REPORT OF THE SECRETARY OF COMMERCE

TO THE CONGRESS OF THE UNITED STATES

ON THE EFFECTS OF PLASTIC DEBRIS

ON THE MARINE ENVIRONMENT

PURSUANT TO SECTION 2203 OF PUBLIC

LAW 100-220

THE "MARINE PLASTIC POLLUTION

RESEARCH AND CONTROL ACT OF 1987"

THE SECRETARY OF COMMERCE
Washington, D.C. 20230

President of the Senate
Speaker of the House of Representatives

Dear Sirs:

I am pleased to submit the report from the Department of Commerce on the effects of plastic materials on the marine environment, as required by Section 2203 of the Marine Pollution Research and Control Act of 1987 (P.L. 100-220, Title II).

Sincerely,

Robert A. Mosbacher

Enclosure

Table of Contents

List of Tables

List of Figures

Report of the Secretary of Commerce to the Congress of theUnited States on the Effects of Plastic Debris on the Marine Environment

Pursuant to Section 2203 of Public Law 100-220

The *Marine Plastic Pollution Research and Control Act of 1987*

Prepared by the
Office of Protected Resources and Habitat Conservation,
National Marine Fisheries Service,
Silver Spring, Maryland 20910

U.S. Department of Commerce
Robert A. Mosbacher, Secretary

National Oceanic and Atmospheric Administration
William E. Evans, Under Secretary

National Marine Fisheries Service
James W. Brennan, Assistant Administrator

EXECUTIVE SUMMARY

The Marine Plastic Pollution Research and Control Act of 1987

Persistent plastic debris is recognized as a problem in the oceans and on the beaches throughout the world. The U.S. Congress responded to the national and international implications of the marine debris problem by signing Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL) and passing Public Law 100-220. Title II of P.L. 100-220, the Marine Plastic Pollution Research and Control Act of 1987 (MPPRCA), addresses the plastic debris problem, implements Annex V of MARPOL (the international convention that prohibits all ocean discharge of plastics), and charges the U.S. Coast Guard with writing appropriate regulations. Subtitle B of the Act charges the Secretary of Commerce to submit to Congress a report on the effects of plastic materials in the marine environment. The report shall-

(1) identify and quantify the harmful effects of plastic materials on the marine environment;

(2) assess the specific effects of plastic materials on living marine resources in the marine environment;

(3) identify the types and classes of plastic materials that pose the greatest potential hazard to living marine resources;

(4) analyze, in consultation with the Director of the National Institute for Standards and Technology*, plastic materials which are claimed to be capable of reduction to environmentally benign submits [sic] under the action of normal environ mental forces (including biological decomposition, photodegradation, and hydrolysis); and

(5) recommend legislation which is necessary to prohibit, tax, or regulate sources of plastic materials that enter the marine environment."

This report was prepared in response to that charge. Much of the information in this report was drawn from the "Report of the Interagency Task Force on Persistent Marine Debris (NOAA 1988).

The Problem

Shortages of rubber and other suitable materials during World War II heightened the demand for development of affordable, versatile plastics. Since then, demand by consumers combined with improved technology has resulted in a steady increase in plastic production in the United States. Plastic production has risen from approximately 6.3 billion pounds in 1960 to over 53 billion pounds in 1987.

Plastics are synthetic polymer-based materials derived from petroleum products. Monomers (small molecules) are chemically combined, or polymerized, to form a polymer (a macromolecule).
The polymer is compounded with various additives to provide the raw plastic, or resin, which is then formed into the desired product. "Plastic" is a generic term, which is used to describe a suite of polymers possessing very different physical properties. Some of the more common plastic materials are polyethylene, polyvinyl chloride, polypropylene, and polystyrene. Plastic materials range from rigid to flexible, from transparent to opaque, but all are lightweight, inert, resistant to environmental degradation, and versatile. Since its introduction to commercial use in 1868, polymer production has proliferated and produced the materials of choice in thousands of old and new uses.

*National Bureau of Standards has been renamed National Institute for Standards and Technology according to Pub. L. 100-418.

Plastics are used for a variety of applications, ranging from domestic (plastic bags, six-pack yokes) to industrial (building material, automotive parts). The qualities that make plastics so desirable - strength, durability, light weight, ease of production and handling, and low cost - also make them a potential environmental problem.

An estimated 7.2 percent (by weight) of municipal solid waste generated in this country in 1984 was plastic (Franklin 1986). This amounted to nearly 9.6 million tons of discarded plastic. More recent data indicate that between 6 and 12.8 million tons of plastic are discarded each year (Cal Recovery Systems Inc. 1988). It is anticipated that by the year 2000, 15.5 million tons of plastic will be disposed of by our society every year. Most discarded plastic products end up in landfills or are burned. However, unknown, but seemingly increasing, amounts end up as litter on land and in our rivers, estuaries, and oceans. It has been estimated that the U.S. alone may contribute up to 600,000 tons of plastic debris per year to the world's oceans (Bean 1987). Plastics, once discarded, may persist in the environment for several decades.

Persistent marine debris causes a multitude of problems ranging from aesthetic to life-threatening. The costs associated with these problems may be in the billions of dollars, and affect many segments of society. Seashore communities lose money due to decreased tourism and are forced to spend millions of dollars cleaning trash from their beaches; vessel owners incur repair costs when propellers and engine cooling intakes are fouled by plastic debris; commercial fishermen destroy costly gear and lose valuable fishing time when gear becomes snagged on large pieces of debris, and lose potential income when lost or discarded gear continues to kill fish and shellfish.

Effects of plastic marine debris on living marine resources range from temporary injury to death, and result from either entanglement in debris or ingestion of plastic objects. Marine mammals, birds, sea turtles, fish, and shellfish are affected by interactions with plastic debris in the oceans and on our beaches. For example:

Scientists monitoring the Pribilof Islands population of North Pacific fur seals have documented that many animals, especially juveniles, become entangled in persistent marine debris. Some scientists attribute a major portion of the current population decline to entanglement (Fowler 1987).

The five species of sea turtles that inhabit U.S. waters, all of which are endangered or threatened, are known to ingest plastic, perhaps mistaking it for natural prey. Some scientists believe that the potential exists for significant numbers of young turtles to be killed by interactions with plastics during the pelagic phase of their life cycle.

Fifty species of seabirds from around the world have been found to ingest a variety of plastic products. Seabirds and shorebirds become entangled in persistent marine debris, which may result in drowning, choking, or lacerations (NOAA 1988).

Discarded fishing gear may continue to capture fish and shellfish long after its intentional use has ceased. It has been estimated that over 1,200 crab pots a year are lost by fishermen in Alaska and along the Pacific coast. Plastics by design resist normal environmental degradation processes. The lifetimes at sea of the various polymers are not known. There is little doubt, however, that they are much more persistent than natural fibers, wood, and metal. The rate at which plastic products degrade depends on several environmental factors - the levels of exposure to light, heat, water and biochemical and biophysical processes; as well as the physical properties of the particular polymer. Considerable research has been conducted on the development of enhanced degradable plastics. Currently available controlled-lifetime plastics technologies accelerate the environmental weathering process of polymers by chemical means. Many questions remain regarding the extent to which these plastics actually degrade, the environmental effects of the intermediate breakdown products, and the effects of the resultant increased number of small particles on the environment and marine organisms. Degradable plastics should not be viewed as the solution to the persistent marine debris problem, but rather, as one part of a much broader plan to deal with our overall marine pollution and solid waste disposal dilemma.

Recommendations

-Recognizing that solution of the growing solid waste disposal crisis on land is necessary to solve the marine debris problem, Congress should act to support a broad national solid waste agenda including technology, education, and infrastructure.

-Federal, state, and local agencies should cooperate fully with USDA/APHIS to facilitate safe, effective handling of increases in foreign garbage deliveries to U.S. ports resulting from compliance with MARPOL Annex V.

-Federal agencies should explore the need for and feasibility of a national recycling initiative.

-Federal agencies should continue to educate the public regarding marine debris issues.

-Compliance with Annex Vshould be monitored through the Coast Guard's report on compliance which is required by the Plastic Pollution Research and Control Act of 1987. If the Coast Guard's reports indicate a low level of compliance, alternative ways to handle the problem should be considered, either by amending current legislation or regulations, increasing enforcement efforts, or other appropriate measures.

-Federal and state agencies should enter into agreements with the U.S. Coast Guard to enforce MARPOL Annex V.

-Federal agencies should give preference to purchase of materials, supplies, and equipment made from recycled materials.

-Fishery management plans developed by the Regional Fishery Management Councils and Interstate (Fishery) Commissions should include provisions relating to disposal of gear and escape panels in traps and pots.

-Federal agencies should insure that best use is made of beach debris data collected by voluntary beach clean-ups around the country, including support for organized data collection, its storage, analysis, and reporting.

-All observer reporting forms used in domestic and joint-venture fisheries in the U.S. EEZ should address gear disposal.

-Congress should support funding requests in President's Budget for research efforts related to marine debris issues. Primary research efforts should include:

1) development and evaluation of degradable technologies;
2) effects of degradable plastics (and their breakdown products) on the marine environment, particularly living marine resources;
3) the determination of impacts of marine debris on local and regional economies;
4) the biological and ecological impacts of marine debris, especially on endangered and protected species; and
5) ways to assure adequate handling facilities in ports.

-Federal and state agencies should recognize the special problems of remote ports in providing adequate reception facilities for ships and assist in their solutions.

-Federal agencies should encourage citizens and employees in coastal communities, to participate in local beach clean-up campaigns.

CHAPTER I

PLASTIC DEBRIS IN THE MARINE ENVIRONMENT

Increasing demand by consumers, combined with improved technology, has resulted in a steady increase in plastic production in the United States since World War II (Fig. 1). Shortages of rubber and other suitable materials during the war heightened the demand for development of affordable, versatile plastics. In 1960, approximately 6.3 billion pounds of plastic resin were produced. By 1987, over 53 billion pounds of plastic resin were produced in the U.S. (Anon. 1988).

