Characterization and Mitigation of Marine Debris in the Gulf of Maine

A report prepared for the the U.S. Gulf of Maine Association
under contract no. GM 97-13

Gulf of Maine Council on the Marine Environment

Porter Hoagland and Hauke L. Kite-Powell
Woods Hole Research Consortium
168 Alden Street, Duxbury MA 02332-3836

October 1997

Acknowledgments

Three state beach cleanup coordinators were of great help to us in gathering data and discussing preliminary findings: Paul Dest (Maine), Cynthia Lay (New Hampshire), and Anne Donovan (Massachusetts). Seba Sheavley of the Center for Marine Conservation provided access to beach cleanup data. Information, discussion, and useful comments were also provided by: David Baird (Atlantic Coastal Action Program, New Brunswick), Brad Barr (Stellwagen Bank National Marine Sanctuary), Andrew Cameron (Nova Scotia Dept. of Fisheries and Aquaculture), Arnie Carr (Massachusetts Division of Marine Fisheries), Russ DeConti (Consultant to the Center for Coastal Studies), Paul Dion (Nova Scotia Lifeguard Service), Judy Engalichev (NH Office of Travel and Tourism Development), Pat Gerrior (Northeast Fisheries Science Center), Debbie Hadden (Massport, Boston), David Laist (Marine Mammal Commission), Tom Matson (NH Dept. of Resources and Economic Development), Scott McMillan (Clean Nova Scotia Foundation), Ollie Pierce, Roger Trof (Port of Portsmouth), Allard van Veen (Pitch-In Canada), and Professor Marino Xanthos (Polymer Processing Institute). Susan Snow-Cotter (Mass. Coastal Zone Management), Paul Topping (Environment Canada), and Stephen Barrett (Mass. Coastal Zone Management) reviewed a draft of the report and gave us helpful comments. We are grateful to the Gulf of Maine Council on the Marine Environment and the U.S. Environmental Protection Agency for the funding that made this work possible.

To contact the authors, write to Woods Hole Research Consortium, 168 Alden Street, Duxbury MA 02332-3836; or contact Dr. Hauke Kite-Powell at the Woods Hole Oceanographic Institution at 508-289-2938, email hauke@whoi.edu.

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Executive Summary

This report examines data on the temporal and spatial distribution of marine debris in the Gulf of Maine and the effectiveness of policy responses. It consists of two main parts: (1) the development of a historical "baseline" for marine debris distributions in the Gulf of Maine and (2) a review of existing debris reduction and prevention policies in the Gulf and elsewhere. The purpose of the report is to provide guidance for future efforts to address the problems of marine debris in the Gulf of Maine.

Some 80 to 85 percent of marine debris collected in beach cleanups appears to be from shore-based sources. Commercial fishermen account for half of ocean-based debris. More than half of all marine debris is plastic, metal, glass, and paper make up most of the rest. No significant trends appear in the volume of most debris types in the Gulf of Maine from 1988 to the present. The data are sketchy, but nearshore debris volume appears to be perhaps five times greater in New Hampshire, northern Massachusetts, and parts of Nova Scotia than in Maine and southern Massachusetts.

We reviewed a limited literature on the benefits of reducing marine debris. The true social cost of marine debris is not known, but it seems likely that the largest component of this cost is the reduced aesthetic value of fouled shorelines. Data on the benefits of cleanups are extremely limited, but suggest a willingness-to-pay for clean shoreline along the Gulf of Maine on the order of $14/foot/year.

We identify a diverse array of policy approaches to the problem of marine debris. These include: (1) disposal standards (prohibitions on littering); (2) disposal facilities; (3) tax/subsidy programs; (4) moral suasion; (5) education programs; (6) beach cleanups; (7) research. Absent solid data on the costs and benefits of cleanups, we find it difficult to select the best policy approach or combination of approaches. The most effective policies appear to involve some combination of all approaches, with the implementation of incentive-based approaches under the right conditions (bottle bills). Notably, deposit/refund policies for beverage containers appear to have reduced associated marine debris in Maine and Massachusetts (but not necessarily in Nova Scotia). Beach cleanups appear to be one of the most effective ways to address nearshore marine debris. Certain practices, such as overcapitalization of the fishing industry, are likely to lead to excessive amounts of certain classes of marine debris. Reductions in fishing effort will help reduce this source of debris.

Recommendations for future efforts include:

- in general, continuing to combine a range of policy approaches, emphasizing economic incentives;
- targeting onshore recreationists and commercial fishers with deposit/refund on beverage containers (New Hampshire) and possibly fishing gear (all states and provinces);

1. Introduction

This report examines the temporal and spatial distribution of marine debris in the Gulf of Maine and the effectiveness of policy responses. It consists of two main parts: (1) the development of a historical "baseline" for marine debris distributions in the Gulf of Maine from published and "gray literature" data and (2) a review of existing debris reduction and prevention policies in the Gulf and elsewhere. The purpose of the report is to provide guidance for future efforts to address the problems of marine debris in the Gulf of Maine.

Marine debris has been recognized as a problem for decades, but data on its geographic distribution and aesthetic and environmental impacts remain scarce. Over the past ten years, limited data, mainly from surveys associated with beach cleanups, have become available. According to reports issued by the Center for Marine Conservation (CMC) and others, in the United States, plastic packaging and fragments make up the bulk of marine debris located on beaches and in harbors. Some 80 percent of marine debris is estimated to enter the water from shore-based activities; the remainder comes from ships and boats (CMC, various). Recreationists, primarily on shore, are likely the largest source of marine debris in U.S. waters (CMC, various). Additional marine debris enters the oceans via sewer overflow and street runoff. Table 1, from a recent study conducted by the U.S. Environmental Protection Agency (EPA), lists the types and sources of marine debris (EPA 1994).

Data on the effects of marine debris are sketchy, but rope (entanglement) and plastic fragments and pellets (ingestion) appear to pose the greatest threat to wildlife, while sewage, medical debris, and broken bottles/cans appear to pose the greatest threat to human health. Reduced recreational use of fouled shore areas is perhaps the most significant economic impact of marine debris.

Based on a review of existing literature and discussions with organizers of beach cleanup and other marine debris activities in Maine, New Hampshire, and Massachusetts, we have developed a profile of marine debris in the Gulf of Maine in the past decade (Section 2) and assembled a review of the advantages, disadvantages, and effectiveness of policies for the control of marine debris (Section 3). We summarize our conclusions and recommendations in section 4.

2. Marine Debris in the Gulf of Maine

2.1. Sources of Data

Marine debris--usually defined as man-made solid objects introduced into the marine environment--is present on the surface, in the water column, on the seafloor, and along the shoreline. No useful data exist on the prevalence or distribution of floating debris in the Gulf of Maine, and only very limited data are available on seafloor debris for a few nearshore sites cleaned by divers in recent years as part of the annual beach cleanups. The only useful data on marine debris distributions in the Gulf of Maine describes debris found along the shore during annual beach cleanups. These data are recorded by cleanup volunteers and maintained by the Center for Marine Conservation (CMC). They provide "snapshot" views of debris along some 430 miles of coast (primarily beaches used for recreation) in Maine, New Hampshire, and Massachusetts, as well as smaller sections of New Brunswick and Nova Scotia, back to 1988. A detailed, ongoing survey program of limited sites in Nova Scotia (Topping 1997) and other parts of Canada began to provide data in 1995.

Table 1: Types and Sources of Aquatic Debris (EPA 1994)

Source	*Examples of Debris Released*
Storm-water discharges	Street litter, medical-related items (e.g., syringes), resin pellets
Combined sewer overflows	Street litter, sewage- (e.g., condoms, tampons, applicators) and medical-related (e.g., syringes) items, resin pellets
Beachgoers	Food-related items (e.g., beverage yokes, bags), trash*
Recreational boaters and fishermen	Trash*, fishing line and nets, traps, floats and lures, buoys, rope, bait boxes, strapping bands, light sticks, salt bags, beverage yokes
Commercial fishermen	Trash*, fishing line and nets, traps, floats and lures, buoys, rope, bait boxes, strapping bands light sticks, salt bags
Cruiseliners	Galley wastes, trash*
Merchant and military vessels	Galley wastes (garbage*), plastic bags and sheeting, trash*
Solid waste disposal and landfills	Assorted household trash* and garbage*
Offshore mineral exploration	Operational wastes (e.g., plastic sheeting, wooden pallets, hard hats, 55-gal. Drums), trash* and garbage*
Plastics industry	Resin pellets (raw material from which plastic products are molded)
Illegal waste-disposal	Medical waste, trash from solid waste handlers

* According to Webster's Ninth New Collegiate Dictionary (1988), the terms trash and garbage are defined as follows: trash is something worth little or nothing (as junk, rubbish), or something in a crumbled or broken condition or mass; garbage is food wastes, unwanted or worthless material, or trash.

As reported by CMC in its annual *Coastal Cleanup Results* publication (CMC, various years), since 1990 these data are reported only as state aggregates and not for individual sections of coastline. Through contacts with state and local cleanup coordinators, we were able to obtain limited amounts of more detailed data at the local level from the same cleanups.

While the CMC data are the only useful source of time-series on marine debris in the Gulf of Maine, and provide some insights, it is important to recognize the limitations of these data. The cleanups from which they are taken take place once a year. Many of the same beaches are cleaned at other times as well, in some cases weekly during the summer season; and no records are kept from these cleanups. Thus, the CMC data do not represent an "annual accumulation." In addition, the amount and nature of debris found on a cleanup day depends in part on weather events; for example, a storm just prior to cleanup may wash light debris out to sea and deposit heavier items on the shore. These factors should be kept in mind when interpreting the data presented in the following section.

