QUANTITATIVE ESTIMATES OF GARBAGE GENERATION AND DISPOSAL IN THE U.S. MARITIME SECTORS BEFORE AND AFTER MARPOL ANNEX V

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ABSTRACT

Annex V of MARPOL 73/78 is regarded as an important instrument for reducing the amounts of plastics and other debris discarded into the ocean. Estimates of the aggregate quantities of garbage discarded are outdated, however, and represent only order of magnitude efforts. In this paper, the authors present updated estimates of the amounts of plastics and other debris generated in the U.S. maritime sectors.

The analysis covers both public and private sectors, including merchant marine vessels active in U.S. trade; commercial fishing vessels; recreational boats; research and industrial vessels; U.S. Navy, Coast Guard, and Army ships; and vessels and structures associated with offshore oil and gas operations. Current disposal practices as well as disposal practices under Annex V are analyzed and used to develop estimates of how the disposition of garbage generated at sea, i.e., the amounts dumped overboard, brought back to shore for disposal, and incinerated, will change under the new regulations.

INTRODUCTION

Two questions which underlie the debate over the U.S. ratification of MARPOL Annex V are: (1) How much garbage is being dumped overboard from vessels? and (2) What effect would the specific restrictions contained in Annex V have on the overall marine debris problem? Throughout the numerous congressional hearings which led up to U.S. ratification, only one source of aggregate data, a 1975 study by the National Academy of Sciences (NAS), was identified which addressed these questions. That study, however, examined the entire world fleet and included sources of debris which will not be regulated by Annex V (Table 1). It also made no attempt to account for actual disposal practices, reporting instead on the quantities of garbage "potentially" dumped (NAS 1975).

The present study utilizes current information for the U.S. maritime sectors to develop current and more comprehensive estimates of garbage

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In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Table 1.--Global marine litter estimates
(National Academy of Science 1975).

Garbage types and sources	Ton/year	Percent
Sources regulated under MARPOL Annex V		
Crew-related wastes		
Merchant marine	11,000	1.8
Passenger vessels	2,800	0.4
Commercial fishing	34,000	5.4
Recreational boats	10,300	1.6
Military	7,400	1.2
Oil drilling and platforms	400	0.1
Commercial wastes		
Merchant cargo wastes or dunnage	560,000	89.5
Annex V subtotal	625,900	100.0
Sources not regulated under MARPOL Annex V		
Fishing gear loss	100	1.0
Loss due to catastrophe[a]	10,000	99.0
Non-Annex V subtotal	10,000	1000.0
Total	636,000	100.0

[a]Includes debris from shipwrecks or marine storms.

quantities. The main components of the model are: vessel populations, entrances to U.S. ports, crew sizes, garbage generation factors, and plastics as a percent of total garbage. It also fills a gap left in previous studies by addressing historical shipboard disposal practices and changes in practice expected to result from implementation of Annex V. It must be noted, however, that few direct measurements of garbage generation and disposal practices exist. The methodological improvements offered in this study are based on updated data where they exist, and on substantial anecdotal information collected throughout the course of broader regulatory studies of MARPOL Annex V (Eastern Research Group (ERG) 1988a, 1988b).

The study first reviews information related to the sources, types, and quantities of garbage generated in the various maritime sectors. Data on per capita garbage generation, crew size, voyage length, and annual ship utilization factors are used to derive estimates of per voyage, per vessel, and annual aggregate garbage quantities generated. Estimates are made for the following sectors:

- Merchant shipping.
- Commercial fishing.

- Commercial passenger vessels.
- Recreational boating.
- Offshore oil and gas operations.
- Research and other miscellaneous vessels.
- U.S. Navy, Coast Guard, Army, and other government vessels.

An analysis of historical garbage disposal practices in these sectors is used to estimate the pre-Annex V garbage quantities dumped overboard, brought back to shore for disposal, or burned in marine incinerators. Under MARPOL Annex V, ships may be forced to alter their current disposal practices. An analysis of options available for compliance with Annex V is used to derive the post-Annex V disposition of vessel garbage.