Since the first reports of marine debris on Alaskan beaches in 1972 (Merrell 1980) and in the Sargasso Sea (Carpenter and Smith 1972), plastic debris has been found on all U.S. coasts and in virtually every ocean in the world. According to Schoning (1988), more than 100,000 pieces of plastic per linear meter of beach were found in New Zealand. It was estimated in 1984 that the Japanese central Pacific salmon and squid drift net fisheries lose 1,624 miles of monofilament gill net annually (Schoning 1988). In October 1984, over 26 tons of plastic debris were collected from Oregon's coastline (Neilson 1985). Plastic bags have been found in the digestive tracts of sea turtles off the coasts of Australia, Central America, France, French Guiana, Japan, South Africa, the South China Sea, the United Kingdom, and the United States. Plastic waste has been found from the most remote beaches in the Arctic to surface waters in the middle of the oceans (Recht 1988).

Plastic in the oceans comes from many sources: discarded trash from merchant ships, cruise ships, military vessels, barge and tug operations, and drilling rigs; fishing gear that has been accidentally lost or intentionally discarded or abandoned; trash left by beachgoers or tossed over the side by recreational boaters and fishermen; river-borne debris; and through municipal sewage treatment systems, especially stormwater overflows (Table 1).

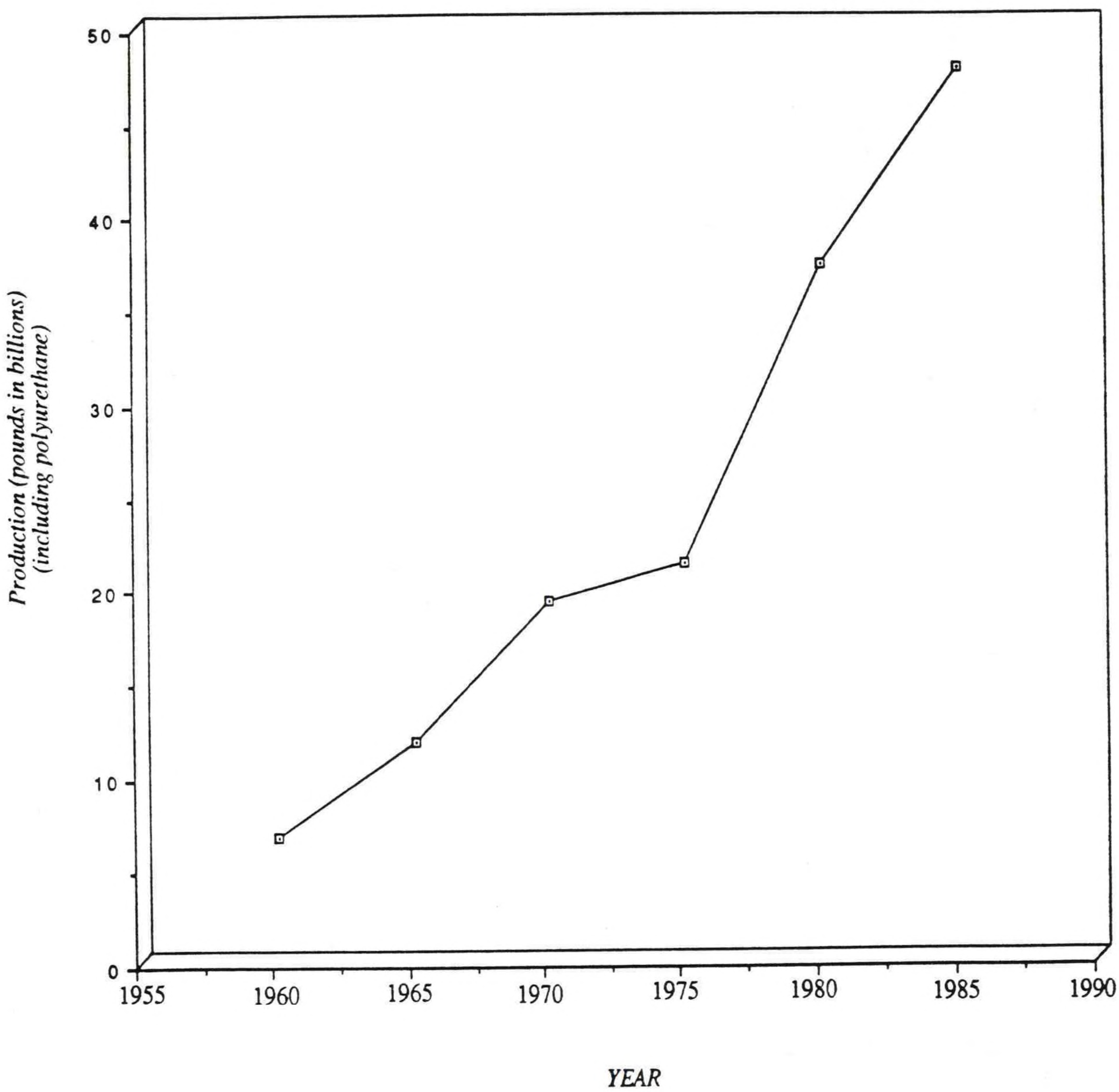
There are four basic problems associated with plastic debris in the marine environment:

- it is aesthetically damaging;
- it causes economic damage;
- it is biologically damaging; and
- it may pose health risks to people.

Currently there is very limited standardized quantitative work being done to determine the types, amounts, and distribution of persistent marine debris in the U.S. One study is being conducted in Alaska to assess the quantities of entangling materials generated by the major fisheries operating in that region.

Surveys conducted at sea between 1982 and 1984 quantified the amounts of net material lost, discarded, or encountered by vessels in foreign and joint venture fishing off Alaska (Berger and Armistead 1987). Normal trawling operations resulted in 1,551 pieces of net material being brought aboard ships from the fall of 1982 through the end of 1984.

Figure 1 Total U.S. Production of Plastic Resin
1960 - 1985



Data for 1960 - 1970 from U.S. tariff commission
Data for 1971 - 1985 from SPI
Source: NOAA 1988

Table1. Sources of Marine Debris

	Commercial Fishing	Recreational Fishing and Boating	Merchant Shipping	Cruise Ships	Offshore Oil & Gas	Plastic Manufacturing	Sewage Treatment Plants	Municipal Landfills
Fishing Gear								
Nets/Fragment:	X							
Trap	X	X						
Buoys	X	X						
Rope	X	X	X	X	X			
Monofilament Line	X	X						
Cargo Wastes								
Strapping Bands	X		X					
Plastic Sheeting	X		X					X
Domestic Plastics								
Bags	X	X	X	X	X		X	X
Six-pack Yokes	X	X	X	X	X			X
Bottles and Jugs	X	X	X	X	X			X
Containers	X	X	X	X	X		X	X
Tampon Applicators		X		X			X	X
Styrofoam	X	X	X	X	X		X	X
Pellets/Fragments								
Raw Plastic Pellets						X		
Plastic Fragments	X	X	X	X	X	X	X	X

In 1987, over 26,000 volunteers, participating in "COASTWEEK" activities, picked up trash on U.S. beaches. The quantities of debris that they found varied tremendously, from almost 2 tons/mile in Texas to 60 pounds/mile in Delaware (Center for Environmental Education 1988b) (Table 2). In Texas, 252,569 plastic items (including styrofoam) accounted for 66 percent of the total items collected in the 1987 beach clean-up. The most common plastic materials found were styrofoam, bottles, bags, caps/lids, miscellaneous plastic pieces, rope, and six-pack rings (Table 3).

In 1987 Massachusetts beach clean-ups, volunteers collected almost 2 tons of debris from 39.5 miles of beach (Center for Environmental Education 1988). Plastics (including styrofoam and fishing gear) accounted for 95 percent of the total number of items collected. Styrofoam alone accounted for 19.5 percent of the total items collected, followed by plastic containers, rope and strapping, bags and sheeting, fishing gear, miscellaneous plastic pieces, plastic utensils, and 6-pack yokes (Table 3).

A 1984 Oregon beach clean-up involved 2,100 volunteers who collected 26.3 tons of plastic and other debris on 150 miles of accessible beach (Neilson 1985). Styrofoam was the most common item reported, with 48,898 chunks of styrofoam larger than a baseball collected. The remaining 25,746 plastic pieces were rope and strapping, food utensils, bags or sheets of plastic, bottles and jugs, 6-pack yokes, and fishing gear (Table 3).

In Alaska, fishing gear accounts for a much higher percentage of total debris collected. Merrell (1984) estimated that 85-98 percent by weight and 70-80 percent by number of plastic debris items found on Amchitka Island, Alaska between 1972 and 1982 was derived from commercial fishing operations. Surveys conducted during 1985 at 34 Alaskan beaches found rope, trawl web, and packing straps to be the most common items at all locations (Merrell and Johnson 1987). Monofilament gill net was the least common type of fishing gear found. Through their study to determine trends in accumulation and disappearance of plastic litter Merrell and Johnson (1987) discovered that all beaches surveyed in Alaska had less plastic litter in 1985 than they did in prior surveys. Litter on Amchitka Island beaches declined by 3 percent since 1982. Litter declined 8 percent on Middleton Island beaches and 65 percent on Yakutat beaches since last surveyed in 1984. The dramatic decline in plastic litter on the beaches at Yakutat is attributed to the decrease of foreign trawl fishing in the eastern Gulf of Alaska. The investigators reported great variability in the quantity of debris found at different locations, which makes determining trends in abundance of plastic litter very difficult.

In 1988 47,475 volunteers, participating in COASTWEEKS '88 Beach Cleanups in 23 coastal states, Puerto Rico, and the U.S. Virgin Islands collected 1,843,800 pounds of plastic and styrofoam debris (Pers. comm. O'Hara, CEE) (Appendix A).

There are obvious regional differences in the quantity and types of plastic litter found on beaches. Beaches in close proximity to major urban areas are more likely to have a higher percentage of domestic trash than would remote locations in Alaska, which are more affected by debris from the growing commercial fisheries near them. Beaches in New England and along the Gulf of Mexico are subjected to various sources of plastic debris including, among others: fishing, oil and gas development, combined sewer overflows in older cities, and landfills, all of which contribute different materials to the total debris problem.