2.2. Debris Types, Distributions, and Trends

Plastics account for between 50 and 60 percent of marine debris found in all three U.S. states and the two Canadian provinces (see Topping 1997; Topping et al. 1994a) bordering the Gulf of Maine (ignoring data on the volume of cigarette butts); metals, glass, and paper make up most of the remainder in roughly equal parts. Ocean-based sources account for 15 to 20 percent of debris collected in the three U.S. states, according to CMC data. (CMC classifies debris as ocean-based if it can be traced clearly to a marine source, e.g. commercial fishing gear, marine operational and galley wastes.) About half of the ocean-based debris along the U.S. coast of the Gulf of Maine--around five percent of marine debris in Massachusetts and from five to ten percent in Maine and New Hampshire--can be traced to commercial fishing vessels. The percentage is somewhat greater for Canadian parts of the Gulf (Topping, p.c., 1997). Recreational fishing accounts for around one percent of marine debris in all three states. These proportions are fairly consistent from 1988 to the present and show no significant trend over time. They are consistent with Crampton's (1989) estimate that commercial fishing and recreational boating together account for about 80 percent of garbage generated by and disposed of from vessels in U.S. waters.

Limited information is available about the distribution of debris along the coast of the Gulf of Maine. In Figure 1, we show data by county for Maine (1996) and by region for Massachusetts (1990), along with overall data for New Hampshire (1995) and Nova Scotia (1996).

The overall density of marine debris collected along the shores of the Gulf of Maine from 1988 to 1995 is shown in Figure 2. There is no significant trend in the time series for any of the three states. Debris densities in the northern parts of Massachusetts (North Shore, Metro Boston, and South Shore; see Figure 1) are closer to those found in

New Hampshire. Densities in Maine and in southern parts of Massachusetts are also comparable, and lower.

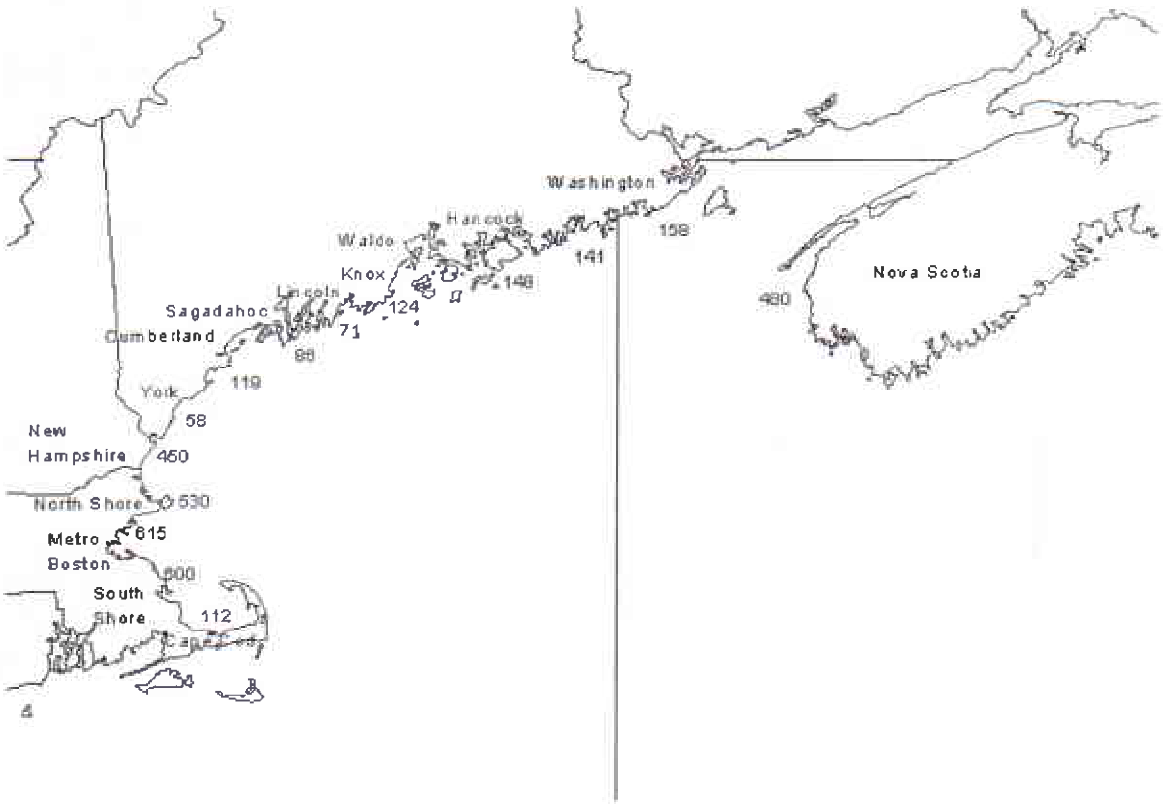

Figure 1: Density of marine debris (average lbs of debris per mile cleaned) along the Gulf of Maine coast, based on beach cleanup data from CMC and the Clean Nova Scotia Foundation. Data for Nova Scotia (estimated) and Maine are from 1996, for New Hampshire from 1995, and Massachachusetts from 1990.