GARBAGE ESTIMATION PARAMETERS

This section reviews the types and quantities of garbage generated in the maritime sectors. This information is combined with data on vessel populations, crew sizes, and voyage lengths from the supporting statistical section to produce estimates of the per voyage, per vessel, and aggregate annual garbage quantities generated.

Types of Garbage Generated

Several types of garbage are generated by vessels operating at sea. In this study, "domestic" garbage refers to general garbage such as galley refuse (food wastes, food packaging materials) and garbage from the hotel areas of the vessel (discarded items such as smoking materials and packaging, shampoo bottles, and razors). Wastes associated with normal ship operations, such as rags and containers, are also included. Some vessels generate an additional amount of "commercial" waste. Examples include cargo dunnage, spent fishing gear, and disposable or single-use oceanographic research instruments. These are discussed separately.

Domestic Wastes

Several sources of information on the quantities of garbage generated by ships are available. A series of studies done for the Intergovernmental Maritime Consultative Organization, the predecessor to the International Maritime Organization (IMO), are judged to represent the best available estimates (IMO 1987). These rates, representing per capita daily quantities, were reported as follows:

- Harbor vessels--1.0 kg (2.2 lb).
- Inland and coastal vessels--1.5 kg (3.3 lb).
- Oceangoing cargo vessels--2.0 kg (4.4 lb).
- Oceangoing cruise vessels--2.4 kg (5.3 lb).

As shown, the rates vary depending upon the type of vessel and where the vessel operates.

These rates appear consistent with those obtained elsewhere. The U.S. Navy, for example, examined garbage generation aboard naval ships in 1971 (Naval Ship Engineering Center 1971) and again in 1988 (L. Koss and Lt. Mullenhard, U.S. Navy, pers. commun. 1988), and reported estimates of 1.39 and 1.43 kg/person/day (3.05 and 3.15 lb), respectively. On land, the U.S. Environmental Protection Agency (EPA) estimates that each person generates an average of 1.82 kg (4.0 lb) of garbage per day (National Solid Waste Management Association (NSWMA) n.d.). Thus, the rates from the IMO studies appear consistent with those obtained elsewhere.

In this study, the IMO rates for oceangoing cargo and cruise vessels are applied respectively to cargo and passenger vessels which operate over the open ocean. The IMO rate for inland and coastal vessels is applied to crafts which travel inland or along the coastline.

Commercial Wastes

Several classes of vessels generate wastes associated with their commercial activities. These wastes are distinct from any operational wastes generated through normal vessel repair and maintenance activities, which are included under the category of domestic wastes.

Commercial cargo wastes or dunnage.--The term "dunnage" covers materials such as timber, plywood, pallets, rope, and plastic sheeting used to protect, separate, and secure cargo carried in break-bulk form. In the study (NAS 1975), these types of cargo wastes dominated the aggregate waste quantity estimates (Table 1). Since the mid-1970's, however, the trend towards containerization, and changes in cargo handling methods, are believed to have greatly reduced the amount of dunnage used. Cargo carried by containerships or other types of intermodal ships (barge carriers, roll-on/roll-off) is generally unloaded for transshipment in port without being disturbed. According to officials of the American Institute of Merchant Shipping, therefore, the "vast majority" of cargo ships now produce no dunnage waste (J. Cox, American Institute of Merchant Shipping, pers. commun. 1988).

The quantities and types of dunnage still used in general cargo trade vary, and depend upon the type of cargo being carried. Break-bulk shipments of food products, for example, use mainly cardboard for separation and protection of the cargo. For a highly explosive shipment of ammunition, however, extensive wooden encasements are constructed to protect against movement of the cargo. In such cases, tens of thousands of board feet of lumber may be used. Palletized cargoes may be shrink-wrapped and secured with steel or plastic strapping, but these are not normally removed prior to final delivery at the customer's facilities. Lumber and plywood are the most common materials used.

Marine terminal operators familiar with the loading and unloading of break-bulk ships indicate that very little plastic waste is generated. One reported use for plastic is to capture leaks of moisture or hydraulic

fluids in the vessel's cargo hatches. This plastic would likely be removed when the vessel is being unloaded. As indicated, plastic shrink-wrap is used with palletized cargo, but this is generally not removed either on board the ship or in port.