Table 2. COASTWEEK 1987 Beach Clean-up Results

State	Number Volunteers	Miles Covered	Tons Collected	Tons/ Volunteer	Tons/ Mile
Alabama	127	3	NR	NR	NR
California	4,000	1,000	75.0	0.019	0.075
Connecticut	15	1	0.1	0.007	0.100
Delaware	700	50	1.5	0.002	0.030
Florida	1,232	50	4.0	0.003	0.080
Georgia	20	5	0.5	0.025	0.100
Hawaii	2,726	NR	36.8	0.013	NR
Louisiana	3,300	85	200.0	0.061	2.350
Maine	350	31	3.0	0.009	0.097
Massachusetts	391	39.5	1.9	0.005	0.048
Mississippi	100	5	3.5	0.035	0.700
New Hampshire	112	3	2.0	0.018	0.667
New Jersey	1,250	100	40.0	0.032	0.400
New York	80	2	1.5	0.019	0.750
North Carolina	1,000	150	10.0	0.010	0.067
Oregon	2,600	120	17.0	0.007	0.142
Rhode Island	450	40	NR	NR	NR
Texas	7,132	154	306.5	0.043	1.990
Washington	1,000	100	6.0	0.006	0.060
TOTAL	26,585	1,938.5	709.3		

NR indicates data not reported.
Adapted from: Center for Environmental Education (1987).

Table 3. Common Plastic Debris Items Collected During Beach Clean-Ups on U.S. Coasts

	% of Total Plastic Items			
Material	Massachusetts[1]	Texas[2]	Oregon[3]	Louisiana[2]
Styrofoam	19.5	15.3	65.5	35.5
Plastic containers	16.9	NR	NR	NR
Plastic rope and strapping	13.2	9.4	10.9	6.3
Plastic bags and sheeting	12.6	14.4	6.6	9.7
Fishing gear	11.4	6.0	1.5	2.7
Misc. plastic pieces	10.4	8.6	NR	7.4
Plastic utensils	9.4	4.9	7.2	3.5
6-pack yokes	2.4	6.2	1.9	2.9
Plastic bottles and jugs	NR	14.9	6.4	16.7
Caps and lids	NR	11.3	NR	NR

Sources: [1]Bigford 1987 Pers. comm., as reported in NOAA 1988.
[2]Center for Environmental Education (1988b). Data from September 1987 survey.
[3]Neilson (1985).

Floating plastic particulates in the North Pacific Ocean were sampled by Day et al. (1986). Samples collected at stations between Korea and Hawaii indicated mean densities of plastic, floating on the sea's surface, to be 48,500 pieces/km^2. Plastic fragments (91.7% of the total pieces) were the most abundant of all plastic types, followed by monofilament line fragments (2.9%), styrofoam fragments (1.1%), pellets (0.5%), and polypropylene line fragments (0.5%).

Henderson et al. (1987) summarized results of beach surveys of nets and net fragments on Northwest Hawaiian Island (NWHI) beaches between 1982 and 1986. Net materials were found on all beaches surveyed, with no apparent difference in the amount of webbing washing ashore at different locations in the NWHI. Yearly totals ranged from 54 net fragments recovered in 1983 to 239 fragments in 1985. Accumulation of net fragments often occurs on beaches where endangered monk seals are born and weaned, leading to entanglement of young seals (Henderson 1985).

To more accurately assess the situation, the National Park Service and National Marine Fisheries Service signed an agreement to set up a national sampling system at the following Park Service managed beaches: Channel Islands and Olympic National Parks, and Assateague, Canaveral, Cape Cod, Cape Hatteras, Gulf Islands, and Padre Island National Seashores. Under the agreement, the two agencies will begin to gather the data necessary to systematically quantify marine debris on U.S. shores and monitor the success of implementation of the Marine Plastic Pollution Research and Control Act in reducing marine debris.

CHAPTER II

EFFECTS OF PLASTIC MATERIALS ON MARINE RESOURCES

An estimated $1 billion dollars has been lost over each of the last two summers due to decreased tourism along the shores of New Jersey alone. New Jersey reported a 22 percent decrease in the number of tourists visiting the shore in 1988, when compared to the number of tourists in 1987 (R. L. Associates 1988). As long ago as 1976, debris washing up on the beaches of Long Island closed beaches and resulted in an estimated economic loss to local businesses of $30 million (Swanson et al. 1978). Clean-up can also cost local communities millions. Gateway National Recreation Area in New York and New Jersey spent over $500,000 to clean its 53 miles of public beaches in 1985. In Texas, it is estimated that local governments spend $14 million each year to clean debris from beaches along the Gulf of Mexico (Cal Recovery Systems, Inc. 1988) where coastal tourism has become a $5 billion-a-year industry. The growing number of voluntary beach clean-ups around the country attests to the public's concern for the aesthetic, economic, and human and wildlife hazards posed by debris on our beaches and in our oceans.

Marine debris is a global problem, which, in addition to littering beaches, affects wildlife, commercial and recreational fishermen, recreational boaters, maritime transporters, port authorities, and recreational divers. Commercial and recreational fishermen are affected in several ways. Income is lost as potential future catches are reduced when target species continue to be captured in lost traps, nets, or lines. Debris may foul or damage active fishing gear as well as damage fishing boats, foul ship propellers, and clog vessel water intake systems, resulting in economic losses and endangerment of human lives.

EFFECTS ON LIVING MARINE RESOURCES

Five groups of wildlife are most susceptible to problems associated with marine debris: mammals, birds, sea turtles, fish, and crustaceans. Debris affects living marine resources in two ways - entanglement and ingestion. Entanglement may be accidental, as a result of random encounters or in the case of some mammals, the animal's curiosity may result in deliberate contact. Many species ingest plastic items, apparently mistaking them for natural food items. Less apparent, and yet to be investigated, are the effects of small plastic particles on lower trophic levels in the sea (planktonic systems, filter feeders, and shellfish).

To date, adverse impacts have been well studied for only a few wildlife populations, e.g., northern fur seals (*Callorhinus ursinus*) and the endangered Hawaiian Island monk seals (*Monachus schauinslandi*). Determining the "significance" of marine debris impacts on wildlife is difficult without further research on population-level effects. We do know, however, that marine debris affects individuals of many endangered, threatened, and commercially and recreationally valuable species.

MARINE MAMMALS

Marine mammals have attracted the most attention in terms of marine debris. The species that make up this group are highly visible and evoke strong emotional responses from the public. Many populations of marine mammals are endangered or threatened, and their interactions with plastic and non-plastic marine debris are the best documented. Entanglement may kill marine mammals as a result of drowning, if they cannot surface to breathe, or through starvation or exhaustion as a result of impaired swimming and feeding from dragging around excess weight. Entanglement in plastic debris can also kill more slowly, as the animal grows into a plastic loop and vital organs are constricted or cut through (Wallace 1985). Entanglement in fishing gear may result from encounters with gear that is actively being fished or with derelict fishing gear (debris). It is generally impossible to discern the source of entangling debris, and the discussions that follow do not attempt to separate out the sources, but only address the resultant effects. Entanglement or ingestion of plastics has been reported in seals, sea lions, whales, and dolphins.

Seals and Sea Lions

Fowler (1988) presented a review of seal and sea lion entanglement in marine fishing debris. He reported that six species of fur seals, four species of sea lions, and six species of phocids (true seals and elephant seals) are documented as being entangled in debris.

The Pribilof Island (northern) fur seal population, which accounts for approximately 72 percent of the current estimated worldwide population, declined at about 4 to 8 percent per year between the mid 1970's and mid-1980's. Counts of adult males have declined in several more recent years. The Pribilof Island population is currently below 50 percent of population levels observed as recently as the early 1950s, but existing data do not support reduced reproductive rates or food availability as causes of the decline. Population declines have continued despite the cessation of harvest of female seals in 1969. A commercial harvest for skins (about 25,000 sub-adult males annually) ended in 1985 with the expiration of the Interim Convention on Conservation of North Pacific Fur Seals. Presently, there is only a small subsistence harvest by Native Alaskans for food (less than 2,000 each summer). The decline in the fur seal population is not thought to be a result of the continuing harvest of sub-adult males, but rather, a result of declines caused at least in part, by increased mortality at sea. The causes of this mortality are not fully determined but include deaths caused by entanglement in debris. It is estimated that entanglement may kill 30,000 northern fur seals per year, and Fowler (1987) suggests that entanglement may be a principle cause of the recent decline in the Pribilof Islands population.

The annual seal harvest on the Pribilof island of St. Paul was monitored between 1981 and 1984 for signs of entanglement. A total of 403 entangled seals, 0.42 percent of harvested juvenile male animals, were encountered during the survey. The most common type of debris entangling seals was net fragments with mesh size of 20cm or greater (46% of total), followed by plastic packing bands (21% of total) (Scordino 1985). Observed entanglement has remained relatively constant at about 0.4 percent since it peaked in 1975 at 0.71 percent (Table 4). The actual rate of entanglement is probably higher, as only those animals that are able to swim back to land are counted. Researchers believe that most entangled animals never return to land (Fowler 1985; Scordino 1985).

In an effort to study the effect of entanglement on fur seals, Scordino (1985) tagged and released 150 entangled seals in 1983 and 1984. Data from seals resighted the year following tagging indicate that mortality of entangled seals is not significantly different from that of non-entangled seals over a 1-year period. Results also indicated that seals were able to rid themselves of entangling debris at a higher rate than was expected. However, statistical analyses conducted by Fowler (1985) indicate that there is a relationship between entanglement observed in the harvest of juvenile males and the current population decline of northern fur seals. Precise estimates of entanglement-caused mortality are not available.

Table 4. Northern Fur Seals Observed Entangled in Debris During the Harvest on St. Paul Island, 1967-84.