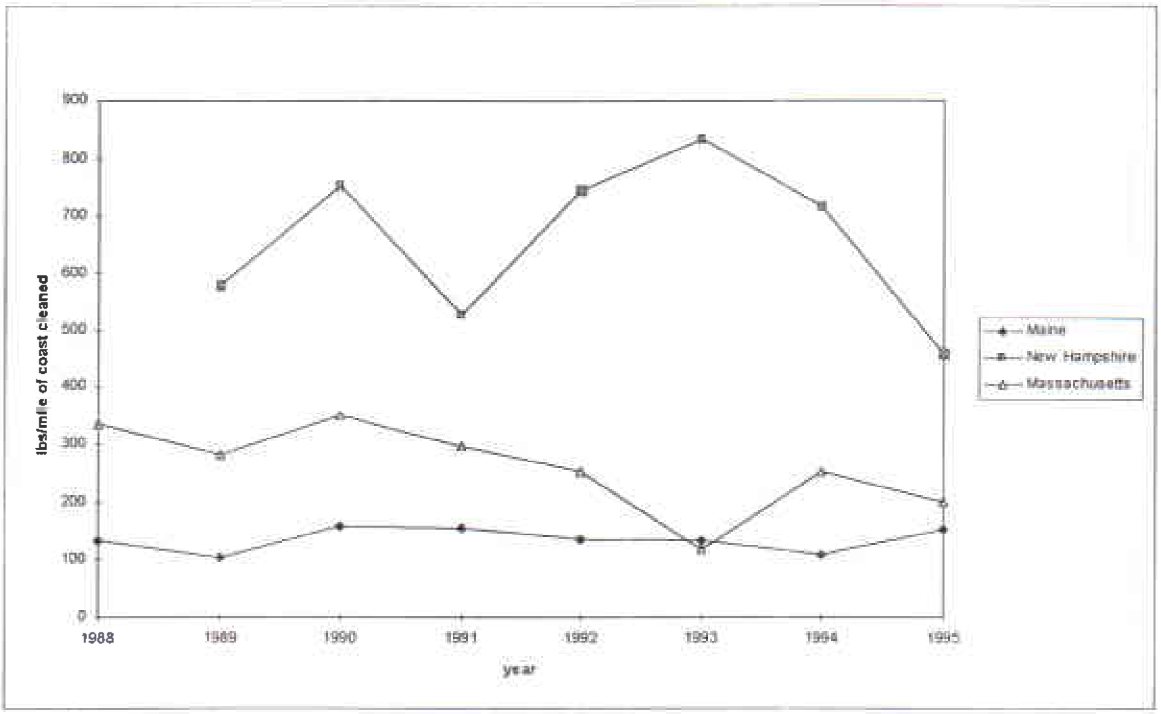

Figure 2: **Weight of marine debris per mile cleaned, based on CMC data.**

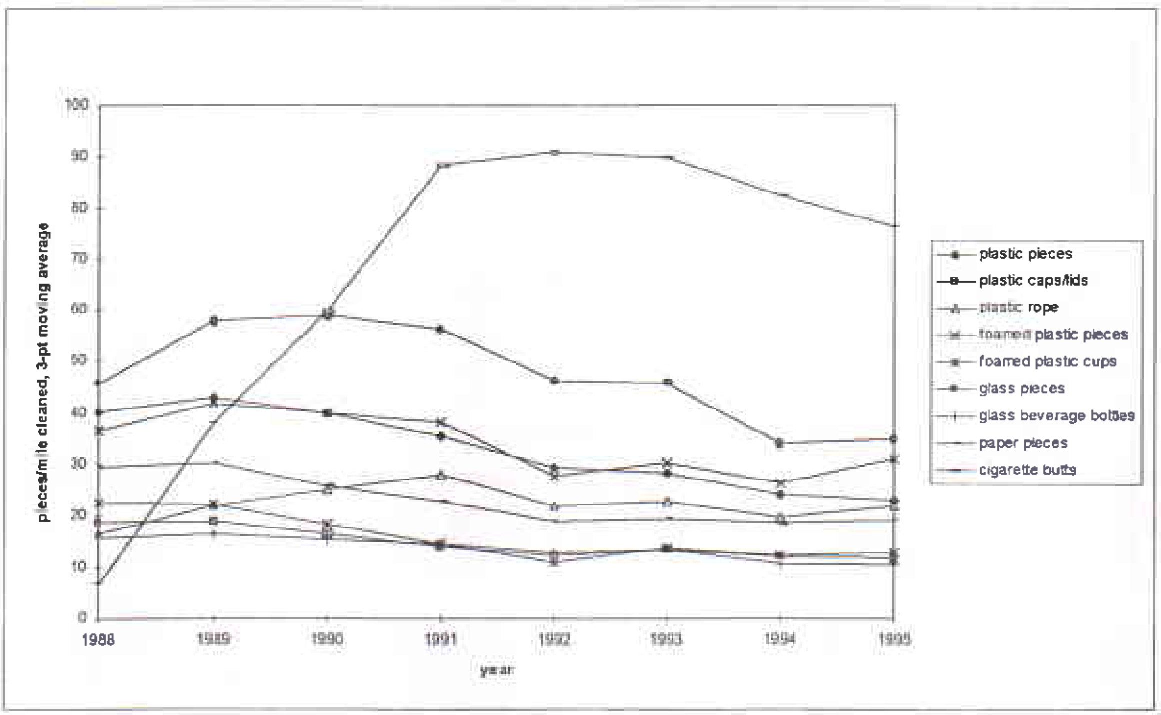

Figure 3: **Marine debris density in Maine, based on CMC data.**

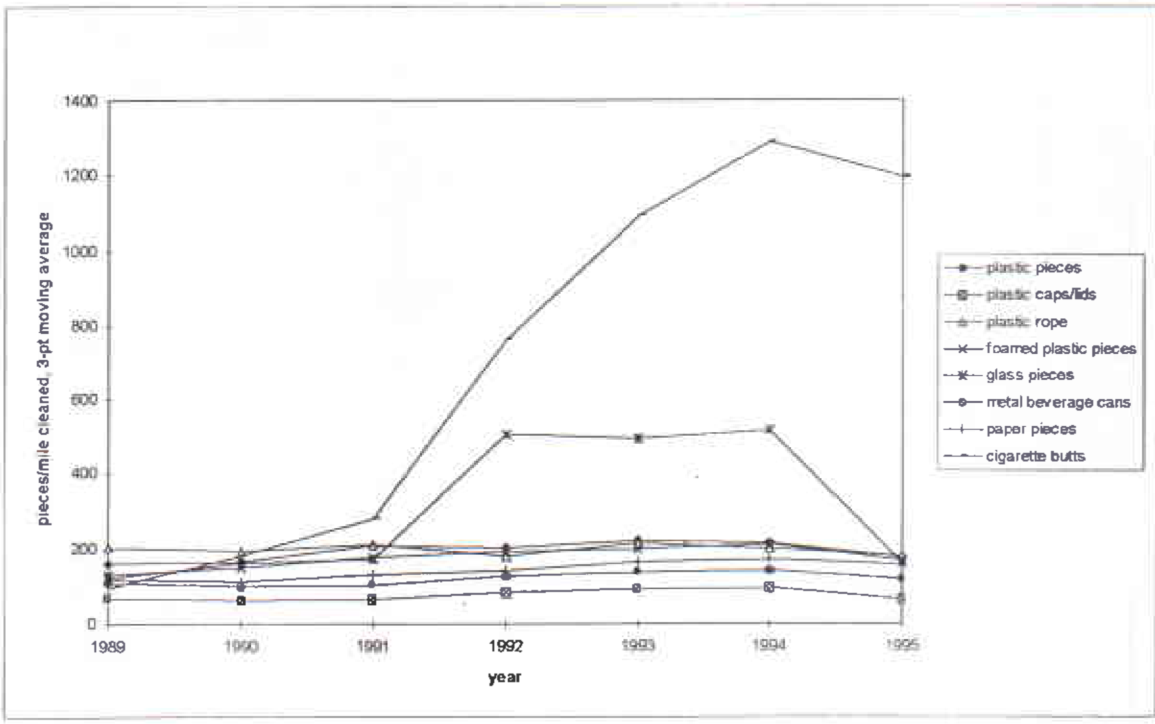

Figure 4: Marine debris density in New Hampshire, based on CMC data.

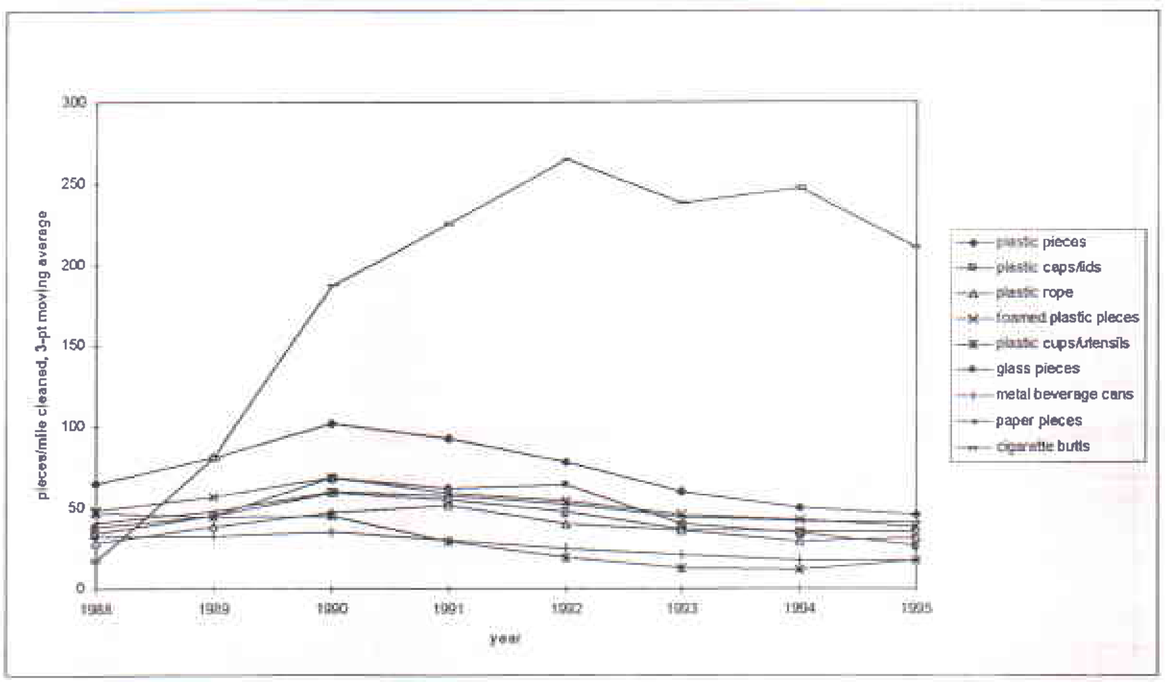

Figure 5: Marine debris density in Massachusetts, based on CMC data.

Figures 3, 4, and 5 display time series of the density of particular debris types for each state. No major trends are evident, although it may be that glass and plastic piece debris has declined slightly in Maine and Massachusetts. (Cigarette butts were added to cleanup records around 1990.)

It appears from the CMC data that the density and composition of marine debris in the Gulf of Maine has not changed in significant ways since 1988. Anecdotal reports from some beach cleanup participants suggest that debris volumes may have declined slightly in recent years, but no significant trends appear in the statewide data.

One type of debris of particular interest is beverage containers, which have been the target of specific litter reduction and recycling policies (see section 3.3). Figure 6 shows trends in the density of bottles and associated goods found in beach cleanups around the Gulf of Maine. In 1995, volunteers found about 30 bottles/mile in Maine, 280 bottles/mile in New Hampshire, and 60 bottles/mile in Massachusetts. Massachusetts and Maine appear to have achieved modest reductions in bottle debris over time; New Hampshire has not. These data are compatible roughly with the adoption of bottle deposit/refund laws. (Nova Scotia and New Brunswick also have beverage container refund systems in place.)

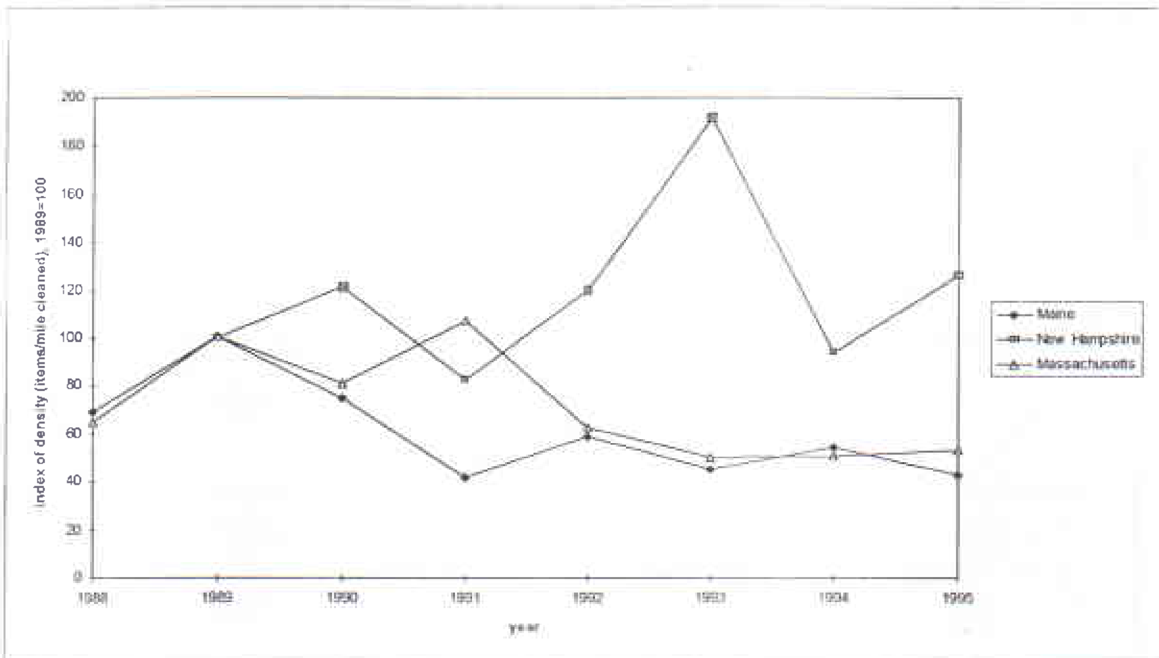

Figure 6: Index of bottles and associated items in marine debris, based on CMC data.

2.3. Sources and Pathways

As noted, onshore sources contribute 80 to 85 percent of marine debris collected in beach cleanups. The most significant offshore source is the commercial fishing industry, which accounts for about half of all ocean-based debris.