Estimates of per-vessel and aggregate dunnage quantities are difficult to make based upon the limited data. The study (NAS 1975) estimated that general cargo ships generate up to 285 tons of dunnage per year. This estimate contrasts significantly with information provided by marine terminal operators and shipping interests. Due largely to the trend towards containerization of cargo, there appears to be much less dunnage used today. Relying on current reports, this study assumes that two-thirds of the general cargo vessels entering U.S. ports generate dunnage in the form of lumber, one third generate only cardboard, and that 10% generate plastic waste. The quantities used are estimated as follows:

- Lumber--48.6 m^3 (approximately 20,000 board ft) per vessel entrance.
- Cardboard--23.6 m^3 (30 yd^3) per vessel entrance.
- Plastic--assumed to be generated by only 1 of every 10 break-bulk ships entering U.S. ports, in minimal quantities of 0.12 m^3 (4.0 ft^3) per entrance.

As the estimates presented later will show, under these assumptions the amount of waste generated by general cargo ships represents only a small proportion of the total garbage volume regulated by Annex V. Furthermore, overall estimates of plastics are not particularly sensitive to assumptions regarding dunnage volumes.

Fishing gear wastes.--Commercial fishing activity also contributes to the problem of marine debris, and to plastics in particular. Whether trawl gear, set nets, or lines are being used, occasional fouling of equipment, such as the tearing or twisting of nets and lines, will occur. During repair, portions of nets, excess line, floats, and other gear wastes may be generated. All such materials are nowadays made of synthetics, and are prohibited from disposal under Annex V. In addition to these items, substantial quantities of fishing gear are also lost accidentally. Annex V, however, does not cover this category of debris, hence no estimates are made here.

Limited information is available on the amounts of gear waste generated. The Foreign Fisheries Observer Program, National Marine Fisheries Service (NMFS) has monitored fishing gear repair operations on board foreign vessels active in Alaskan waters. Berger and Armistead (1987) analyzed data from this program and found that fishing gear repair operations took place about once every 4.9 days. The U.S. vessels active in the same fisheries report a similar incidence of gear repair (J. Gnagey, Alaska Trawl Fisheries, pers. commun. 1988; Z. Grader, Pacific Coast Federation of Fishermen's Associations, pers. commun. 1988). Discarded webbing was found to be typically small, with only 21.2% of pieces deemed to be "of a mesh

size or area thought most likely to entangle marine mammals" (Berger and Armistead 1987). Some 57.9% of discarded pieces consisted of "primarily loose strands of twine or pieces with a mesh size of less than 100 mm."

Working with these data, the amount of gear waste generated over a typical cruise is estimated to be relatively small. Assuming that (1) the average piece of webbing produced during net repair is 1 m^2, (2) webbing is composed of 15 mm diameter twine (Uchida 1985), and (3) the incidence of net repair and discard is twice per week, than the volume of waste generated over even a 30-day fishing expedition would amount to just over 0.12 m^3 (4 ft^3) of net material (ERG estimates).

Evidence suggests that these estimates from the Alaskan fisheries may represent an upper bound on the frequency and amount of fishing gear waste discarded. Beach surveys have found the concentration of fishing gear waste off the Alaskan islands to be among the highest noted anywhere (e.g., Merrell 1985). Discussions with fishery representatives elsewhere in the United States have indicated that net repair operations while at sea are relatively less common. Moreover, net fragments and floats in other fisheries are reported to be retained on board for use in repair operations, rather than discarded. Spare nets may also be carried in order to avoid at-sea repairs completely (ERG 1988a, 1988b). In this study, it is assumed that the average volume of fishing gear waste generated in all U.S. fisheries is half of that calculated for Alaska. An estimate of 0.03 m^3 (1 ft^3) of gear waste per week at sea is assumed.