Year	Number of Seals Harvested/Sampled	Number of Entangled Seals				Percent of Total
		Net	Band	Other	Total	
1967	50,229	—	—	—	75	0.15
1968	46,893	—	—	—	75	0.16
1969	32,819	—	—	—	66	0.20
1970	36,307	71	5	24	101	0.28
1971	27,289	69	35	6	113	0.41
1972	33,173	85	53	6	144	0.43
1973	28,482	82	54	1	137	0.48
1974	33,027	90	100	—	190	0.58
1975	29,148	105	101	—	206	0.71
1976	23,096	50	47	—	97	0.42
1977	28,444	45	54	—	99	0.35
1978	24,885	75	40	—	115	0.46
1979	25,762	63	34	7	104	0.40
1980	24,327	83	36	—	119	0.49
1981	23,928	6	20	14	102	0.43
1982	24,828	62	26	14	102	0.41
1983	25,768	79	18	15	112	0.43
1984	22,066	50	20	17	87	0.39
1985*	22,211	—	—	—	101	0.45
1986*	22,574	—	—	—	95	0.42
1987	—	—	—	—	—	—
1988*	24,519	—	—	—	70	0.28

Sources: Scordino (1985)

* Data from experimental roundups, not harvest (Fowler, pers. comm. 1988).

Observers collecting marine mammal sighting data in the North Pacific Ocean and Bering Sea during May to August 1978 reported three northern fur seals entangled in trawl webbing and one entangled in a piece of gill net (Jones and Ferrero 1985). An abandoned gill net containing several hundred seabirds and salmon was also retrieved. Although the frequency of entanglement observations is low, many different species are involved and most researchers agree that actual sightings are probably an underestimate of the number of animals entangled. Sighting effort is quite low, considering the vastness of the sea, and many entangled animals undoubtedly go unnoticed.

At-sea observations conducted between 1982 and 1984 revealed eight entangled pinnipeds (six sea lions and two northern fur seals) and one entangled cetacean (humpbackwhale - *Megaptera novaeangliae)*. The whale and two of the pinnipeds were dead (Berger and Armistead 1987).

Alaska Department of Fish and Game surveys in the Kodiak Archipelago found nets, plastic packing bands, ropes and buoys on the beach; and observed Steller sea lions (*Eumetopias jubatus*) entangled in plastic bands and net fragments (Calkins 1985).

Loughlin et al. (1986) evaluated the nature and magnitude of entanglement in debris on northern (Steller) sea lions on the Aleutian Islands. A total of 15,957 adults were counted, of which only 11 animals showed signs of entanglement. Data derived from this study are inadequate to address the question of entanglement of pups. Although entanglement has not been implicated as a contributing factor, the Eastern Aleutian Island population of sea lions has exhibited an overall decline of 79 percent, from about 50,000 animals in the 1960's to about 10,000 adult animals in 1985.

Stewart and Yochem (1985) investigated entanglement of sea lions, elephant seals, and harbor seals at San Nicholas and San Miguel Islands off California. Individuals of all three groups had encountered plastic debris, but less than one percent of the animals examined were affected. Entangling materials were fishing gear (monofilament gill net, monofilament line, trawl webbing) and plastic strapping bands.

Hawaiian monk seals are highly endangered, numbering only 500 to 1,500 animals. Henderson (1985) reported 27 to 35 animals entangled between 1974 and 1984. Hawaiian monk seals are particularly susceptible to buoy lines from spiny lobster traps and net debris from gill net and groundfish trawl fisheries. On one of their few remaining breeding islands, in 1983 alone, 11 of 26 pups were either entangled in netting or observed playing among netting and debris in the water (Wallace 1985).

In her review of debris entanglement in the marine environment, Wallace (1985) cited reports of entangled Cape (South African) fur seals (*Arctocephalus pusillus*), Juan Fernandez fur seals (*Arctocephalus phillippi)* along the Argentine coast, and southern sea lions (*Otaria flavescens*) on the Chile coast. Reports of New Zealand fur seals (*Arctocephalus forsteri*) found with strapping bands about their necks have increased in recent years (Cawthorn 1985). Other reported entanglement incidences in New Zealand involve Hooker's sea lion (*Phocarctos hookeri*) and three species of whales.

Whales and Dolphins

The most common materials entangling whales and dolphins are gill nets (and fragments of them) and buoy lines used to mark traps. Weinrich (1987) reports that 56 percent of endangered right whales (*Balaena glacialis*) photographed by the New England Aquarium had scars from probable gillnet or lobster gear entanglement. Forty percent of the humpback whales photographed by the Center for

Coastal Studies, in New England waters, bear scars indicating they have encountered nets or lines (Weinrich 1987). Numerous sightings of gray whales (*Eschrichtius robustus*) with crab pot buoy lines between their baleen plates have been reported off the Oregon coast (Mate 1985). These entanglements are thought to be a result of encounters with actively fished crab pots, not ghost fishing gear.

There is also evidence that whales and dolphins ingest plastic materials. Of 38 sperm whale stomachs examined by Mate (1985), one contained trawl net material. According to Wallace (1985) there are reports of plastic debris being ingested by a minke whale (*Balaenoptera acutorostrata*), pygmy sperm whale (*Kogia breviceps*), Cuvier's beaked whale (*Ziphius cavirostris*), and rough-toothed dolphin (*Steno bredanensis*). Walker (1988) reported on records of ingestion of marine debris by small cetaceans stranded on U.S. and Canadian beaches. Plastic objects were found in the stomachs of individuals of seven species of whales, seven species of dolphins, and two species of porpoises.

BIRDS

Plastics in the marine environment cause similar problems for all types of birds. Seabirds and shorebirds, particularly, become entangled in active fishing nets, discarded nets, and other marine debris such as beverage container rings and monofilament line. Entanglement can lead to drowning, choking, or lacerations. Diving birds are particularly susceptible to entanglement and drowning in ghost fishing nets.

There have been reports of pelicans with beverage container rings and monofilament line around their beaks, which prevented them from catching prey. A greater source of concern, however, appears to be entanglement of monofilament fishing line around the wings and legs of pelicans and egrets which then become tangled in trees where the birds roost. Birds caught in this manner die of exhaustion or starvation (NOAA 1988).

Heneman (1988) cites one study that was conducted specifically on seabird entanglement in marine debris. German researchers investigated data on 42 debris-related seabird deaths involving grebes, gannets, eiders, kittiwakes, and murres. The most common entangling materials included fishing line, net fragments, 6-pack yokes, and plastic sheeting. Jones and Ferrero (1985) reported entanglement of auklets, puffins, murres, and shearwaters in the western North Pacific.

Researchers have found plastic particles in the stomachs of 50 species of seabirds from around the world (Day et al, 1985). Raw plastic pellets appeared to be the major form of plastic ingested. Other commonly ingested articles included broken plastic pieces, toys, bottle caps, plastic sheets, and monofilament and polypropylene line. The problem is very widespread geographically, having been found in seabirds in the North and South Atlantic, the North and South Pacific, the Arctic, and the subantarctic. Ingestion of plastics can affect young and adult birds in several ways: blockage of digestive passages, ulcerations, internal injuries, false satiation, and accumulation of toxic substances.

In one California study, shearwaters and parakeet auklets showed the highest incidence of ingested plastic, as high as 21.7 particles per individual (Morejohn 1976 as cited in Day et al, 1985). Resin pellets are the most common form of plastic ingested by seabirds. Puffins, auklets, and murres ingest floating resin pellets, probably because they resemble fish eggs or invertebrate prey. These pellets and other forms of plastics may be especially harmful to young birds, which rely on regurgitated food from their parents during the first weeks of life. Despite numerous reports of entanglement and ingestion, marine debris has not yet been associated conclusively with the decline of any seabird population.

SEA TURTLES

All five species of sea turtles that inhabit U.S. waters are listed as either endangered or threatened under the Endangered Species Act. As with other wildlife, ingestion or entanglement in marine debris affects turtles. Entanglement may cause a turtle to drown, reduce its swimming efficiency, lacerate appendages, etc. Balazs (1985) reviewed the available literature and identified 79 reports of ingestion of plastic and 60 reports of entangled sea turtles from all over the world. U.S. coastal waters accounted for a large portion of reported ingestion (40.8%) and entanglement (31.7%).

Young sea turtles are especially vulnerable to plastic debris. They spend up to the first five years of life drifting with oceanic currents, and as with other floating material, they appear to be concentrated along lines of current convergences or at the centers of major current gyres, such as the Sargasso Sea in the Atlantic. Carr (1987) reported that these areas have high concentrations of plastic marine debris, particularly pieces of styrofoam, resin pellets, and floating nets which intermingle with sargassum weed and other flotsam. Young turtles may ingest plastic, mistaking it for food items, or become entangled in nets and line. Stomachs of dead young loggerheads (*Caretta caretta*) that wash ashore on Florida beaches often contain plastic beads (Carr 1987).

Adult leatherback turtles (*Dermochelys coriacea*) have been found dead on beaches with plastic bags and sheets in their digestive tracts. Researchers attribute consumption of plastic bags and sheeting to their resemblance to jellyfish, the primary food of leatherbacks (Carr 1987). Data collected by the National Marine Fisheries Service indicate that 30 to 50 percent of Kemps ridley, green, and loggerhead turtles ingest plastic (NOAA 1988). These estimates are somewhat higher than information presented by Balazs (1985) that 13 percent of leatherback turtles and 23 percent of green sea turtles (*Chelonia mydas*) examined had consumed plastic bags. Wallace (1985) reported that ingestion of plastic has been documented in leatherbacks from New Jersey, New York, France, French Guiana, and South Africa; in green turtles from Australia, Central America, Japan, and the South China Sea; in hawksbill turtles (*Eretmochelys imbricata*) from the Caribbean coast of Costa Rica; and in olive ridley turtles (*Lepidochelys olivacea*) from the western coast of Mexico.

FISH AND SHELLFISH

Fishing pots, traps, gill nets, and other fishing gear may continue to capture fish and shellfish long after they are discarded or lost. High (1985) estimated that king crab and Dungeness crab (*Cancer magister*) fishermen in Alaska and along the Pacific coast lose over 10 percent (>1200) of their pots annually. Lost pots continue to trap fish and shellfish which in turn attract other predators, such as crabs. The cycle continues, sometimes up to several years, until the trap disintegrates.

