID=309&DID=919, (June 27, 2005).

Andrady, Anthony. 2000. Plastics and Their Impacts in the Marine Environment, http://www.mindfully.org/Plastic/Ocean/Plastics-Impacts-Marine-Andrady6aug00.htm, (June 27, 2005).

Anonymous. 2005. National Pollutant Discharge Elimination System (NPDES). *Environment, Health and Safety Online.* http://www.ehso.com/npdes2.htm, (August 16, 2005).

Boland, R. and M.J. Donahue. 2003. Marine Debris Accumulation in the Nearshore Marine Habitat of the Endangered Hawaiian Monk Seal, *Monachus schauinslandi*, 1999-2001. *Marine Pollution Bulletin* 46: 1385-1394.

Bretz, C.K., P.J. Iampietro, and R.G. Kuitek. 1998. Dealing with the Past. Marine and Coastal Management. In *Earth Observation Magazine Online,* http://www.eomonline.com/Common/Archives/1998sep/98sep_bretz.html, (August 16, 2005).

Canada's National Programme of Action for the Protection of the Marine Environment from Land-Based Activities (NPA). 2003. Marine Debris in Canada. http://www.ec.gc.ca/marine/debris/eng/facts.htm, (August 13, 2005).

Cawthorn, M. 1989. Impacts of Marine Debris on Wildlife in New Zealand Coastal Waters. Proceedings of Marine Debris in New Zealand's Coastal Waters Workshop, 9 March 1989. Department of Conservation, New Zealand: 5–6.

Center for Disease Control. 2005. CDC Healthy Swimming. http://www.cdc.gov/healthyswimming/index.htm, (June 21, 2005).

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

Curlee, R. and S. Das. 1991. *Plastic wastes: management, control, recycling, and disposal.* U.S. Environmental Protection Agency: Washington, D.C.

Donohue, M.J., R.C. Boland, C.M. Sramek, and G.A. Antonelis. 2001. Derelict Fishing Gear in the Northwestern Hawaiian Islands: Diving Surveys and Debris Removal in 1999 Confirm Threat to Coral Reef Ecosystems. *Marine Pollution Bulletin* 42 (12): 1301-1312.

Galgani, F., T. Burgeot, G. Bocquene, F. Vincent, J.P. Leaute, K. Labastie, A. Forest, and R. Guichet. 1995. Distribution and abundance of debris on the continental shelf of the Bay of Biscay and in Seine Bay. *Marine Pollution Bulletin* 30 (1*).*

Gloman, Chuck. 2003. Inlet and Drain Protection. *Erosion Control Online* http://www.forester.net/ecm_0303_inlet.html, (August 16, 2005).

Gregory, M.R. 1996. Plastic "scrubbers" in hand cleansers: a further (and minor) source for marine pollution identified. *Marine Pollution Bulletin* 32: 867–871.

Grumbine, Edward. 1997. Reflections on "What is Ecosystem Management?" *Conservation Biology* 11: 41-47.

Ingraham, W. James. 1997. Getting to Know OSCURS. Alaska Fisheries Science Center Quarterly Report. http://www.afsc.noaa.gov/refm/docs/oscurs/get_to_know.htm, (August 16, 2005).

Laist, D.W. 1996. Impacts of Marine Debris: Entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In J.M. Coe and D.R. Rogers (eds), *Marine Debris: Sources, Impacts and Solutions.* Springer-Verlag: New York, 99-139.

Laist, D.W. and M. Liffmann. 2005. Impacts of Marine Debris: Research and Management Needs. National Oceanic and Atmospheric Administration, http://hawaiihumpbackwhale.noaa.gov/graphics/special_offerings/Issue_Paper_2.pdf, (June 27, 2005).

Lattin, G.L., C.J Moore, A.F Zellers, S.L. Moore, and S.B Weisburg. 2004. A comparison of neustonic plastic and zooplankton at different depths near the southern California shore. *Marine Pollution Bulletin* 49: 291-294.

Kolybaba, M., L.G. Tabil, S. Panigrahi, W.J. Crerar, T. Powell, and B. Wang. 2003. Biodegradable Polymers: Past, Present, and Future. The Society for Engineering in Agricultural, Food, and Biological Systems, Paper No. RRV03-0007. St. Joseph, Michigan: ASAE.

Marine Biodiversity and Ecosystem Functioning (MarBEF). 2005. Why is marine biodiversity important? http://www.marbef.org/outreach/whyis.html, (August 13, 2005).

Marine Conservation Society. 2003. Litter Impacts. http://www.adoptabeach.org.uk/LitterFacts/lifeimpact.htm, (August 12, 2005).