Little is known about specific pathways of marine debris in the Gulf of Maine. Some floating ocean-based debris may be carried by prevailing currents counterclockwise around the Gulf (for example, debris traced to Canadian sources has been found along the coast of Maine), and onshore winds and waves carry ocean-based debris toward the coast throughout the Gulf. However, most marine debris in the coastal zone is of local, on-shore origin. This is confirmed by an ongoing study of marine debris at national seashores (including Cape Cod National Seashore), conducted for the U.S. National Park Service, in which Cole et al. (1992) found that the observed distribution of marine debris is influenced by proximity to and location downcurrent from urban and fishing centers, ports, shipping lanes, and military installations.

Historically, solid debris and other pollution entered the Gulf of Maine via Boston Harbor sewage discharges. This input of debris to the Gulf has declined in importance with improvements to the greater Boston area sewage treatment system. A new primary treatment facility was brought on line by the Massachusetts Water Resources Authority (MWRA) in January 1995. By 1999, secondary treatment, and an outfall tunnel that will discharge treated sewage 9.5 miles into Massachusetts Bay, will be operational (the present outfalls are located around the entrance to Boston Harbor). Other MWRA initiatives include projects to reduce combined sewage overflows, which will further cut back the amount of debris entering the harbor from urban runoff (MWRA 1995).

3. Policy Approaches to the Reduction of Marine Debris

A number of policy approaches have been identified and implemented to aid in controlling and reducing the problem of marine debris. As in many areas of pollution control, it is unlikely that any one approach can be effective if implemented in isolation. One reason for this may be the diversity in the sources, types, and fates of marine debris (Table 1). In most cases, all of the policy approaches described below are implemented simultaneously.

A conceptual model for attacking the problem of marine debris is presented in a recent study by the Committee on Shipborne Wastes (CSW), an ad hoc committee organized under the auspices of the U.S. National Academy of Sciences to examine approaches to the problems of marine debris originating from ships. This approach, known as a "hazard evolution model" (Table 2), has been borrowed from the emerging literature on ecological risk assessment.[1] The model presents a sequence of events, from the expression of

[1] The conceptual model is borrowed from work done on societal responses to major hazard events. See Kasperson and Pijawka (1985).

consumer tastes through the satisfaction of demands, the release of pollutants, and subsequent exposures and consequences. An important feature of the conceptual model is that it is possible to identify points in the sequence at which intervention may take place to reduce adverse environmental or aesthetic consequences. We have adapted and modified the model to present hazard evolution (top row), points of intervention (middle row), and policy approaches (bottom row) as they relate specifically to the problem of marine debris. We refer back to this conceptual model in the discussion of policy approaches below.

Table 2: Hazard Evolution Model

Hazard Evolution	*Consumer Tastes*	*Production Decision (Choice of Technology)*	*Consumption: Use of Product and Packaging*	*Littering; Illicit Disposal; Loss*	*Environmental Exposure*	*Ecological, Aesthetic Impacts*
Intervention	Alter Tastes	Alter Production Decision	Alter Consumption Rates or Patterns	Limit Littering, Disposal, Losses	Limit Exposure	Mitigate Impacts
Policy Approach (Examples)	Education; Moral Suasion; Signage	Virgin Materials Tax	Bottle and Can Deposits	Receptacle Placement; Prohibitions and Fines; Bottle and Can Refunds; Labelling; Signage	Beach Cleanups; Beach Adoptions	Beach Cleanups; Stranding Programs; Research on Scale of Problem

In the Gulf of Maine, most coastal resource managers and environmental advocates start with the twin goals that all marine debris should be cleaned up and that all littering and disposal of marine debris should be stopped. As laudatory and idealistic as such goals are, it is unlikely that they will ever be achieved. Further, because the economic costs are much too steep for a complete cleanup of all marine debris in the Gulf of Maine, these goals may not make sense. For example, imagine the futility of trying to clean up all of the cigarette butts flicked into the Gulf of Maine and its watershed.[2]

[2] We don't employ this example flippantly. Coastal zone managers interviewed in all three Gulf of Maine states identified the flicking of cigarette butts as one of the most flagrant violations of marine debris control policies.

Imagine the futility of trying to stop the flicking of cigarette butts! Instead, it may be more rational to think of an acceptable or "optimal" level of marine debris.

From the perspective of economic efficiency, very little research has been conducted to determine the optimal level of marine debris pollution. Ideally, to determine this level, we need to know two important classes of information. First, we need to have an idea of the environmental and aesthetic effects of marine debris pollution. As marine debris is cleaned up, the reductions in these effects are properly accounted for as the benefits of cleaning up--or of not littering in the first place. Second, we need to have an idea of either the costs of cleaning up marine debris or the costs of preventing littering.[3]

Littering and disposal of debris is widely regarded as affecting the environment, but little data exists to substantiate this understanding. Impacts on marine species include entanglement in nets, other plastics, and monofilament line, ingestion of plastics, and ghost fishing (CSW 1995). Impacts occur because of the combination of the human disposal of debris, the concentration of debris by oceanographic phenomena (currents, winds) in critical habitats, and the natural attraction of certain species to debris (Laist 1987). Data on marine mammal strandings are collected in the United States portion of the Gulf of Maine (Figure 7), but these data are reports from a voluntary network, and so they are likely to underestimate strandings. In general, necropsies are not conducted on all strandings, most notably they are usually not conducted on stranded seals. For those strandings that are necropsied, it is quite difficult to tell whether or not any plastics discovered in gut contents contributed in some way to the death of the animal. In 1996, marine debris was not given as a reason for any of the necropsied strandings (Gerrior, p.c., 1997).

Nothwithstanding this general understanding, the evidence of ecological impacts has been collected only sporadically and is primarily anecdotal (Table 3) (Laist 1997b). The entanglement threat to the viability of a stock from marine debris has been documented only in the case of the northern fur seal in Alaska (CSW 1995). Carr (1988) and others (Carr et al. 1992; Cooper et al. 1988) have studied ghost gillnets in the Gulf of Maine and nearby waters, finding little evidence of adverse effects. Marine plastics have been found in the stomach contents of dead sea turtles, seabirds, marine mammals, and fish, but it is not clear in all cases that these plastics are a cause of mortality. Even if entanglement or ingestion causes mortality, the scale of the problem may be hidden by widespread species migrations or through predation or sinking (Laist, p.c., 1997a). In part because of the paucity of the data and in part because the impacts occur in noncommercial stocks, there have been no economic studies conducted to estimate the damage associated with these effects.

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[3] As strange as it may sound, littering occurs because someone who litters perceives individual "net benefits" from littering.

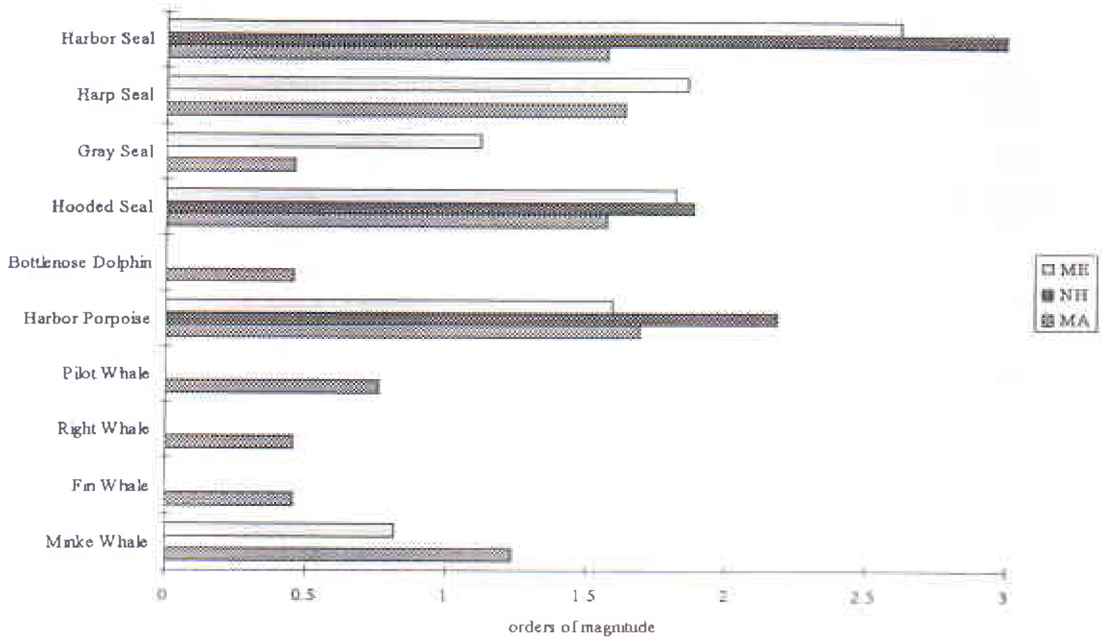

Figure 7: **Reported marine mammal strandings in 1996 along the U.S. coastline in the Gulf of Maine by species. For comparison purposes, units are a log of a multiple of the number of strandings per mile of coastline for each of the three states: log[(strandings/mile)x10^4]. The length of the bars can be interpreted as differences in orders of magnitude of the number of strandings per mile of coastline. Note that the reasons for most of the the strandings are unknown. Data source: Gerrior (p.c., 1997).**

Table 3: The number and percentage of species worldwide with records of marine debris entanglement and ingestion by species group. Source: MMC (1997).

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**

Aesthetic impacts in harbors, beaches, wetlands and other coastal and marine areas impose economic costs as well. Because of the high rate of use of these areas, particularly at beaches, the aesthetic impacts may be larger in an economic sense than ecological impacts.[4] Certainly the problem of beach and harbor debris is much more in the public eye than the problem of ocean and seabed debris. Here too, studies of economic damages associated with marine debris are limited. Holdnak (1992) finds that overall satisfaction with boating on the inland bays of Delaware declined with encounters of larger amounts of marine debris. Smith et al. (1997) find that people are willing to pay higher amounts for cleanup programs that address more serious marine debris problems.