Lost or discarded monofilament gill nets will also continue to catch target and non-target fish for varying periods of time after active fishing with them has stopped. Gerrodette et al. (1987) studied the changes in shape of derelict gill net fragments of varying sizes to determine the fishing ability, over time, of these nets. The study showed that drifting gill nets will eventually collapse and ball up, thus reducing their fishing ability. Results indicated that free-floating gillnets less than 100 meters long collapse in less than a day, while longer nets may continue fishing for several days to several weeks. High (1985) reported synthetic gill nets grounded on the sea floor that remained strong enough to continue capturing fish and other wildlife for over six years. Work done by Carr et al. (1985) found nine lost gill nets in a 100 acre

(40.5 ha) area near Gloucester, Massachusetts. They estimated the age of one of these nets at over four years. Jones and Ferrero (1985) reported numerous entanglement incidents in the western North Pacific involving salmon shark (*Lamna ditropis*), ragfish (*Icosteus aenigmaticus*), chum salmon (*Oncorhynchus keta*), coho salmon (*O. kisutch*), and spiny dogfish (*Squalus acanthias*).

There are numerous reports of plastic ingestion by marine fish (Manooch and Hogarth 1983; Manooch and Mason 1983). These investigators reported plastic in the guts of adults of five species of marine fish and one anadromous species. Additionally, plastics have been found in the gut of larval and juvenile stages of 14 marine fish species (Carpenter et al, 1972; Kartar et al, 1973; Kartar et al, 1976).

To date, there are no population-level data on the effects of marine debris on fish or shellfish. The long-term impacts on fishery resources, while certainly negative, remain largely unknown.

LOWER TROPHIC LEVEL ORGANISMS

Lower trophic level organisms in the marine environment (zooplankton, filter feeders, and shellfish) may also be affected by ingestion of small plastic particles. Although there has been no research done on this problem, surface plankton tows in the North Pacific (Day et. al., 1986) indicate that small plastic particles are present in the surface microlayer where many lower trophic level organisms feed. Ingestion of small plastic particles could cause the same problems for these organisms as seen in birds and turtles.

CHAPTER III

PLASTIC MATERIALS THAT POSE THE GREATEST POTENTIAL HAZARD TO LIVING MARINE RESOURCES

The most commonly found plastic debris items on our beaches and in our oceans are bottles, sheeting, bags, fishing nets and fragments, styrofoam cups and fragments, rope and strapping bands, and plastic fragments. This debris is generated by land-based sources (littering, manufacturing, through sewage treatment plants, and waste disposal) and ocean-based sources (shipping, fishing, boating, and oil development activities).

The types of plastic debris that pose the greatest potential hazard to living marine resources are ghost fishing gear (commercial and recreational), plastic strapping bands, plastic bags, synthetic rope and line, small plastic objects, and raw plastic pellets (Laist 1987). Table 5 lists those common marine debris items that pose the greatest risk (hazard + exposure) to marine resources. Fishing debris in the world's oceans is probably the most significant source of entanglement for marine animals. The three kinds of synthetic fishing material most commonly involved in entanglement are polyethylene trawl webbing, monofilament gill net, and monofilament fishing line (from recreational and commercial fisheries). Ropes, traps and pots can also contribute to the entanglement problem. As with other types of debris, "ghost" fishing gear may be either deliberately or inadvertently introduced into the marine environment. Entanglement in fishing gear has been documented for every major group of species for which entanglement data exist, and is believed to cause mortality through starvation, suffocation, infection, exhaustion, bleeding, drowning, and increased predation (Fowler 1988).

Merchant shipping is also a major source of marine debris. Cargo-associated plastic wastes that pose a threat to living marine resources are plastic strapping, plastic sheeting, and raw plastic pellets. Strapping materials are known to entangle many species of marine mammals (Stewart and Yochem 1987). Plastic sheeting is ingested by mammals and turtles, and pellets are ingested by turtles, fish, and birds. Raw plastic pellets can cause serious problems for fish and birds that ingest them. If ingested in large enough quantities, pellets may reduce a bird's appetite, block the digestive tract, and decrease reproductive performance. Young birds are often fed pellets by adult birds who pass them to the young through routine feeding (Fry et al. 1987).

Interactions with common domestic plastic items from all sources can be fatal for marine animals. Ingestion of plastic bags has been documented in whales and sea turtles. There are numerous reported cases of dead turtles with plastic bags in their digestive tracts (Balazs 1985). Six-pack yokes have been found around the necks of birds, fish, and young marine mammals, in some cases leading to strangulation. Caps and lids as well as a wide variety of whole and fragmented plastic products are ingestion hazards for many species of marine animals.

Sewage-associated plastics (tampon applicators, condoms, disposable diapers) are primarily an aesthetic problem on beaches, although they may be ingested by birds, turtles, and marine mammals that haul-out on affected beaches.

Particulate plastic results from the breakdown of plastic articles into progressively smaller pieces. The advent of degradable plastics may increase the number of smaller plastic particles in the marine environment. These small pieces often become floating marine debris. Ingestion of plastic particles by sea turtles and seabirds has been documented, and may well occur in lower trophic level animals.

Table 5. Debris Items that Pose the Greatest Risk to Marine Life.

Item	Possible Marine Problem	Service life
Plastic bags/ sheets	Entanglement/ Ingestion	Single or multiple use
Net fragments	Entanglement	Multiple use (1-5 yrs.)
Ropes, strapping and lines	Entanglement	Multiple use
Lost traps	Entanglement	Multiple use (1-5 yrs.)
Styrofoam pieces	Ingestion	Multiple use
Resin pellets	Ingestion	Single use
Six-pack yoke	Entanglement	Single use

Adapted from Pruter (1987)

CHAPTER IV

DEGRADABLE PLASTICS TECHNOLOGIES

Plastics, by design, resist normal degradation processes. Deterioration of plastic materials in the environment occurs in stages during which several physical changes are readily apparent (Figure 2). No reliable information is available, however, on the length of time it takes plastics to degrade in the marine environment (Andrady 1988b). The rate at which plastic products degrade depends on several environmental factors - the levels of exposure to light, heat, and water; and biochemical and biophysical processes, as well as the physical properties of the particular polymer. The following section, based on Andrady (1987, 1988a, 1988b), briefly discusses the effects of these environmental factors on plastics.

Polymers, such as plastics, deteriorate slowly due to the action of sunlight, gradually undergoing discoloration and a reduction in strength. Higher temperatures tend to accelerate deterioration by sunlight. Additionally, some thermal oxidation occurs at high temperatures. Plastics do not readily dissolve in water. In general, water only acts to reduce the available sunlight and the temperature of plastics. Carbon chain polymers (e.g., polypropylene, polyethylene) are generally microbially inert and any microbial action occurs only at the ends of the polymer chains. Actions of crustaceans, bryozoans, and microbes may attack a composite material where one component is biodegradable, leading to a weakening of the composite. Exposure to these factors, when combined with movement due to wind or currents, may break the plastic into smaller pieces reducing the risk of entanglement, but increasing the risk of ingestion. Even in combination, however, these factors degrade plastics very slowly in the marine environment. In the strictest chemical sense, the degradation is not complete until the products of degradation are in turn broken down into chemically simpler compounds such as carbon dioxide and water.

Currently available controlled-lifetime plastics technologies accelerate the environmental weathering process of polymers by chemical means. These might broadly be classified into two groups: a) enhanced photodegradable polymers and; b) enhanced biodegradable polymers. In both cases, the plastic is chemically modified by pre-reaction or by use of an additive incorporated into the plastic to make it degradable. However, not all these technologies have developed to the point of economically-feasible commercial production.

Several manufacturers are currently producing photodegradable composites. Ethylene-carbon monoxide copolymers have a ketone group in the chain of the polymer which allows it to absorb ultraviolet light and consequently rapidly photodegrade. Photodegradable six pack yokes made from such low density polyethylene copolymers are currently commercially available and in widespread use.

Ecolyte (TM) is a photodegradable polymer developed by a process in which a ketone group is incorporated as a branch on the polymer chain. This process can be used to render polyvinyl chloride, polystyrene, polyesters, and polyethylene polymers photodegradable. Ecolyte is currently commercially available.

Several other technologies have been suggested for enhancing the degradability of plastics. A pro-oxidant additive, developed by the Princeton Polymer Laboratory, might be used to render polyolefins and polystyrene photodegradable (Princeton Polymer Laboratories 1985). A mixture of two salts of

Figure 2. Fate of plastic material in the environment.

Plastic Product ———> Weakened Plastic ———>

Embrittled Plastic ———> Large Plastic Pieces ———>

Smaller Plastic Pieces ———> ———> ———>

Simple Compounds ———> Small Molecules

Source: Andrady (1988a)

transition metals may also enhance the rate of photodegradation (Mellor *et al.*, 1973; Osawa and Nakano 1976). A process which renders polyethylene photodegradable is available through the Ampacet Company (Carlson and Mimeault 1987) and is used in photodegradable garbage bags.

Biodegradable composites are also available. Several thermoplastic resins, which are inherently biodegradable, could be used as packaging material. The use of these materials for packaging, however, is unproven and very expensive. Starch-plastic composites are made by incorporating starch into the polymer matrix of the product. The starch breaks down, leading to rapid embrittlement and smaller particle size; the resulting polymer particles are likely to biodegrade faster due to increased surface area (Griffin 1972, 1975, 1977). Such starch-resins are currently available through a Canadian and U.S. company. In a similar way, starch is also used in starch-bound plastic compositions. Pre-reaction of the starch with the polymer results in a partially biodegradable material. Depending on the amount of starch incorporated, the material is expected to biodegrade and become brittle in a short time (Otey *et al.* 1985).

There are several limitations to current degradable technologies:

1. The degradability of most polymers has not been demonstrated under marine conditions.

2. Photodegradable technology can not be applied to things that sink.

3. The degradation rate, which is critical to the product's service life, is difficult to control.

4. There is a lack of basic technical data on most degradable compounds.

5. There are still uncertainties regarding the effect of additives, degradation products, and decreased particle size (resulting from the accelerated breakdown of one piece into many smaller pieces) on the environment.