Marine Mammal Commission. 1998. Annual Report to Congress. http://www.nmfs.noaa.gov/pr/readingrm/MMPAannual/1998_MMPA_Annual_Report.pdf, (July 4, 2005).

Maso, M., E. Garces, F. Pages, and J. Camp. 2003. Drifting plastic debris as a potential vector for dispersing Harmful Algal Bloom (HAB) species. *Scientia Marina* 67(1): 107-111.

Mato, Y., T. Isobe, H. Takada, H. Kahnehiro, C. Ohtake, and T. Kaminum. 2001. Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment. *Environmental Science and Technology* 35: 318-324.

McDermid, K.J. and T.L. McMullen. 2004. Quantitative analysis of small-plastic debris on beaches in the Hawaiian archipelago. *Marine Pollution Bulletin* 48: 790-794.

Mohanty, A.K., M. Misra, and G. Hinrichsen. 2000. Biofibres, biodegradable polymers and biocomposites: An overview. Macromolecular Materials and Engineering 276/277: 1-24.

Moore, Charles. November 2003. Trashed. *Natural History Magazine*.

Ohtaki, A., and K. Nakasaki. 2000. Comparison of the weight-loss degradability of various biodegradable plastics under laboratory composting conditions. Materials Cycle and Waste Management 2: 118-124.

Salt, David. 2002. Making packaging greener – biodegradable plastics. *Nova: Science in the News.* http://www.science.org.au/nova/061/061key.htm, (August 9, 2005).

The Ocean Conservancy and U.S. Environmental Protection Agency. 1993. Marine Debris Pocket Guide. http://sacoast.uwc.ac.za/education/resources/marinedebris/index.htm, (June 27, 2005).

THOMAS: Legislative Information on the Internet. 2005. http://thomas.loc.gov/, (August 16, 2005).

Thompson, R.C., Y. Olsen, R.P. Mitchel, A. Davis, S.J. Rowland, A. John, D. McGonigle, and A.E. Russel. 2004. Lost at Sea: Where Is All the Plastic? *Science* 304 (5672): 838.

UNESCO, 1994. Marine Debris: Solid Waste Management Action Plan for the Wider Caribbean. IOC Technical Series 41.

United Marine International LLC. TrashCat™ Trash Skimmers. http://www.trashskimmer.com/trashcat.htm, (August 16, 2005).

U.S. Coast Guard. Garbage Dumping Restrictions in U.S. Waters. www.uscg.mil/hq/g-m/nmc/mardeb.htm, (August 12, 2005).

U.S. Commission on Ocean Policy. In-Press. Protecting Marine Mammals and Endangered Marine Species. http://www.oceancommission.gov/documents/prepub_report/chapter20.pdf, (June 27, 2005).

U.S. Department of Transportation. 2004. Maritime Administration (MARAD) Mission, Goals, and Vision. http://www.marad.dot.gov/welcome/mission.html, (August 12, 2005).

U.S. Environmental Protection Agency. 2002. Assessing and Monitoring Floatable Debris. http://www.epa.gov/owow/oceans/debris/floatingdebris/debris-final.pdf, (June 27, 2005).

U.S. Environmental Protection Agency. 2003. EPA's Missions and Goals. http://www.epa.gov/ocfo/budget/2003/2003bib.pdf, (August 4, 2005).

U.S. Environmental Protection Agency. 2004. Performance Indicators Visualization and Outreach Tool Introduction. http://www.epa.gov/owow/estuaries/pivot/overview/intro.htm, (August 12, 2005).

U.S. Fish & Wildlife Service. 2005. Coastal Program: Partnering for Coastal Conservation. http://www.fws.gov/coastal/CoastalProgram, (August 12, 2005).

U.S. Government Accountability Office. http://www.gao.gov/, (August 16, 2005).

U.S. Senate. 2004. Senate Report 108-401 – Marine Debris Research and Reduction Act. http://thomas.loc.gov/cgi-bin/cpquery/?&db_id=cp108&r_n=sr401.108&sel=TOC_0&, (August 13, 2005).