Using hedonic pricing techniques,[5] Wilman (1984) examined the potential external costs of oil pollution on Cape Cod from the development of offshore oil and gas on Georges Bank. In applying the technique, Wilman employed an observation of the presence of marine debris on nearby beaches as a proxy for the potential costs of oil pollution. Wilman found that the presence of marine debris negatively affected the price only of rented vacation homes, lowering the monthly rental price by approximately $193.00.[6] The largest costs (up to $384.00) occurred for large vacation homes with amenities near urban centers and beaches. Wilman's estimate could be used to produce an estimate of a portion of the economic costs (or alternatively of willingness to pay to avoid these costs) associated with the aesthetic impacts of marine debris if (1) we have data on the coastal distribution of rented vacation homes in the Gulf of Maine and (2) we assume that the preferences of renters in other locations in the Gulf of Maine are similar to those on Cape Cod.

Zhang (1995) is the only analyst, of whom we are aware, who has attempted to value the willingness-to-pay (WTP) of individuals for the control of marine debris. Using a direct survey (contingent valuation) method, Zhang questioned both users and nonusers of beaches and estuarine reserves in North Carolina and New Jersey. The results of Zhang's study are summarized in Figure 8, which compares estimates for different "payment vehicles" (an increase in annual income tax payments versus an increase in beach user fees) of the average annual WTP per person for the cleanup of marine debris. Note that the estimates for cleanup of beaches are more than double the estimates for the cleanup of estuarine reserves. This difference is a significant result, because it suggests

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[4] Some may argue that such a statement is irresponsible, because we do not yet know the size of the economic damages associated with the ecological effects of marine debris. Yet even Laist (1987: 324) states that "In the absence of reliable data on the number of animals killed by plastic debris, it is difficult to determine the importance of this effect relative to other mortality factors (e.g., natural, commercial fishing, other pollutants, etc.)."

[5] Hedonic pricing is a method that can be used to factor out the value of different components of a "multiattribute commodity," such as a house. For example, the quality of the surrounding environment is believed to be one component of the value of a house.

[6] The presence of debris on nearby beaches had no significant effect on the price of Cape Cod cottages and apartments, guesthouses and inns, hotels and motels, or Martha's Vineyard accomodations.

that coastal resource use or the possibility of use is an important consideration to individuals when they consider how much they are willing to pay for debris cleanups. Zhang also found little difference between payment vehicles, although he discovered that a higher percentage of those paying a beach user fee voted in favor of a beach cleanup program than those paying income taxes.

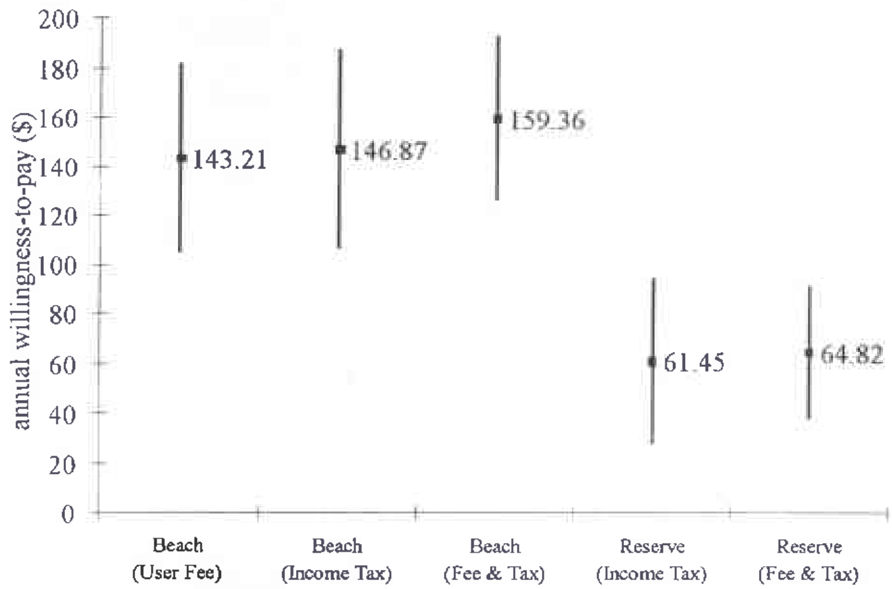

Figure 8: Estimated average annual willingness-to-pay (WTP) per person (users and nonusers) for the cleanup of marine debris from beaches and estuarine reserves in North Carolina and New Jersey. Respondents to contingent valuation surveys were requested to state their WTP in terms of an increase in their annual income tax or the payment of a user fee. The "fee & tax" is an estimate made by pooling the two groups. The data displayed are the average plus or minus one standard deviation. Source: Zhang (1995).

Because of some difficulties in implementing a random sampling design, Zhang was reluctant to calculate aggregate estimates of population WTP for cleanups. However, he could not reject the two hypotheses that (1) valuations for cleanups in North Carolina and New Jersey were identical and (2) valuations for users and nonusers were identical. Both findings suggest that "benefit transfers" of his results to other jurisdictions might be feasible.

We can employ Zhang's estimate to get a very rough estimate of the value of the cleanup of marine debris in the U.S. portion of the Gulf of Maine. There are approximately 5128 total miles of U.S. shoreline in the Gulf of Maine (including all of Massachusetts' shoreline). Roughly 9 percent (440 miles) of the total is beach. We calculate a weighted WTP of $68 by multiplying the proportion of beach shoreline times the average annual WTP for beach cleanups and adding this to the proportion of nonbeach shoreline times the average annual WTP for reserve cleanups (using the "income tax" numbers). Multiplying the weighted WTP by the total coastal county populations (ignoring tourists) in all three states gives us an estimate of total WTP for beach cleanups of \$392 million. Dividing total WTP by total shoreline gives us an estimate of a total WTP of approximately \$14 (± ≈\$7) per foot of shoreline for the cleanup of marine debris in the Gulf of Maine. This number is an admittedly crude estimate of the benefits of cleaning up marine debris from the shoreline.

We emphasize that this calculation glosses over many important issues related to the process of benefits transfer, the heterogeneity of coastal resources (e.g., industrialized shoreline is unlikely to be valued as high as estuarine reserve shoreline, if it is valued at all), and the selection of an accounting frame, among others. Zhang (1995) cautioned against the use of his estimates in such a manner (e.g., to calculate population averages), arguing that they should be considered merely "preliminary and directional." Nevertheless, we believe that the calculation gives us a reasonable order of magnitude estimate that might be compared with cleanup costs (per foot) to determine, from an economic standpoint, whether or not stretches of shoreline should be cleaned up.

Absent reliable economic data on either the costs or the benefits of cleaning up (or preventing) marine debris pollution in specific locations, it is difficult to say anything profound about the effectiveness of policy approaches to the problem (cf. Bernstein 1993; Quayle 1991; Bohm and Russell 1985). (This problem is compounded when we must consider combinations of policy approaches.) However, we can make some general statements about the advantages, disadvantages, and political feasibility (distributional effects) of the diverse array of approaches. These aspects are summarized in Table 4. Each policy approach is described in greater detail below.

3.1. Disposal Standards

This approach is very common, occurring in all jurisdictions in the Gulf of Maine and at all levels of government. In general, the disposal of plastic marine debris is prohibited in the Gulf of Maine. The disposal of other debris is prohibited near the coast and permitted further offshore. The U.S. federal Marine Plastics Pollution Research and Control Act (MPPRCA) of 1987 [P.L. 100-220] implements Annex V of the international MARPOL 73/78 convention in the United States. While Canada is not a signatory to Annex V, the Canadian Shipping Act regulates the discharge of garbage from ships in Canadian waters and contains standards that exceed the provisions of MARPOL Annex V. Table 5, from the Center for Marine Conservation (CMC) depicts the marine jurisdictions and the relevant rules. Table 6, reprinted from EPA (1996), presents a summary description of the relevant international and federal regulatory framework in the Gulf of Maine.

Table 4: Policy Instruments for Control of Marine Debris

Policy Instrument	*Gulf of Maine Example(s)*	*Advantage(s)*	*Disadvantage(s)*	*Political Feasibility*
Disposal Standards	Federal, state, local prohibitions on littering and solid waste disposal	Encourages reduction of littering and disposal of harmful materials into the marine environment; maypromote technological solutions	Economically inefficient "command and control" approach; high costs of monitoring and enforcement; resulting low compliance implies ineffectiveness; "cigarette butt problem"	Widely accepted policy solution; compliance costs borne by litterers: high costs of enforcement imply compliance costs are low
Provision of Disposal Facilities	Local sanitary landfills; regional incineration plants (SEMASS); placement of dumpsters at marinas (Portland, Rockland Harbors); trash cans at public beaches (ME, NH, MA)	Provides "opportunity" for disposal; cost to users is small	Cost to the public can be substantial in the case of landfills and incinerators; available coastal property for landfills is becoming scarce; problems of receptacle overflow and redeposition of trash by wildlife; discourages recycling and alternative uses	Disposal and management costs borne primarily by the public; siting decisions may be opposed by neighbors due to localized externalities
Tax/Subsidy System	State bottle bills: Maine ($0.05); Massachusetts ($0.05); Nova Scotia; New Brunswick	Potential for economic efficiency; promotes cleanup and recycling; minimal government administration	Administrative costs can be significant	Administrative costs usually borne by the private sector, implying political opposition
Moral Suasion	"Do not litter" notices on packaging	Increases awareness of problem; promotes onshore disposal; firms seen as environmentally responsible; some potential for product differentiation ("green labelling")	Consumers may not pay attention to message; not truly a green label unless the manufacturer is seen to be a participant in pollution reduction	Public benefits at low cost; manufacturers benefit from perception of environmental responsibility
Education Programs	State, provincial coastal zone management efforts; brochures; local harbor efforts	Creates awareness of the problem; promotes compliance with laws and regulations	some sectors of the public ignore educational programs; effects may be lagged	Public bears the immediate costs of the programs; education is widely perceived as providing benefits to society in the longrun
Beach Cleanups	Annual fall "Coastweek" cleanup; weekly public beach cleanups in all three states; New Hampshire "Beach Buddy" program	Cleans up beach; promotes awareness of problems of marine debris; provides opportunity for those who are among the most aggrieved to rectify the problem; volunteers benefit from public service; data collection may allow evaluation of other policies	Wetlands, salt marshes, rocky coasts usually ignored; marine environment ignored; cleanup occurs <u>after</u> period of highest beach use; data collection perceived as onerous	No public opposition; popular among environmental community
Beach Adoption	New Hampshire state program	Cleans up beach in spring and fall; participants benefit from public service and publicity	Same as above	Same as above
Research	CMC data collection; Massachusetts DMF surveys in mid-1980s	Provides information on the nature and scale of the problem	Costs of conducting research	Some user groups may be opposed to research if the potential exists of identificaton as a significant polluter

Table 5: Summary of garbage discharge regulations under the International Convention for the Prevention of Pollution from Ships (1973-1978) and the U.S. Act to Prevent Pollution from Ships, as Amended. Source: CMC.