6. Their use may detract from the success of anti-litter education efforts and may actually promote littering.

7. The degradable products are unlikely to be re-utilized, recycled, or have their heat content recovered.

In spite of these limitations, when combined with public education regarding the full range of waste disposal options, degradable polymers represent a promising, practical technology that might be used to help reduce some of the litter and entanglement problems caused by marine debris. Degradable plastic products may be better suited for some uses than others.

Six-pack yokes, which replaced cardboard containers, are one of the more ubiquitous and hazardous components of marine debris. In states that require degradable yokes, a rapidly photodegradable yoke is available which the manufacturer claims becomes brittle after about 3 months of exposure outdoors. There is no evidence that it differs substantially in toxicity from the regular material (NOAA 1988). Its

Table 6 MARPOL Annex V: Garbage Disposal Restrictions

GARBAGE	ALL VESSELS EXCEPT OFFSHORE PLATFORMS AND ASSOCIATED VESSELS		OFFSHORE PLATFORMS AND ASSOCIATED VESSELS[1]
	Outside Special Areas	In Special Areas[2]	
Plastics—includes synthetic ropes, fishing nets, and plastic bags	Disposal prohibited	Disposal prohibited	Disposal prohibited
Floating dunnage, lining and packing materials	Disposal prohibited less than 25 miles from nearest land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, metal, bottles, crockery and similar refuse	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, etc., comminuted or ground[3]	Disposal prohibited less than 3 miles from nearest land	Disposal prohibited	Disposal prohibited
Food waste not comminuted or ground	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited
Food waste comminuted or ground[3]	Disposal prohibited less than 3 miles from nearest land	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited less than 12 miles from nearest land
Mixed refuse	Varies by component[4]	Varies by component[4]	Varies by component[4]

Adapted from U.S. Federal Register *Advance Notice of Proposed Rulemaking*, June 24, 1988, p. 23887.

[1]Includes all fixed or floating platforms engaged in exploration or exploitation and associated offshore processing of seabed mineral resources, and all vessels alongside or within 500 m (approximately one-third mile) of such platforms.

[2]The Mediterranean, Baltic, Red, and Black seas and the Persian Gulf.

[3]Must be able to pass through a screen with a mesh size no larger than 25 mm.

[4]When substances having different disposal or discharge requirements are mixed, the more stringent disposal requirement shall apply.

effectiveness under marine conditions has not been completely demonstrated; but preliminary results indicate that it performs well in sea water (Andrady 1988b). However, there may be a problem with biofouling; once it sinks or is covered with algae it cannot photodegrade. Additional information needed to assess this product includes:

1) it's effectiveness in the marine environment;
2) the nature and rates of release of degradation products into the environment; and
3) the extension of the technology to plastic bottle carrier devices.

The easiest method for reducing the contribution of tampon applicators to marine debris would be to make them out of paper, as currently done by one manufacturer. Manufacturing them from photodegradable material may also be a viable option, but has not been investigated.

A grade of rapidly photodegradable, expandable polystyrene which could be used in the manufacture of styrofoam products is currently being marketed by a resin supplier in Canada. The manufacturer claims that it degrades in several months and only costs about 10 percent more than traditional materials. In general, there is a need for research to determine its performance under marine conditions, variability introduced by climatic and other factors, toxicity of reaction products, feasibility of rendering the material biodegradable, and the effect of increased particles, resulting from breakdown to smaller pieces, on the environment.

No degradable balloons are currently available. Under some conditions, latex balloons become brittle in 3-5 months when exposed on land (Andrady 1988a); there is no information on degradation in the marine environment. Balloons are good candidates for manufacture from degradable materials because they are used only once. The development of degradable rubber balloons should require only a minimal research effort. Additionally, they would be only marginally more expensive than regular balloons (NOAA 1988).

The development of degradable fishing equipment, such as nets, lines, and traps, poses a difficult problem. Fishing equipment is used repeatedly throughout the year and over a period of several years. Therefore, a balance must be reached between the service life of the gear and the rate at which the composite materials degrade. A rapidly degrading net would not be economical, and could be dangerous. Additionally, the precise rate at which the gear degrades would have to be known to discontinue its use before it reduces the gear's ability to catch fish. None of the available controlled-lifetime plastic technologies have been demonstrated to work in sea water or have such precise degradation rates (NOAA 1988). Further, degradable synthetic fishing gear will probably not be voluntarily accepted by the fishing industry if it is more expensive or has a shorter life span than currently used gear.

Alternatively, proper disposal and recycling of used fishing gear are being promoted by the fishing industry. Work is presently being done under two Saltonstall-Kennedy Grants to develop cost effective methods to comply with prohibition of at-sea disposal of plastics and other wastes. Funding was provided to the Gulf and South Atlantic Fisheries Development Foundation and the Pacific Marine Fisheries Commission to focus on education of commercial fishermen, establishment of reception facilities, and evaluation of cost effective methods to dispose of or recycle fishing gear and other debris generated by fishing vessels.

CHAPTER V

EXISTING LEGAL AUTHORITIES AND PROGRAMS FOR ADDRESSING MARINE DEBRIS PROBLEMS

LEGAL AUTHORITIES

There are numerous international conventions and U.S. Federal laws that prohibit, tax, or regulate sources of plastic materials that enter the marine environment. International agreements to control ocean pollution include: MARPOL, the London Dumping Convention, and the Cartagena Convention.

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the primary international mechanism for preventing the discharge of pollutants by ships. Annex V, Regulations for the Prevention of Pollution by Garbage from Ships, prohibits discharge into the sea of "all plastics including, but not limited to, synthetic ropes, synthetic fishing nets, and plastic garbage bags," and "floating dunnage, lining, and packing materials" (Table 6). Annex V will enter into force on December 31, 1988. Annex V does not address land-based sources of persistent marine debris or the accidental loss of synthetic fishing gear.

The International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention) prohibits the dumping at sea of wastes generated on land (including plastics and other persistent synthetic materials, e.g., nets and ropes). The Cartagena Convention calls for all signatory nations to take "all appropriate measures" to prevent, reduce, and control pollution from ships.

A variety of U.S. Federal laws address regulation of discharges of persistent debris that ends up in the marine environment. The Act to Prevent Pollution from Ships, as amended, is the implementing legislation for Annex V of MARPOL, and provides a major step in controlling the at-sea disposal of plastic wastes by U.S. ships. Subtitle B of the Marine Plastic Pollution Research and Control Act of 1987 (MPPRCA) requires that the Environmental Protection Agency (EPA) conduct a study of methods to reduce plastic pollution. EPA, the National Oceanic and Atmospheric Administration (NOAA), and the Department of Transportation are required to conduct a public outreach program to educate the public about the effects of marine debris. Title IV of the MPPRCA is the Driftnet Impact Monitoring, Assessment and Control Act of 1987. This Act requires the Secretary of Commerce to collect information and report to Congress on numbers of U.S. marine resources harmed by foreign driftnet fishing vessels which are fishing outside the Exclusive Economic Zone of any nation.

P.L. 100-556, which was signed into law on October 28, 1988, addresses the specific problem of plastic six-pack yokes. Title I, entitled "Degradable Plastic Ring Carriers", directs the Environmental Protection Agency to require, by regulation, that any regulated item (six-pack yoke) intended for use in the United States shall be made of naturally degradable material.

Other Federal laws that address some aspect of the persistent marine debris problem include:

Federal Water Pollution Control Act,
Ocean Dumping Act,
National Ocean Pollution Planning Act of 1978,
Magnuson Fishery Conservation and Management Act,
Marine Mammal Protection Act, and
Endangered Species Act.

The Report of the Interagency Task Force on Persistent Marine Debris (NOAA 1988) describes these and other Federal and state laws that relate to marine debris.

The U.S. Coast Guard is charged with enforcing the provisions of the Act to Prevent Pollution from Ships, as amended. The Coast Guard is finalizing regulations implementing the pollution prevention requirements of Annex V of MARPOL 73/78. The regulations include definitions, a listing of special areas, garbage handling requirements, penalties for violations, reception facilities, certificates of adequacy, and garbage retention criteria.

Existing legislation should be sufficient to prevent plastics from entering the marine environment from ocean sources. Emphasis should now be placed on enforcement of existing laws and public education regarding those laws. Compliance with Annex V should be monitored through the Coast Guard's report on compliance, which is required by the Plastic Pollution Research and Control Act of 1987. If the Coast Guard's reports indicate a low level of compliance, alternative ways to handle the problem should be considered, either by amending current legislation or regulations, increasing enforcement efforts, or other appropriate means.

Existing Programs

Before the Domestic Policy Council established the Interagency Task Force on Persistent Marine Debris (June 1987) and the President signed the Marine Plastics Pollution Research and Control Act (December 1987) several Federal agencies were operating programs regarding persistent marine debris with little coordination. In accordance with MPPRCA, agencies are undertaking several new activities:

-The Coast Guard is preparing regulations to implement the provisions of the MPPRCA which include a prohibition against disposal of plastic materials from ships into the marine environment. Final regulations will become effective by December 31, 1988.

-NOAA, EPA, Coast Guard, and the Department of the Interior are collectively developing campaigns to increase public awareness of marine debris issues.

-EPA and NOAA are conducting studies on ways to reduce plastic in the marine environment.

-The EPA is preparing studies and plans to address problems in the New York Bight, including assessing ways to reduce plastic pollution there.

Citizen's groups have become more active in recycling and beach clean-up efforts. Much of the existing data on types and distribution of plastic litter on beaches were generated by local beach cleanups. In 1987 and 1988, 19 and 23 states, respectively, held beach cleanups during COASTWEEKS, a national event dedicated to focus attention on our coastal areas. The Center for Environmental Education has been instrumental in organizing and standardizing beach cleanup data collection and reporting.

Several workshops on marine debris and fishery-generated debris have been convened. In late 1987, a coalition of commercial fishermen sponsored the North Pacific Rim Fishermen's Conference on Marine Debris. Technical problems and solutions were addressed, and the following goals were independently established by the fishing industry:

-Every effort should be made to ensure that plastic materials are not discarded at sea and loss of fishing gear should be avoided.