Nongear fishing wastes.--Certain fisheries produce additional quantities of wastes due to their use of specialized fishing techniques. These include longline fishing, which uses packaged bait (B. Alverson, Longliner Vessel Owners Association, pers. commun. 1988), and the herring fishery, which utilizes quantities of packaged salt (J. Kaelin, Associated Fisheries of Maine, pers. commun. 1988). Longline bait is sold frozen, with packages wrapped in plastic, packed in cardboard boxes, and secured with plastic strapping. Chemical light or Cyalume sticks are also used to attract fish. These sticks, about the size of a pencil, are themselves made of plastic. Salt used in the herring fishery comes in large plastic bags.

Available estimates of marine waste disposal do not address this source of waste. The Center for Environmental Education (CEE) reports that longline gear is used in at least five different fisheries (CEE 1986), and that longline vessels can bait up to 5,000 hooks per day. In order to capture the additional wastes produced by vessels in these fisheries, it is assumed in this study that they generate twice the normal volume of fishing gear waste.

Research vessel wastes.--Research vessels may generate additional plastic wastes in the form of packing materials from research instruments brought on board, and from disposable measuring instruments used in monitoring oceanic experiments. Based on discussions with representatives at various research institutions, an additional 0.12 m^3 (4 ft^3) of plastic waste per voyage is assumed.

Dry Versus Wet Garbage

The nature of the MARPOL Annex V regulations makes it necessary to estimate separately the amounts of "wet" garbage (food waste) and "dry" garbage generated. Many vessels are expected to separate plastics from their dry garbage and then dispose of the remainder while in areas where no Annex V restrictions apply. Some, however, may have to retain all dry garbage for onshore disposal (and even wet garbage, in some cases) depending on whether they operate in Annex V "special areas" or in coastal waters. (Special areas currently include the Mediterranean Sea, Baltic Sea, Red Sea, Black Sea, and Persian Gulf Areas; Table 2.)

The dry garbage component of the overall solid waste stream is estimated based on the recent U.S. Navy study (Koss and Mullenhard, pers. commun. 1988). In this study, dry garbage accounted for 59.4% of domestic waste by weight, while wet garbage accounted for 40.6%. These percentages are similar to those found in the earlier, more extensive Navy studies, where the dry garbage component was estimated at 43.6%.

Plastics as a Percentage of Total Wastes

Annex V places a complete prohibition on the overboard disposal of plastics. Estimates of the percentage of the overall vessel waste stream accounted for by plastics are needed in order to develop projections of the quantity of garbage that may be brought back to shore for disposal.

The EPA estimates that plastics represent 6.5% (by weight) of all household and commercial solid waste on land (NSWMA n.d.). The relevance of this estimate to vessel operations is uncertain, however, because of likely differences in the types of waste generated at sea. In the national EPA estimate, paper and paperboard waste makes up 42% of the total, and yard waste accounts for another 16%. Garbage generated at sea is likely to contain much less paper waste and no yard waste. Under these assumptions, plastics would represent a larger share of the waste stream at sea than it would on land. At the same time, though, national estimates would include discards of durable plastic objects and industrial plastic waste, very little of which is generated at sea.

Studies done by the U.S. Navy in 1971 (Naval Ship Engineering Center 1971) and 1988 (Koss and Mullenhard, pers. commun. 1988) represent the only direct estimates of plastic wastes based on actual operating experience. In 1971, plastics were found to account for only 0.3% of total garbage by weight. This study covered numerous vessels and was used by the NAS in their estimates (NAS 1975). In 1988, however, the Navy found that the plastics share of total garbage weight had risen to 6.7%--an apparent twentyfold increase. It must be noted that the more recent study is based on an analysis of a single Navy vessel operating over a short (32-h) cruise. Thus, the figures may not be representative.

In reviewing the data from the Navy studies, the question of potential differences in plastics usage between Navy and other vessels arises. Navy vessels carry extensive electronic equipment on board which may be wrapped in plastic "bubble" wrap and other cushioning materials. This source of

Table 2.--Summary of MARPOL Annex V restrictions (International Maritime Organization 1987).