Type of Garbage	Discharge Prohibitions for All Vessels Outside Special Areas	Discharge Prohibitions Inside Special Areas for Offshore Platforms	and Associated Vessels
Plastics, including synthetic ropes and fishing nets and plastic bags	Disposal prohibited	Disposal prohibited	Disposal prohibited
Dunnage, lining, and packing materials that float	Disposal prohibited less than 25 n.mi. from nearest land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, metal bottles, crockery, and similar refuse	Disposal prohibited less than 12 n.mi. from nearest land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, etc., comminuted or ground	Disposal prohibited less than 3 n.mi. from nearest land	Disposal prohibited	Disposal prohibited
Food waste not comminuted or ground	Disposal prohibited less than 12 n.mi. from nearest land	Disposal prohibited less than 12 n-mi. from nearest land	Disposal prohibited
Food waste comminuted or ground	Disposal prohibited less than 3 n.mi. from nearest land	Disposal prohibited less than 12 n.mi. from nearest land	Disposal prohibited less than 12 n.mi. from nearest land
Mixed refuse types	apply most stringent disposal restriction	Apply most stringent disposal restriction	Apply most stringent disposal restriction

Notes: (1) Under the Act To Prevent Pollution from Ships, discharge limitations in the United States apply within all navigable waters, including rivers, lakes, and other inland waters. (2) Special Areas listed in Annex V are the Mediterranean, Baltic, Red, Black, and North Seas; the Persian Gulf/Gulf of Oman; the Wider Caribbean Region; and the Antarctic Ocean. However, at the end of 1995 only the North Sea, the Baltic Sea, and the Antarctic Ocean Special Areas were actually in effect because nations bordering the other listed areas had not yet affirmed to the IMO that adequate port reception facilities were in place. (3) Offshore platforms and associated vessels include all fixed or floating platforms engaged in exploitation or exploration of seabed mineral resources and all vessels alongside or within 500 m of such platforms. (4) Comminuted or ground garbage must be able to pass through a 25-mm (1-inch) mesh screen. (5) For the Special Area in the Wider Caribbean Region only, disposal is prohibited within 3 rather than 12 n.mi. from the nearest land.

Table 6: U.S. Regulatory Framework (Source: EPA 1994).

Many international, Federal, State, and local authorities exist that address the release and presence of man-made debris in the aquatic environment. These laws and international agreements address the debris problem in several ways, including prohibiting the disposal of wastes from vessels, preventing harm to endangered and threatened species, establishing environmental planning and policy, and minimizing the production of wastes that could become persistent aquatic debris. There has been a wealth of legislation introduced at the State and local levels to address solid-waste management and recycling. Individual state laws are not described in this table.

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.

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.

State and local standards may be more restrictive than the MPPRCA rules, and they may apply to land-based sources that have the potential to move into the marine environment. For example, Table 7 compares the basic provisions of international, U.S. federal, state and local by-laws (using Plymouth, Massachusetts as an example) relating to littering on land and in the ocean.

Disposal standards (prohibitions) encourage the reduction of littering and disposal if properly enforced. However, monitoring and enforcement of pollution control laws is notoriously difficult (costly) at sea, thus the effect of such prohibitions is difficult to determine. Where enforcement is known to be slack, the incentives for compliance are therefore weak, and we might expect that the relevant policy is not as effective as it might otherwise be.

One study has examined the impact of a ban on the littering of plastics on the beaches and roads of Suffolk County, New York (Ross and Swanson 1994-95). The relevant law banned the use of all plastic grocery bags, polystyrene and polyvinyl chloride food packaging. Ross and Swanson sampled several beaches in 1993, comparing the volume of plastics with data from a beach cleanup in 1991. The authors conclude that although the law could change the composition of litter, it would have no impact on the volume of litter on the beaches. Several possible reasons for this result include the facts that (1) the plastic component of the waste stream may have increased (although the authors did not have enough evidence of this); (2) the banned plastic was only a small component of the waste stream; (3) surrounding communities, including New York City, were a significant source of debris to Suffolk County; and (4) the samples were taken at different times of the year, rendering them potentially incomparable.

Even if prohibitions on the disposal of debris into the marine environment are not likely to be effective for reasons of low compliance, costly enforcement, or other reasons, they serve the important purpose of providing a rationale for the other policy approaches. For example, it is more difficult to press the case that littering should be reduced if it is not explicitly prohibited.

Prohibitions on littering and illicit disposal often are combined with fines in an attempt to increase compliance. Notably, as shown in Table 7, fines may be imposed at all levels of government. It appears from the table that fines tend to be higher at the higher levels of government. For example, the disposal of plastics in the territorial sea off the coast of Plymouth, Massachusetts will result in a $25,000 per day fine under the provisions of the federal MPPRCA, up to $3,000 for each offense under the Massachusetts public health statutes, and $50 under the bylaws of the Town of Plymouth. One reason for this gradient in fines may relate to the probability of enforcement. For example, if the probability of enforcement is lower for higher levels of government, then the expected fine will be lower as well. Prohibitions and associated fines are sometimes posted in high use areas to increase the effectiveness of this approach.

Table 7: Hierarchy of Marine Litter Control Laws in the United States

Level of Government	*Juris-diction*	*Relevant Law*	*Policy Statement*	*Civil Penalty*	*Fine*
International	IMO	MARPOL 73/78, Annex V	the disposal into the sea of all plastics, including but not limited to synthetic ropes, synthetic fishing nets and plastic garbage bags, is prohibited; the disposal into the sea of the following garbage shall be made as far as practicable from the nearest land but in any case is prohibited if the distance from the nearest land is less than: (I) 25 nautical miles for dunnage, lining and packing materials which will float; (ii) 12 nautical miles for food wastes and all other garbage including paper products, rags, glass, metal, bottles, crockery and similar refuse; disposal into the sea of garbage . . . may be permitted when it has passed through a comminuter or grinder and made as far as proacticable from the nearest land but in any case is prohibited if the distance from the nearest land is less than 3 nautical miles. . .	Left up to state-party	Left up to state-party
National	United States	MPPRCA, 33 U.S.C § 1802 et seq (1996)	It is unlawful to act in violation of the MARPOL Protocol, Annex IV to the Antarctic protocol, this Act, or the regulations issued thereunder. . .	Class D Felony	Up to $25,000 fine per day for a violation of the Act; up to $5,000 fine for each false, fictitious, or fraudulent statement or representation
State	Maine	Maine Litter Control Act [Ch. 80, 17 MRSA §2262 et seq.]	No person may throw, drop, deposit, discard, dump or otherwise dispose of any litter in any manner or amount: . . . In any fresh water lake, river, stream, tidal or coastal water or on ice over water.	Civil violation subject to "forfeitures"; if on watercraft, both operator and litterer are in violation	<15 lbs or 27 cu.ft.: $100-500; <500 lbs or 100 cu.ft.: $200-1000; >500 lbs or 100 cu.ft. for a commercial purpose: special penalties
	New Hampshire	Litter Control Law [NHRSA, Ch. 163-B] Rules of the Road [NHRSA, Ch. 265:102]; Fish and Game [NHRSA, Ch. 214:18-a]	It shall be unlawful for any person or persons to dump, deposit, throw or leave, or to cause to permit the dumping, depositing, throwing or leaving of litter on any public or private property in this state, or in or on ice or in any waters in this state . . . No person shall put or place or caused to be put or placed, in or upon any . . . public bathing place or the approaches thereto, or onto the ice over any public water, streams or watercourse or the approaches thereto or land bordering the same in any city or town any bottles, glass, crockery, cans, scrap metal, junk, paper, garbage, old automobile or parts thereof, or refuse of any nature whatsoever or any noxious thing.	Misdemeanor or must pick up all litter deposited by anyone at relevant location	Loss of fishing or hunting license for the current year; Suspension of license for any motor vehicle, boat, airplane or other conveyance for up to 7 days
	Massachusetts	Crimes Against Public Health [270 MRSA § 16] Agriculture and Conservation [131 MRSA § 44]	Whoever places, throws, deposits, discharges, or causes to be placed, thrown, deposited or discharged, any trash, bottles or cans, refuse, rubbish, garbage, debris, scrap, waste, or any other material of any kind . . .on any . . . public land, or in or upon coatal or inland waters . . . or within twenty yards of any such water, or on property of another, shall be punished . . . A person while engaged in hunting, fishing or trapping shall not deposit or cause to be deposited garbage, paper, refuse, bottles, cans, rubbish or trash of any kind or nature on any public or private property without permission of the owner, tenant or lessee of such property.		Up to $3,000 for the first offense, up to $10,000 for each subsequent offense; court may require removal of litter; car may be impounded, drivers license may be suspended for up to 30 days
Local	Plymouth, Massachusetts	Plymouth Town Bylaws, Art. 8—Plymouth Beaches Plymouth Town Bylaws, Art. 26—Harbor Bylaws	All persons on any public beach, except owners and occupants of cottages located in Plymouth must deposit garbage and rubbish in barrels which shall be provided along the beach. . . . Glass containers of any kind are prohibited from all public beaches. Untreated sewage, rubbish, debris, garbage or dead fish shall not be discharged into Plymouth Harbor. Rules for the [harbor] ramp and adjacent parking area shall be as follows: . . . No littering. . .		$100 fine for deposit of rubbish on beaches; $50 fine for discharge into harbor

facilities since the inception of the Act because of the lack of technical standards to determine the adequacy of the facilities. Furthermore, there is no federal requirement for the many small piers and boat launch ramps to have reception facilities. The situation is similar in Canada, where small craft ports are being shifted from national to local municipal control; not all of the more than 200 such harbors along the Canadian Gulf of Maine coast have solid waste disposal facilities (Topping, p.c., 1997).