-A maximum effort should be made to reduce the quantities of synthetic refuse on board by minimal use of plastic materials.

-Special attention should be given to promoting the development of affordable technology and operational procedures to reduce the loss of fishing gear and enhance recovery of lost gear.

-Promulgation of regulations to implement Annex V of MARPOL should be encouraged.

-Fishing groups should focus their efforts to encourage other industries contributing to the marine debris problem to become involved in seeking solutions.

-Fishing groups should promote local programs to further the education of fishermen, port authorities, resource managers, and the general public regarding the marine debris problem.

-Fishing vessel operators should post in plain view a notice to officers and crew that discharge of plastic materials into the oceans is contrary to international law.

-Participants should encourage their organizations to cooperate with dock/port authorities and other government agencies to establish effective shoreside refuse disposal systems.

In February 1988, fishermen, marine researchers, educators, plastics manufacturers, and government representatives met in Portland, Oregon, for "Oceans of Plastic", a NOAA-sponsored workshop to address problems caused by fisheries-generated plastic debris and derelict fishing gear. Discussions indicated that many commercial fishermen have assumed leadership roles in fighting marine plastic debris and their industry does not at this time need special government regulation. Fishing industry representatives said the best incentive for fishermen to reduce their contribution to the marine debris problem is education, coupled with assistance in shoreside solid waste disposal. Although some participants doubted whether education alone can rectify the problem, most agreed educational efforts will help reduce marine plastic debris. If compliance reports indicate that education efforts are inadequate, participants recommended that regulatory programs should be pursued in cooperation with the fishing industry. Specific recommendations that came out of the workshop are as follows:

-Distribute nationally summaries of the Newport Marine Refuse Disposal Project for application and use, and support funding of similar projects in other selected ports.

-Develop a national repository and clearinghouse for collection and dissemination of information on the marine debris problem.

-Maximize development of voluntary approaches to attack the marine debris problem through involvement of the domestic commercial and recreational fishing communities and general public through expansion of current successful programs.

-Encourage the plastics industry to work more aggressively and directly with the fishing industry to address plastic-oriented problems associated with individual fisheries.

-Explore practical ways to dispose of plastic debris and derelict fishing gear ashore. Explore technologies such as on-board incineration and recycling to reduce the impact of fisheries-generated debris on shore-based disposal facilities. Encourage use of alternative packaging materials aboard vessels.

Work is under way that addresses several of these recommendations. Saltonstall-Kennedy grants have been awarded for port projects to develop programs to deal with plastic debris from fishing vessels. The NOAA Marine Entanglement Research Program has contracted with the Center for Environmental Education to establish and operate two Marine Debris Information Offices, one on the Pacific Coast (San Francisco) and one in Washington, D.C. to deal with the Atlantic Coast and Gulf of Mexico. The primary objective of these offices is to maintain and distribute, to industries and the general public, information and educational materials on the impacts of persistent marine debris and, their roles in its creation, removal, and proper disposal. The Departments of Commerce and Transportation and the U.S. EPA are providing support for the National Marine Debris Data Base.

CHAPTER VI

RECOMMENDATIONS

Integrated efforts involving regulation, enforcement, research and education will be the key to resolving the complex problems associated with marine debris. In light of the many existing statutes and programs, enforcement of existing laws and regulations and education of the general public are probably the most needed actions in the immediate future. Marine litter could be reduced significantly through increased compliance and enforcement of existing laws and regulations.

In May 1988, the Interagency Task Force on Persistent Marine Debris made 23 recommendations in the following five general categories:

-Federal leadership,
-Public awareness/education program,
-Implementing laws related to marine debris,
-Research and monitoring, and
-Beach clean-up and monitoring

We concur with the recommendations made by that group. The five general recommendations are summarized below:

1) Federal agencies should provide leadership and continue formal and in formal coordination activities related to marine debris with international organizations, state and local governments, private industry, and environmental groups. Federal agencies acknowledge that an effective program is possible only with strong state and local involvement.

2) Concerned Federal agencies should work with each other, state and local governments, private industry, and environmental groups to develop comprehensive educational materials on problems caused by marine debris and ways to solve them.

3) The Department of Transportation, EPA, NOAA, and Navy should vigorously implement the Marine Plastic Pollution Research and Control Act and other laws to reduce plastic pollution in the marine environment.

4) Federal agencies should carry out research to:

a) identify and quantify deleterious effects that marine debris causes for fish and wildlife, coastal communities, and vessels;
b) determine land-based sources of marine debris; and
c) assess potential uses for, by-products of, and effects of by-products of degradable plastic products.

5) Federal agencies should work cooperatively among them- selves, as well as with state agencies, private industry, and environmental groups to remove marine debris from beaches and other parts of the marine environment. Federal agencies should encourage

coordination with state and local authorities to conduct systematic monitoring of marine debris accumulation and impacts to assess compliance with regulations prohibiting dis posal of plastics and controlling other solid waste discharges into U.S. waters.

Task Force members unanimously agreed that the most important undertaking should be a public education campaign. Additionally, the Department of Commerce recommends:

-Recognizing that solution of the growing solid waste disposal crisis on land is necessary to solve the marine debris problem, Congress should act to support a broad national solid waste agenda including technology, education, and infrastructure.

-Federal, state, and local agencies should cooperate fully with USDA/APHIS to facilitate safe, effective handling of increases in foreign garbage deliveries to U.S. ports resulting from compliance with MARPOL Annex V.

-Compliance with Annex V should be monitored through the Coast Guard's report on compliance which is required by the Plastic Pollution Research and Control Act of 1987. If the Coast Guard's reports indicate a low level of compliance, alternative ways to handle the problem should be considered, either by amending current legislation or regulations, increasing enforcement efforts, or other appropriate measures.

-Federal agencies should explore the need for and feasibility of a national recycling initiative.

-Federal agencies should continue to educate the public regarding marine debris issues.

-Federal and state agencies should enter into agreements with the U.S. Coast Guard to enforce MARPOL Annex V.

-Federal agencies should give preference to purchase of materials, supplies, and equipment made from recycled materials.

-Fishery management plans developed by the Regional Fishery Management Councils and Interstate (Fishery) Commissions should include provisions relating to disposal of gear and escape panels in traps and pots.

-Federal agencies should insure that best use is made of beach debris data collected by voluntary beach clean-ups around the country, including support for organized data collection, its storage, analysis, and reporting.

-All observer reporting forms used in domestic and joint-venture fisheries in the U.S. EEZ should address gear disposal.

-Congress should support funding requests in President's Budget for research efforts related to marine debris issues. Primary research efforts should include:

1) development and evaluation of degradable technologies;
2) effects of degradable plastics (and their breakdown products) on themarine environment, particularly living marine resources;
3) the determination of impacts of marine debris on local and regional economies;
4) the biological and ecological impacts of marine debris, especially on endangered and protected species; and
5) ways to assure adequate handling facilities in ports.

-Federal and state agencies should recognize the special problems of remote ports in providing adequate reception facilities for ships and assist in their solutions.

-Federal agencies should encourage citizens and employees in coastal communities, to participate in local beach clean-up campaigns.

REFERENCES

Andrady, A.L. 1987. Research on the use of degradable fishing gear and packaging material. NWAFC Processed Report 87-03. Seattle, Washington. January, 1987. 49 pp.

Andrady, A.L. 1988a. Experimental demonstration of controlled photodegradation of relevant plastic compositions under marine environmental conditions. NWAFC Processed Report 88-19. Seattle, Washington. September, 1988. 68pp.

Andrady, A.L. 1988b. The use of enhanced degradable plastics for control of plastic debris in the marine environment. In Alverson, D.L. and J.A. June (eds.). Proceedings of the North Pacific Rim Fishermen's Conference on Marine Debris, Kailua-Kona, Hawaii, October 1987.

Anonymous. 1988. Brakes on growth in store for 1988. In Modern Plastics, January 1988. p. 95.

Balazs, G.H. 1985. Impact of ocean debris on marine turtles: Entanglement and ingestion. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.387-429.

Bean, M.J. 1987. Legal strategies for reducing persistent plastics in the marine environment. Marine Poll. Bull. 18(6b): 357-360.

Berger, J.D. and C.E. Armistead. 1987. Discarded net material in Alaskan Waters, 1982-84. NOAA Tech. Mem. NMFS F/NWC-110. Seattle, WA. 66 pp.

Bigford, T. E. 1987. Unpublished data, Pers. Comm. National Marine Fisheries Service, Gloucester, MA.

Cal Recovery Systems, Inc. 1988. Evaluation of Plastics Recycling Systems. NWAFC Processed Report 88-16. 43pp.

Calkins, D.G. 1985. Steller sea lion entanglement in the marine debris. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp. 308-314.

Carlson, A.W. and V.J. Mimeault. 1987. Degradable concentrates for polyolefins. In Proceedings of symposium on degradable plastics, Washington, D.C. pp.16-30.Carpenter, E.J. and K.L. Smith, Jr. 1972. Plastics on the Sargasso Sea surface. Science 175: 1240-1241.

Carpenter, E.J., S.J. Anderson, G.R. Harvey, H.P. Milkas, and B.B. Peck. 1972. Polystyrene spherules in coastal waters. Science 178: 749-750.

Carr, A. 1987. Impact of nondegradable marine debris on the ecology and survival outlook of sea turtles. Marine Poll. Bull. 18(6b), 352-356.

Carr, H.A., E.H. Amaral, A.W. Hulbert, and R. Cooper. 1985. Underwater survey of simulated lost demersal and lost commercial gill nets off New England. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.336-343.

Cawthorn, M.W. 1985. Entanglement in, and ingestion of, plastic litter by marine mammals, sharks, and turtles in New Zealand waters. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.336-343.

Center for Environmental Education. 1987. Plastics in the ocean: more than a litter problem. Washington, D.C. 128p.

Center for Environmental Education. 1988a. A citizen's guide to plastics in the ocean: more than a litter problem. Washington, D.C. 131pp.

Center for Environmental Education. 1988b. Texas Coastal Cleanup report. Washington, D.C. 105pp.