---

[1] Bill Summary & Status for the 109th Congress. 2004. Senate Report 108-401 – Marine Debris Prevention and Reduction Act. http://thomas.loc.gov/cgi-bin/cpquery/?&db_id=cp108&r_n=sr401.108&sel=TOC_0&., (August 16, 2005).
[2] Bill Summary & Status for the 109th Congress. 2005. S.362. http://thomas.loc.gov/cgi-bin/bdquery/z?d109:s362: (August 16, 2005).
[3] California Coastal Commission. http://www.coastal.ca.gov/publiced/marinedebris.html. (August 16, 2005.)
[4] U.S. Environmental Protection Agency. 2002. Assessing and Monitoring Floatable Debris. http://www.epa.gov/owow/oceans/debris/floatingdebris/debris-final.pdf, (June 27, 2005).
[5] Cawthorn, M. 1989. Impacts of Marine Debris on Wildlife in New Zealand Coastal Waters. Proceedings of Marine Debris in New Zealand's Coastal Waters Workshop, 9 March 1989. Department of Conservation, New Zealand: 5–6.
[6] UNESCO, 1994. Marine Debris: Solid Waste Management Action Plan for the Wider Caribbean. IOC Technical Series 41.
[7] Moore, Charles. November 2003. Trashed. *Natural History Magazine*.
[8] Moore, 2003.
[9] Moore, 2003.
[10] Galgani, F., T. Burgeot, G. Bocquene, F. Vincent, J.P. Leaute, K. Labastie, A. Forest, and R. Guichet. 1995. Distribution and abundance of debris on the continental shelf of the Bay of Biscay and in Seine Bay. *Marine Pollution Bulletin* 30 (1).
[11] Andrady, Anthony. 2000. Plastics and Their Impacts in the Marine Environment, http://www.mindfully.org/Plastic/Ocean/Plastics-Impacts-Marine-Andrady6aug00.htm, (June 27, 2005).
[12] Andrady, 2000.

[13] The Ocean Conservancy and U.S. Environmental Protection Agency. 1993. Marine Debris Pocket Guide. http://sacoast.uwc.ac.za/education/resources/marinedebris/index.htm, (June 27, 2005).
[14] Gregory, M.R. 1996. Plastic "scrubbers" in hand cleansers: a further (and minor) source for marine pollution identified. *Marine Pollution Bulletin* 32: 867–871.
[15] Moore, 2003.
[16] Lattin, G.L., C.J Moore, A.F Zellers, S.L. Moore, and S.B Weisburg. 2004. A comparison of neustonic plastic and zooplankton at different depths near the southern California shore. *Marine Pollution Bulletin* 49: 291-294.
[17] McDermid, K.J. and T.L. McMullen. 2004. Quantitative analysis of small-plastic debris on beaches in the Hawaiian archipelago. *Marine Pollution Bulletin* 48: 790-794.
[18] Gregory, 1996.
[19] Moore, 2003.
[20] Maso, M., E. Garces, F. Pages, and J. Camp. 2003. Drifting plastic debris as a potential vector for dispersing Harmful Algal Bloom (HAB) species. *Scientia Marina* 67(1): 107-111.
[21] Maso et al., 2003.
[22] Maso et al., 2003.
[23] Mato, Y., T. Isobe, H. Takada, H. Kahnehiro, C. Ohtake, and T. Kaminum. 2001. Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment. *Environmental Science and Technology* 35: 318-324.
[24] Marine Mammal Commission. 1998. Annual Report to Congress. http://www.nmfs.noaa.gov/pr/readingrm/MMPAannual/1998_MMPA_Annual_Report.pdf, (August 4, 2005).
[25] Marine Conservation Society, 2003.
[26] Marine Mammal Commission. 1998. Annual Report to Congress. http://www.nmfs.noaa.gov/pr/readingrm/MMPAannual/1998_MMPA_Annual_Report.pdf Last Access: 7/04/05.
[27] Marine Conservation Society, 2003.
[28] Chiappone, M., H. Dienes, D.W. Swanson, and S.L. Miller. 2005. Impacts of Lost Fishing Gear on Coral Reef Sessile Invertebrates in the Florida Keys National Marine Sanctuary. *Biological Conservation* 121(2): 221-230.
[29] Laist, D.W. and M. Liffmann. 2005. Impacts of Marine Debris: Research and Management Needs. National Oceanic and Atmospheric Administration, http://hawaiihumpbackwhale.noaa.gov/graphics/special_offerings/Issue_Paper_2.pdf, (June 27, 2005).
[30] U.S. Commission on Ocean Policy. In-Press. Protecting Marine Mammals and Endangered Marine Species. http://www.oceancommission.gov/documents/prepub_report/chapter20.pdf, (June 27, 2005).
[31] U.S. Commission on Ocean Policy. In-Press.
[32] U.S. Commission on Ocean Policy. In-Press.
[33] Thompson, R.C., Y. Olsen, R.P. Mitchel, A. Davis, S.J. Rowland, A. John, D. McGonigle, and A.E. Russel. 2004. Lost at Sea: Where Is All the Plastic? *Science* 304 (5672): 838.
[34] Curlee, R. and S. Das. 1991. *Plastic wastes: management, control, recycling, and disposal.* U.S. Environmental Protection Agency: Washington, D.C.
[35] Curlee and Das, 1991.
[36] Canada's National Programme of Action for the Protection of the Marine Environment from Land-Based Activities (NPA). 2003. Marine Debris in Canada. http://www.ec.gc.ca/marine/debris/eng/facts.htm, (August 13, 2005).
[37] Canada's National Programme of Action for the Protection of the Marine Environment from Land-Based Activities (NPA). 2003.
[38] Canada's National Programme of Action for the Protection of the Marine Environment from Land-Based Activities (NPA). 2003.
[39] Agency for Toxic Substances and Disease Registry. 1990. The Public Health Implications of Medical Waste: A Report to Congress. U.S. Department of Health and Human Services, PB91-100271.
[40] Curlee and Das. 1991.
[41] U.S. Environmental Protection Agency. 2002. Assessing and Monitoring Floatable Debris.
[42] U.S. Environmental Protection Agency. 2002. Assessing and Monitoring Floatable Debris.