Garbage type	All vessels: Outside special areas[a]	All vessels: Within special areas[a]	Offshore platforms and associated vessels[b]
Plastics	Disposal prohibited	Disposal prohibited	Disposal prohibited
Floating dunnage, lining and packing materials	>25 nmi from land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, etc., not ground	>12 nmi from land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, etc., ground[c]	>3 nmi from land	Disposal prohibited	Disposal prohibited
Food waste, not ground	>12 nmi from land	Disposal prohibited	Disposal prohibited
Food waste, ground[c]	>3 nmi from land	>12 nmi from land	>12 nmi from land
Mixed refuse types	(d)	(d)	(d)

[a]Annex V special areas include the Mediterranean, Baltic, Red, and Black Seas, and the Persian Gulf Areas.

[b]Offshore platforms and associated vessels include 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 of such platforms.

[c]Ground waste must be able to pass through a screen with mesh size no larger than 25 mm (0.1 in).

[d]When garbage is mixed with other harmful substances having different disposal or discharge requirements, the more stringent disposal requirements shall apply.

plastics is not generally present on board other types of vessels. Second, considerably more at-sea repair occurs on board Navy ships than aboard merchant marine or fishing vessels. Tools and replacement parts may be packaged in plastic, and parts themselves may be plastic. Wire and cable have plastic insulation. On the other hand, due to the large crew sizes, food supplies on board Navy vessels are generally purchased in bulk. The reduced packaging associated with this bulk purchasing would suggest smaller

plastic generation rate. Navy vessels may, therefore, generate more plastics from operational sources, but less from galley refuse.

In the absence of any conclusive evidence on the amount of plastics contained in the ship's waste stream, the results from the most recent Navy study (Koss and Mullenhard, pers. commun. 1988) have been used. This study indicates that plastics represent 6.7% of all wet and dry solid waste, and 11.3% of dry solid waste, by weight. Additional studies of this nature relative to shipping and other maritime sectors would certainly be welcome.

Garbage Densities

Further analysis of garbage generation patterns requires estimates of the density of garbage. These are needed in order to convert the weight of a given accumulation of garbage to volume terms. At sea, it may be the volume of garbage, rather than its weight, that figures in decisions regarding disposal options.

Table 3 shows estimates of garbage density for shipboard types of garbage. It will be noted that no sources of data specific to plastics were identified. Studies done for the State of New York by Franklin Associates (V. Sellers, Franklin Associates, pers. commun. 1988) found that 1,000 kg (2,200 lb) of uncompressed plastic soda containers had an average volume of 20.8 m^3 (325 ft^3), suggesting a density of 48.1 kg/m^3 (3.07 lb/ft^3). Navy officials, however, have suggested that a much lower density of 15.4 kg/m^3 (1 lb/ft^3) is appropriate (Koss and Mullenhard, pers. commun. 1988). This would imply that plastics used on board ship weigh one-third as much as much as empty soda bottles--an apparently generous volume estimate. In the absence of any data specific to ships, however, the Navy's estimate of 15.4 kg/m^3 (1 lb/ft^3) is incorporated. Again, this estimate is the more generous of those available in terms of estimating the volume of plastics generated on board.

Table 3.--Estimates of density for shipboard-generated garbage.

Source of estimate and garbage type	Density	
	kg/m^3	lb/ft^3
Society of Naval Architects and Marine Engineers (1982):		
Dry rubbish	100.0	6.3
Dry garbage	120.0	7.5
Refuse, 70% wet	640.0	40.0
Food waste	400 to 1,000	25.0 to 68.8
Gassan (1978):		
Hotel solids	277.0	17.2

Table 4 summarizes the numerous estimates and assumptions used in calculating garbage weights and volumes. The reader should note that densities are calculated for each of the different components of mixed garbage. Any conversions from garbage weight to volume made in this study must be considered, therefore, in the context of the density values used.

GARBAGE HANDLING AND DISPOSAL PRACTICES BEFORE AND AFTER MARPOL ANNEX V

This section summarizes the more substantial review of garbage handling and disposal practices contained in ERG (1988b). Estimates of the percentage of vessels using each of the various garbage handling and disposal methods, both historically and under Annex V, are used to evaluate the disposition of the aggregate garbage quantities under pre- and post-Annex V assumptions.

Pre-Annex V Garbage Handling and Disposal Practices

The historical methods employed by shipboard crews to dispose of garbage provide a basis for determining the current disposition of the garbage generated on board, i.e., how much is discarded overboard, how much brought back to shore for disposal, and how much is burned in onboard incinerators.