Day, R.H., D.M. Clausen, and S.E. Ignell. 1986. Distribution and density of plastic particulates in the North Pacific Ocean in 1986. Document submitted to the International North Pacific Fisheries Commission, Anchorage, Alaska, November 1986. 17p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., Natl. Oceanic Atmos. Admin., Auke Bay Laboratory, Auke Bay, AK.

Day, R.H., D.H.S. Wehle, and F.C. Coleman. 1985. Ingestion of plastic pollutants by marine birds. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.344-386.

Fowler, C.W. 1985. An evaluation of the role of entanglement in the population dynamics of northern fur seals on the Pribilof Islands. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-Tm-NMFS-SWFC-54. pp.291-307.

Fowler, C.W. 1987. Marine Debris and northern fur seals; a case study. Marine Poll. Bull. 18(6b), pp.326-355.

Fowler, C.W. 1988. A review of seal and sea lion entanglement in marine fishing debris. In Alverson, D.L. and J.A. June (eds.). Proceedings of the North Pacific Rim Fishermen's Conference on Marine Debris, October 13-16, 1987, Kailua-Kona, Hawaii.

Fowler, C.W. 1988. Pers. comm. National Marine Fisheries Service, Seattle, Washington.

Franklin, M.A. 1986. Characterization of municipal solid waste in the United States, 1960-2000. Prepared under contract to U.S.E.P.A. Office of Solid Waste, Washington, D.C.

Fry, D.M., S.I. Fefer, and L. Sileo. 1987. Ingestion of plastic debris by Laysan albatrosses and wedge-tailed shearwaters in the Hawaiian Islands. Marine Poll. Bull. 18(6b), 339-343.

Gerrodette, T., B.K. Chay and L.M. Hiruki. 1987. An experimental study of derelict gill nets in the central Pacific Ocean. Southwest Fisheries Center Admin. Rep. H-87-18. Honolulu, Hawaii.

Griffin G.J.L. 1972. UK Patent 1,485,833.

Griffin, G.J.L. 1975. Biodegradable fillers in thermoplastics. ACS Advances in Chemistry Series No. 134.

Griffin, G.J.L. 1977. UK Patent 4,021,388.

Henderson, J.R. 1985. A review of Hawaiian monk seal entangle- ment in marine debris. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.326-335.

Henderson, J.R. 1988. Marine Debris in Hawaii. In Alverson, D.L. and J.A. June (eds.). Proceedings of the North Pacific Rim Fishermen's Conference on Marine Debris, October 13-16, 1987, Kailua-Kona, Hawaii.

Henderson, J.R., S.L. Austin, and M.B. Pillos. 1987. Summary of webbing and net fragments found off Northwestern Hawaiian Islands beaches, 1982-86. Southwest Fisheries Center Admin. Rep. H-87-11. Honolulu, Hawaii. 15pp.

Heneman, B. and Center for Environmental Education. 1988. Persistent marine debris in the North Sea, Northwest Atlantic Ocean, Wider Caribbean Area, and the West Coast of Baja California. Report to the Marine Mammal Commission and the U.S. Department of Commerce, Washington, D.C.

High, W.L. 1985. Some consequences of lost fishing gear. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the work- shop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.430-437.

Jones, L. and R.C. Ferrero. 1985. Observations of net debris and associated entanglements in the North Pacific Ocean and Bering Sea, 1978-84. In Shomura R.S. and H.O. Yoshida (eds.). Proceed- ings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.183-196.

Kartar, S., R.A. Milane, and M. Sainsbury. 1973. Polystyrene waste in the Severn Estuary. Mar. Poll. Bull. 4: 144.

Kartar, S., F. Abou-Seedo, and M. Sainsbury. 1976. Polystyrene spherules in the Severn Estuary - A progress report. Mar. Poll. Bull. 7: 52.

Laist, D.W. 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. Marine Poll. Bull. 18(6b): 319-325.

Loughlin, T.R., PJ. Gearin, R.L. DeLong, and R.L. Merrick. 1986. Assessment of net entanglement on northern Sea Lions in the Aleutian Islands, 15 June-15 July 1985. NWAFC Processed Report 86-02. Seattle, Washington. 50pp.

Manooch, III, C.S., and W.T. Hogarth. 1983. Stomach contents and giant trematodes from wahoo, *Acanthocybium solanderi*, collected along the south Atlantic and gulf coasts of the Unites States. Bull. Mar. Sci. 33:227-238.

Manooch, III, C.S., and D.L. Mason. 1983. Comparative food studies of yellowfin tuna, *Thunnus albacares*, and blackfin tuna, *Thunnus atlanticus* (Pisces: Scombridae) from the southeastern and Gulf Coasts of the United States. Brimleyana No. 9:33-52.

Mate, B.R. 1985 Incidents of marine mammal encounters with debris and active fishing gear. In Shomura, R.S. and H.O. Yoshida (eds.) Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.453-457.

Mellor, D.C., A.B. Moir and G. Scott. 1973. The effect of processing conditions on the U.V. stability of polymers. Eur. Polymer Journal 9:219-225.

Merrell, T.R. 1980. Accumulation of plastic litter on beaches of Amchitka Island, Alaska. Mar. Environ. Res. 3:171-184.

Merrell, T.R. 1984. A decade of change in nets and plastic litter of fisheries off Alaska. Mar. Poll. Bull. 15:378-384.

Merrell, T.R. and S.W. Johnson. 1987. Surveys of plastic litter on Alaskan Beaches, 1985. NOAA Tech. Mem. NMFS F/NWC-116. 21pp.

National Oceanic and Atmospheric Administration. 1988. Report of the interagency task force on persistent marine debris. NOAA, U.S. Department of Commerce. Washington, D.C. 170pp.

Neilson, J. 1985. The Oregon Experience. In Shomura, R.S. and H. O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.154-159.

Osawa, Z. and K. Nakano. 1976. The effect of transition metal N,N diselenocarbonates on the photooxidation of polyethylenes. J. Polymer Science 57:267-280.

Otey, F.H., R.P. Westhoff, and W.M. Doane. 1985. Starch-based blown films. I&EC Product and Research and Development (ACS):592-595.

Princeton Polymer Laboratories. 1985. U.S. Patent 4,495,311.

Pruter, A.T. 1987. Sources, quantities, and distribution of persistent plastics in the marine environment. Marine Poll. Bull. 18(6b):305-310.

Recht, F. 1988. Report on a port-based project to reduce marine debris. NWAFC Processed Report 88-13. Seattle, Washington. 75 pp.

Redpath, A. 1987. Photodegradable controlled lifetime plastic: A strategic environmental advantage for the plastics industry. In Proceedings of symposium on degradable plastics. Washington, D.C., June 1987. pp.31-32.

R.L. Associates. 1988. The economic impact of visitors to the New Jersey shore the summer of 1988. Unpublished report. Princeton, N.J. November 1988.

Schoning, R. 1988. Nature of the Marine Plastic Debris Issue. In Oceans of Plastics: A workshop on fisheries Generated marine debris and derelict fishing gear. February 9-11, 1988, Portland Oregon. Alaska Sea Grant College Program. 61pp.

Scordino, J. 1985. Studies on fur seal entanglement, 1981-1984, St. Paul Island, Alaska. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.278-290.

Shomura, R.S. and H.O. Yoshida (eds.). 1985. Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. 580 pp.

Society of the Plastics Industry, Inc. 1986. Facts and figures of the U.S. plastics industry. Washington, D.C.

Stewart, B.S. and P.K. Yochem. 1985. Entanglement of pinnipeds in net and line fragments and other debris in the Southern California Bight. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp. 315-325.

Swanson, R.L., H.M. Stanford, J.S. O'Connor et. al. 1978. June 1976 pollution of Long Island beaches. J. Environmental Engineering Division, ASCE, 104, Proc. Paper 14238, December 1978: pp.1067-1085.

Walker, W.A. 1988. Survey of marine debris ingestion by cetaceans of the North Pacific.

Wallace, N. 1985. Debris entanglement in the marine environment: A review. In Shomura, R.S. and H.O. Yoshida (eds.). Proceedings of the workshop on the fate and impact of marine debris, November 27-29, 1984, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFC-54. pp.259-277.

Weinrich, M.T. 1987. Managing human impacts on whales in Massachusetts Bay: Countering information limitations through the use of field data. Bull. of the Coastal Soc., 10(3):11-13.

APPENDIX A

Results of COASTWEEKS '88 Beach Cleanups

State	No. Volunteers	No. Miles Cleaned	Debris Collected Pounds	Debris Collected Tons
Alabama	630	40	8,340	4.17
Alaska				
Juneau	100	*	4,500	2.25
Ketchikan	79	10	*	*
California	5,700	1,100	200,000	100.00
Connecticut	14	2	190	0.095
Delaware	650	54	6,054	3.03
Florida	10,676	914.6	388,000	194.00
Georgia	268	50	200,000	100.00
Hawaii	3,250	*	*	*
Louisiana	2,700	77	180,000	90.00
Maine	1,200	100	11,000	5.50
Maryland	171	18	3,750	1.88
Massachusetts	2,200	150	50,000	25.00
Mississippi	1,200	30	90,000	45.00
New Jersey				
Island Beach	100	8	1,500	0.75
Long Beach Island	100	7.25	21	0.01
Sandy Hook	50	0.17	8,500	4.25
New York	150	4.2	4,560	2.28
North Carolina	3,500	150	94,000	47.00
Oregon	2,200	120	28,400	14.20
Pennsylvania	174	7	2,445	1.22
Puerto Rico	407	17.3	12,640	6.32
Rhode Island	500	100	15,000	7.50
South Carolina	3,000	198	30,000	15.00
Texas	5,987	120.6	428,000	214.00
Virginia				
Assateague Island	80	17.5	11,700	5.85
Buckroe Beach	50	2.3	1,200	0.60
Virgin Islands	435	3.15	*	*
Washington				
Puget Sound	904	*	10,000	5.00
Ocean Beach	1,000	100	54,000	27.00
Total	47,475	3,401.07	1,843,800	921.00

Source: National Marine Debris Data Base (Pers. Comm., Kathy O'Hara, CEE)