3.3. Tax/Subsidy Programs

Several "economic incentive" programs have been proposed to solve problems of littering, but few of these have been implemented to help control marine debris. The most important such programs include the deposit-refund "bottle bills" implemented successfully in Maine, Massachusetts, New Brunswick, and Nova Scotia. (Other tax or subsidy programs may be effective at reducing marine debris even though they are not directed at the disposal issue. For example, recent proposed federal tax increases on cigarette sales are likely to reduce consumption of cigarettes, thereby lowering the number of cigarette butts illicitly disposed. We will not address these policies here, but we should keep in mind that they may have an important effect on the marine debris problem in the Gulf of Maine.)

Most jurisdictions impose "lump sum" taxes or charges upon households to cover the disposal of solid waste. It has long been recognized that lump sum payments do not provide the right incentives for reducing the total volume of solid waste or for encouraging recycling to take place. The fundamental problem is that households are charged only for the right to throw trash away--not on the basis of how much they throw away. These policies may result in the classic problems of the filling up of sanitary landfills at too rapid a pace, excessive public expenditures for garbage pickup and disposal, and the unnecessary disposal of potentially recyclable materials. Nevertheless, such policies may alleviate problems of littering and illicit disposal precisely because they provide an opportunity for disposal.

One potential solution that has been implemented in certain jurisdictions is the use of "quantity- (or unit-) based pricing." Quantity-based pricing solves the fundamental problem described above by charging households for how much solid waste they dispose. As a result, this approach increases incentives for reducing the volume of solid waste disposed and for recycling. An unfortunate side-effect is that incentives for illicit disposal, including littering, also are increased. However, in a study that surveyed 21 U.S. cities that implemented quantity-based pricing for the disposal of solid waste, Miranda et al. (1994) found that most cities reported no noticeable increase in littering or illegal dumping. Some cities did report increases in the burning of trash.

Another potential solution is to tax the "virgin material" content of plastics, paper products, or packing materials (Miedema 1983). Such a tax would reduce the incentives of manufacturing firms to use virgin materials in their production activities. Further, such a policy can be expected to increase the demand for recycled materials, thereby raising the prices paid for recyclables, and lower the volume of solid waste disposal. This approach represents an intervention at an earlier stage in the conceptual model of Table 2 than the quantity-based pricing approach.

Some analysts have suggested that the indirect subsidization of the production of virgin materials exacerbates the problem of waste disposal. Miedema (1983: 22) describes this subsidization as "the market's failure to incorporate eventual disposal and collection costs".[7] However, other inefficiencies, such as those associated with natural resource exploitation, have the same kind of effect. An example from the Gulf of Maine is illustrative. To the extent that commercial and recreational fishing for groundfish, lobster, or other species has been "open access," economically inefficient levels of fishing effort have been exerted on the stocks. We might expect higher levels of lost or illicitly disposed of fishing gear associated with excessive levels of effort. A tax on fishing effort (akin to a virgin materials tax--although the fish are not specifically a "material" incorporated into an end product), would act to reduce fishing effort, thereby reducing the likelihood of gear losses and disposals.

Dinan (1993) takes issue with the economic efficiency of both the quantity-based pricing and virgin materials taxes. As noted above, quantity-based pricing has the undesirable feature of increasing the incentives for littering and illicit disposal. Virgin materials taxes are efficient only if recycled materials are used to displace virgin materials in the <u>original</u> products. However, this policy does not increase the demand for the use of recycled materials in <u>alternative</u> products. Dinan's solution is the implementation of a combined tax/subsidy policy in which a tax on the production of an item is set equal to the cost of its future disposal and a subsidy on the recycling of the item is set equal to the current costs of disposal. When commonly recycled goods (newspapers and containers) are recycled, the tax and the subsidy balance out. Items that are not recycled face the disposal charge in the form of the tax.

Dinan's conclusion that a tax/subsidy system is economically optimal is supported by research by other analysts (Palmer and Walls 1994; Fullerton and Kinnaman 1993; Dobbs 1991). The success of "bottle bills" or deposit/refund systems in many jurisdictions—including those in the Gulf of Maine—are empirical proof of the effectiveness of the tax/subsidy approach (Figure 7). Drawbacks to this approach include the potential for significant administrative costs. Indeed, Dinan (1993) suggests that the approach should be limited to selected items in the waste stream, such as those that have a limited number of producers or importers, those that are easy to identify, or those that have a limited number of individuals or firms that qualify for the subsidy.

Lee *et al.* (1988) show that a fine on littering actually dilutes the effectiveness of a deposit/refund approach. This is the case when the size of the deposit—and therefore of the refund—is limited for some reason, such as fairness to producers or consumers. The

[7] Dinan (1993) disagrees with this point, arguing that the market failure is the result only of lump sum pricing of disposal.

combination of a deposit/refund and a fine on littering actually reduces the frequency of littering but increases the amount of litter relative to the implementation of a tax/subsidy system in isolation. This seemingly counterintuitive result occurs because there is a lowered incentive to recycle as the refund is lowered. This conclusion suggests that littering fines might usefully be abandoned for those items in the waste stream that are subject to deposit/refund systems.

In the Gulf of Maine, fishing gear that has been lost or disposed of would appear to be an excellent candidate for a tax/subsidy system.[8] The perception of significant impacts from ghost fishing gear, even if not yet demonstrated empirically, makes this problem a high priority. Research conducted at the *Stevens Institute of Technology* (Xanthos and Dagli 1995; PPI 1989) has demonstrated the technological feasibility of recycling and reprocessing nylon or polyethylene nets by melting and extruding.[9] However, Xanthos and Dagli (1995) conclude that the economics of recycling high density polyethylene (HDPE) nets are marginal at best. Recycling of nylon netting is potentially economically feasible. Volumes of both materials from fishing uses are low and cannot support the construction and operation of a dedicated recycling facility. The price of HDPE is much lower than the costs of recycling it through existing facilities. There is some evidence of an overseas market in Asia for secondary material shipped from the west coast. An attempt to organize a local procedure for the recycling of fishing gear by the Center for Coastal Studies in Provincetown, Massachusetts has been postponed for the time being (DeConti, p.c., 1997).

In 1995, NMFS listed the development of "port reception programs" for recycling old fishing gear in the Gulf of Maine as a priority item in its Marine Entanglement research program. This program was not funded during 1996 and 1997. In accordance with the Lee *et al.* (1988) result, implementation of such a program should be accompanied by a review and possible elimination of the MPPRCA fines on the disposal of fishing gear.

3.4. Moral Suasion

This type of policy approach is neither a command-and-control nor an incentive-based approach. Instead it involves sending a message to potential litterers with the expectation that his or her behavior will be changed as a result of the content of the message (Bohm and Russell 1985). The expectation is that individuals will "do the right thing" when reminded of the need for proper disposal. The most common forms of moral suasion include notices on cans, bottles, bags and other packaging such as "please do not litter" or "please recycle."

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[8] Laist (1997a) suspects that most of the ghost fishing gear in the Gulf of Maine has been lost, not disposed of illicitly.

[9] PPI (1989) found that polypropylene ropes were difficult to reprocess and that asphaltic or alkyd coating on nylon increased the difficulty of reprocessing.

The effectiveness of a policy of moral suasion in reducing litter has not been demonstrated conclusively. If consumers take the time to read labels, then we can expect that public awareness of littering and disposal problems will increase. Ross and Swanson (1994-95) note that research conducted by the organization *Keep America Beautiful* has revealed that people tend to litter for three main reasons: (1) they feel no sense of ownership of property; (2) they expect someone to clean up after them; and (3) other people litter in the same location. To the extent that moral suasion acts to encourage a sense of ownership in a coastal or marine environment and sends the message that no one is going to clean up after litterers, then it may contribute to a reduction in littering activity.

Another important aspect of the moral suasion approach is that it may be employed by private manufacturing firms on the labels of their products. As such, an admonishment not to litter sends a signal that these firms are environmentally responsible. Moral suasion in this sense is analogous to a "green label" in differentiating the product from other related, but presumably less environmentally friendly, products. (However, unless firms are actively involved in recycling or cleaning up litter, the label is not truly "green".) As such, these manufacturers benefit from applying the label to their products. If consumers respond to the message of the labels, then the public benefits too from reductions in littering.

Signage is also a form of moral suasion. Signs are usually posted to let users know about the relevant laws and policies, and they may be made more effective by including information about the size of any relevant fines or other penalties. Given the difficulties with enforcing prohibitions on littering or disposal of debris, signs might be thought of more usefully as a type of moral suasion than as a publication of standards and fees.