In most sectors, garbage handling practices vary depending on where the ship operates. Over deep-sea routes, garbage is typically collected throughout the ship and discharged daily. Closer to shore, crews are more likely to retain garbage for onshore disposal. The historical practice of ocean dumping while out at sea has been confirmed in most sectors. A representative of the American Institute of Merchant Shipping, for instance, states that: "Generally aboard merchant vessels on the high seas, waste generated as a result of vessel operations and deck maintenance is disposed of directly overboard" (Corrado 1986).

The predominance of ocean disposal is also indicated by statistics kept by the Department of Agriculture's Animal and Plant Health Inspection Service (APHIS). This agency requires ships entering the United States from foreign ports to incinerate, sterilize, or otherwise sanitize any garbage prior to disposing of it on shore. The APHIS inspection records for fiscal year 1986, for example, show that only 2.5% of vessels entering the United States from foreign ports off-loaded any garbage (A. Langston, U.S. Department of Agriculture, pers. commun. 1988).

Most commercial fishing groups also acknowledge that garbage dumping has traditionally been the most widely used means of getting rid of any trash which accumulates.

The use of garbage handling equipment such as grinders, compactors, or incinerators has not been widespread in the maritime sectors. Only some newer ships are equipped with such equipment. Until now, overboard disposal while well out at sea has been the most convenient and inexpensive method available. Based on discussions with operators in the merchant

Table 4.--Assumptions and estimates used in garbage generation calculations.

Domestic garbage generation rates (International Maritime Organization 1987)

Vessel category	Per capita per day kg	Per capita per day lb
Oceangoing	2.0	4.4
Coastal	1.5	3.3
Inland/harbor	1.0	2.2
Passenger cruise	2.4	5.3

Fishing waste generations rates (Eastern Research Group estimates)

Vessel category	Per vessel per day m^3	kg	ft^3	lb
Normal vessels	0.004	0.064	0.140	0.140
Longliners, etc.	0.008	0.127	0.280	0.280

Domestic waste components, by weight (Koss and Mullenhard, pers. commun. 1988)

Garbage type	As percent of all garbage by weight	As percent of dry garbage by weight
Wet (food waste)	40.6	--
Dry (nonfood waste)	59.4	100.0
Plastic	6.7	11.3
Glass	4.1	6.9
Metal	13.0	21.9
Rubber	0.3	0.5
Paper, other	35.2	59.3

Garbage density (Society of Naval Architects and Marine Engineers 1982), except for plastic density, which was suggested by Navy personnel

Garbage type	kg/m^3	m^3/kg	lb/ft^3	ft^3/lb
Total garbage	174.2	0.006	10.89	0.10
Dry garbage	100.0	0.010	6.30	0.16
Food waste	640.0	0.002	40.00	0.03
Plastics	16.0	0.063	1.00	1.00

marine, commercial fishing, and government sectors, it is assumed here that for most ships, overboard disposal is the predominant method used.

Vessels which spend more time operating close to shore are less likely to rely on overboard disposal. There are several possible reasons for this: Laws and regulations may already prohibit dumping in such areas; vessels are away from port for shorter periods and thereby generate less garbage; or operators may be conscious about dumping close to shore. Several categories of vessels have been identified as using alternative disposal means. These include segments of the coastal trade fleet, tug and towboat operators, recreational boaters, offshore oil and gas operations, some industrial and research vessels, and some Coast Guard vessels.

Post-Annex V Garbage Handling and Disposal Practices

Under MARPOL Annex V, vessel operators may have to implement changes in garbage handling procedures in order to achieve compliance with the requirements of the regulations. The actions taken by an individual operator will depend upon a number of factors, including (1) where the vessel operates and the specific restrictions of Annex V which apply in those areas, (2) the quantities and types of garbage generated by each vessel, and (3) the cost and noncost factors which influence the selection of compliance methods.

Each vessel owner or operator will evaluate his operations relative to the requirements of MARPOL Annex V. Table 2 presented a summary of the restrictions introduced by Annex V for the various types of garbage. Disposal of plastics is prohibited everywhere, and disposal of other types of wastes is restricted for vessels operating near shore. Vessels operating in special areas are prohibited from disposing of anything except food wastes, and then only beyond 12 mi from shore. A separate set of rules apply to offshore oil and gas operations.