[43] Anonymous. 2005. National Pollutant Discharge Elimination System (NPDES). *Environment, Health and Safety Online.* http://www.ehso.com/npdes2.htm, (August 16, 2005).
[44] Gloman, Chuck. 2003. Inlet and Drain Protection. *Erosion Control Online* http://www.forester.net/ecm_0303_inlet.html, (August 16, 2005).
[45] Bretz, C.K., P.J. Iampietro, and R.G. Kuitek. 1998. Dealing with the Past. Marine and Coastal Management. In *Earth Observation Magazine Online,* http://www.eomonline.com/Common/Archives/1998sep/98sep_bretz.html, (August 16, 2005).
[46] Bretz et al., 1998.
[47] Ingraham, W. James. 1997. Getting to Know OSCURS. Alaska Fisheries Science Center Quarterly Report. http://www.afsc.noaa.gov/refm/docs/oscurs/get_to_know.htm, (August 16, 2005).
[48] Ingraham, 1997.
[49] Ingraham, 1997.
[50] U.S. Environmental Protection Agency. 2002. Assessing and Monitoring Floatable Debris.
[51] United Marine International LLC. TrashCat™ Trash Skimmers. http://www.trashskimmer.com/trashcat.htm, (August 16, 2005).
[52] United Marine International LLC. TrashCat™ Trash Skimmers. http://www.trashskimmer.com/trashcat.htm, (August 16, 2005).
[53] NOAA Coastal Services Center. 2005. Marine Plastic Pollution Research and Control Act. http://www.csc.noaa.gov/opis/html/summary/mpprca.htm, (August 16, 2005).
[54] U.S. Government Accountability Office. http://www.gao.gov/, (August 16, 2005).
[55] http://thomas.loc.gov/cgi-bin/query/D?c109:1:./temp/~c109irXuQv:b114, accessed 6/05/2005.
[56] Grumbine, Edward. 1997. Reflections on "What is Ecosystem Management?" *Conservation Biology* 11: 41-47.
[57] Boland, R. and M.J. Donahue. 2003. Marine Debris Accumulation in the Nearshore Marine Habitat of the Endangered Hawaiian Monk Seal, *Monachus schauinslandi,* 1999-2001. *Marine Pollution Bulletin* 46: 1385-1394.
[58] Kolybaba, M., L.G. Tabil, S. Panigrahi, W.J. Crerar, T. Powell, and B. Wang. 2003. Biodegradable Polymers: Past, Present, and Future. The Society for Engineering in Agricultural, Food, and Biological Systems (ASAE), Paper No. RRV03-0007. St. Joseph, Michigan.
[59] Salt, David. 2002. Making packaging greener – biodegradable plastics. *Nova: Science in the News.* http://www.science.org.au/nova/061/061key.htm, (August 9, 2005).
[60] Salt, 2002.
[61] Mohanty, A.K., M. Misra, & G. Hinrichsen. 2000. Biofibres, biodegradable polymers and biocomposites: An overview. Macromolecular Materials and Engineering 276/277: 1-24.
[62] Ohtaki, A., and K. Nakasaki. 2000. Comparison of the weight-loss degradability of various biodegradable plastics under laboratory composting conditions. Materials Cycle and Waste Management 2: 118-124.
[63] Ohtaki and Nakasaki, 2000.
[64] Ohtaki and Nakasaki, 2000.
[65] Salt, 2002.
[66] Ohtaki and Nakasaki, 2000.
[67] Mohanty et al., 2000.