3.5. Education

Education is often described as one of the most effective policies that can be implemented to control marine debris inputs. Faris and Hart (1995) stress the importance of education programs to increase "awareness" about the problem of marine debris. With increased awareness, we expect to find reductions in littering and disposal activities.

Most jurisdictions in the Gulf of Maine have some mechanism for educating the public about the problem of marine debris. Examples include federal and state laws, local littering bylaws, signage, placement of trash barrels, promotion of beach cleanups , among others.[10] Even with such mechanisms, Niskanen (1993) notes, in the case of Rockland Harbor, Maine, that many users still are aware of neither the relevant laws nor the reasons

[10] Beach cleanups are described as having two components: cleanup and education. Clearly the cleanup component is effective; it is not known how effective the educational component is in reducing the volume of waste. Participants in beach cleanups are typically fairly knowledgeable already about the problem of marine debris.

for such policies. Further, when users are aware of marine debris laws, many are unaware of the alternatives for proper disposal of debris, especially the location of disposal sites.

Although there seems to be a consensus that educational programs are a critical component in a marine debris reduction strategy, few studies have been conducted to evaluate the effectiveness of educational programs. One study, conducted to evaluate the role of education in increasing awareness of commercial fishermen and recreational boaters about marine debris problems, had very mixed results (O'Hara and Wallace 1990). In general, educational programs increased the awareness of federal policies prohibiting the disposal at sea of vessel generated garbage. However, the investigators were unable to measure any change in at-sea disposal activities. One reason for this result was a bias in survey responses away from those who dispose of plastics at sea.

Cheetham and Dorsky (1992) identify a public education campaign as one of the key components of a strategy to reduce marine debris in Portland, Maine. Broadly speaking, the following types of activities are described in the literature as contributing to the effectiveness of an educational program:

- elementary school programs: educational experts believe that environmental attitudes are shaped most strongly at an early age; therefore programs to educate elementary school students are expected to be the most effective in reducing the marine debris problem over the long run;

- media contact: establishing and maintaining contact with the press and the media by providing them with facts, news stories, study results, and pictures (O'Hara and Wallace 1990); drawing the attention of the media to cleanup events (Cheetham and Dorsky 1992);

- leadership persuasion: presentations to persuade leaders of user groups are seen as more effective than presentations to inform individuals in the user groups (O'Hara and Wallace 1990); presentations to executives of firms involved in the tourist industry and of firms whose products are easily disposed in the marine environment are also important (Cheetham and Dorsky 1992);

- beach cleanups: the results of data collected during beach cleanups is thought to be effective in making the case before government policymakers for increased attention to the problem of marine debris (Faris and Hart 1995);

- green labelling: private companies (Morton Salt, R.J. Reynolds Tobacco) may perceive benefits from advertising or labelling their products with admonishments not to contribute to marine debris; in some cases, making private firms aware of the potential for the disposal of their products in the marine environment is an important step (Faris and Hart 1995);

- educational materials: educational materials (brochures, flyers, pamphlets, stickers) may be included in certification programs for users, such as for scuba divers, lifeguards, or for boater registration and commercial vessel operator licensing (Faris and Hart 1995; EPA 1994);

- pledge programs: users may "pledge" not to litter or dispose of plastics and to collect debris that they encounter; pledges are sometimes associated with discounts at marine suppliers or lotteries (Faris and Hart 1995);

- signage: this category includes "do not litter" signs; posters at commercial docks, marinas, along waterfronts, and at public beaches; decals on trash barrels, dumpsters, and used oil buckets; and storm drain stenciling; often the posting of littering fines is perceived as more effective than a general admonishment (Faris and Hart 1995; Niskanen 1993; Cheetham and Dorsky 1992).

3.6. Beach Cleanups

This approach is widely employed in the Gulf of Maine and has been very successful. Annual beach cleanups are organized nationally by the Center for Marine Conservation (CMC) in Hampton, Virginia. Cleanups are coordinated at the state level by officials at state coastal zone management offices. Local cleanup coordinators are responsible for specific beaches. CMC requests that cleanup teams of two individuals each be organized to bag debris and to fill out forms that characterize the amount and type of debris. These forms are sent to the state coordinators. In some cases (Maine and New Hampshire), preliminary data results are collected. The forms are forwarded to CMC in Washington, where the data are compiled and published in reports that describe the distribution and nature of marine debris at the state level.

Beach cleanups are undeniably one of the most effective approaches to the problem of marine debris. Their most important feature is that they enlist the efforts of individuals who are among those that feel the strongest about the problem of debris. Indeed, although there clearly are costs associated with cleaning up litter, these individuals are likely to benefit personally from participating in the cleanup. Taking advantage of scale economies, the costs of data collection and organization are borne by CMC and the state and local coordinators.

New Hampshire has established a "beach adoption" program through which individuals or institutions can gain promotional benefits if they agree to clean up a beach at least twice a year. Many of the public beaches in all three states have programs for the weekly cleaning of beaches.

Beach cleanups are not the ultimate solution to the problem of marine debris, however. Cleanups are focused primarily on beaches, not in the ecologically more sensitive wetlands and harbors, or on rocky shores. By historic accident, most annual cleanups are held in the fall, not at other times of the year when aesthetic and ecological benefits of cleanups may be maximized. The collection of data on the types and amounts of debris, while useful from a research standpoint, was cited as overly onerous by several sources (e.g. counting numbers of cigarette butts).

Some potential recommendations to improve cleanup strategies include:

- holding cleanups in early spring to maximize aesthetic and ecological benefits (some high impact areas might be cleaned in the fall as well);
- enlarging the cleanups to include wetlands and estuarine shorelines as well as beaches;
- adopting a "sampling strategy" to data collection such that only a few cleanup teams on beaches (or teams on only a few beaches) are required to collect detailed data (see Ribic and Ganio 1996);
- estimating (instead of counting) numbers of small, high quantity debris items, such as cigarette butts.

3.7. Research

Conducting research to gain a better understanding of the nature and scale of the marine debris problems in specific localities is an important component of an overall approach. There is no research that attempts to get at the identity of the sources of marine debris in the Gulf of Maine. Other than data on beach cleanups, very little research has been done to understand the distribution of marine debris. There is no research on the distribution of debris in the marine environment or on the seabed. Barr (p.c., 1997) reports that no marine debris was identified on recent video surveys of the seabed at Stellwagen Bank, although the purposes of the survey were to map bottom structure, not to identify debris. Environmental impacts of marine debris have been reported in the region, but the evidence is anecdotal at best.

Several areas of research can contribute to a better understanding of the problem and how best to address the problem. We suggest some here:

- A random sampling of the water column and seabed in ecologically sensitive areas, such as marine mammal migration routes and feeding grounds, in marine sanctuaries, coastal estuaries, and other areas.
- A search of the literature on animal strandings to establish the relationship (if one exists) between gut contents and strandings.
- Analysis of CMC beach cleanup data vis-a-vis the content of local and state littering statutes, the placement of signage and receptacles, and the extent of enforcement (e.g., per capita littering violations). These measures could be collected on the beach cleanup data sheets.

- Analysis of the costs and benefits of a recycling program for lost or abandoned fishing gear.

4. Summary and Recommendations

We have examined data on the temporal and spatial distribution of marine debris in the Gulf of Maine and the effectiveness of policy responses. We have worked toward two main goals: (1) the development of a historical "baseline" for marine debris distributions in the Gulf of Maine and (2) a review of existing debris reduction and prevention policies in the Gulf and elsewhere.

Some 80 to 85 percent of marine debris collected in beach cleanups appears to be from shore-based sources. Commercial fishers account for half of ocean-based debris. More than half of all marine debris is plastic; metal, glass, and paper make up most of the rest. No significant trends appear in the volume of most debris types in the Gulf of Maine from 1988 to the present. The data are sketchy, but nearshore debris volume appears to be perhaps five times greater in New Hampshire, northern Massachusetts, and parts of Nova Scotia than in Maine and southern Massachusetts.

Lack of data makes it difficult to establish the success or failure of particular approaches to marine debris. Deposit/refund policies for beverage containers appear to have reduced associated marine debris in Maine and Massachusetts. Beach cleanups appear to be an effective way to address nearshore marine debris. The social cost of marine debris is not known, but it seems likely that the largest component of this cost is reduced aesthetic value of fouled shorelines. Data on the benefits of cleanups are extremely limited, but suggest a willingness-to-pay for clean shoreline along the Gulf of Maine on the order of $14/foot/year, plus/minus about $7/foot/year.

Recommendations for future efforts include the following.

- In general, continue to combine a range of policy approaches, emphasizing economic incentives.

- Target onshore recreationists and commercial fishers with deposit/refund on beverage containers (New Hampshire) and possibly fishing gear (all states and provinces).

- Improve cleanup procedures by

    - holding cleanups in early spring to maximize aesthetic and ecological benefits (some high impact areas might be cleaned in the fall as well);

    - enlarging the cleanups to include wetlands and estuarine shorelines as well as beaches;

- adopting a "sampling strategy" to data collection such that only a few cleanup teams on beaches (or teams on only a few beaches) are required to collect detailed data (see Ricib and Ganio 1996); and

- estimating (instead of counting) numbers of small, high quantity debris items, such as cigarette butts.

- Support research to improve understanding of the marine debris problem, including:

  - a random sampling of the water column and seabed in ecologically sensitive areas, such as marine mammal migration routes and feeding grounds, in marine sanctuaries, coastal estuaries, and other areas;

  - a search of the literature on animal strandings to establish the relationship (if one exists) between gut contents and strandings;

  - analysis of CMC beach cleanup data vis-a-vis the content of local and state littering statues, the placement of signage and receptacles, and the extent of enforcement (e.g., per capita littering violations); and

  - analysis of the costs and benefits of a recycling program for lost or abandoned fishing gear.

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