Alternative compliance options have been analyzed in terms of their relative costs and conveniences in the regulatory analysis prepared for the Coast Guard (ERG 1988b). Among the compliance methods examined were: substitution of plastics, storage of garbage for onshore disposal, use of compactors to reduce garbage volumes, with subsequent disposal on shore, and installation of onboard garbage incinerators. The model used for comparing these alternatives took into account all of the relevant costs associated with each option, including the volumes and types of garbage generated; equipment, installation, and operating costs; the opportunity costs of current garbage handling and disposal procedures (i.e., not paying crews to dump garbage); and costs associated with off-loading and disposing of garbage in port.

The cost comparison model shows that for most vessels, onboard separation and storage of plastic garbage, with eventual disposal in port, is the least costly alternative (see ERG 1988b). As the garbage generation tables below will show, the quantities of plastics generated by most vessels would not present extreme storage difficulties. Where garbage volumes may cause inconveniences or storage problems, compactors can be used to reduce the volumes.

Several factors not captured by the cost comparison may steer vessel operators towards more costly compliance methods. If, for whatever reason, vessels anticipate the accumulation of large quantities of garbage on board, they may consider methods that reduce or eliminate this burden, even if it increases their costs. Operators may be concerned about situations where onshore garbage disposal would not be possible for extended periods of time, due to delays or the inability to obtain removal service in port. Finally, the cost comparisons do not consider issues caused by operations in special areas, where additional restrictions on the disposal of garbage will apply.

When both the cost and noncost issues are considered, most smaller vessels are still projected to choose separation and storage of garbage which they will no longer be able to dump overboard. Extensive use of onboard garbage compaction equipment is forecast, however, for larger commercial fishing vessels and for a majority of domestic trade merchant ships. Such equipment will be used to reduce the volume of garbage retained on board and to facilitate handling and disposal in port. Equipment manufacturers indicate that equipment suitable for onboard use can achieve a compaction ratio of between 500 and 1,000%, although for pure plastics the ratio is lower unless the material is first shredded. Only ships in the merchant shipping foreign trade category and some larger research and passenger ships are expected to select onboard incinerators. In the case of foreign trade vessels, the decision to invest in incinerators will not be based simply on economics, as incinerators represent the most expensive means of compliance, but rather upon the increased convenience afforded to the vessel. Time spent in port is extremely costly, thus incinerators may be viewed as "insurance" against the possibility of being delayed due to difficulties in obtaining garbage disposal services. It must be noted, however, that current or future air pollution standards for marine incinerators could greatly increase the cost of this option.

Special mention should be made of the solution expected to be adopted by U.S. Navy ships. As shown below, the Navy has particular garbage disposal problems due to the large number of crewmen on board. According to the most recent reports, Navy ships are expected to be outfitted with thermal extrusion equipment specially designed for shipboard application. This technology will enable Navy crews to melt down all plastics generated on board and extrude them into a storable form.

Pre- and Post-Annex V Garbage Disposition

Table 5 presents estimates of the pre- and post-Annex V distribution of vessels in the merchant shipping sector according to the garbage handling and disposal practices used. The distributions reflect ERG conclusions from the review of disposal practices and options described above. Similar distributions have been developed for each of the maritime sectors under study, but are not shown here.

Aggregate quantities of domestic garbage derived in the supporting statistical section are shown in the first column of Table 6 below. The table shows the pre- and post-Annex V disposition of these garbage

Table 5.--Current garbage handling and disposal practices and projected practices under MARPOL Annex V merchant shipping sector (Eastern Research Group estimates).

Merchant shipping	Current compliance rate (%)	Current compliance choices (%)				Annex V compliance choices (%)		
		Dump	Store	Compact	Incinerate	Store[a]	Compact	Incinerate
Foreign trade								
U.S. vessels								
Atlantic/Gulf/Pacific ports	5	95	0	0	5	5	70	25
Noncontiguous ports	5	95	0	0	5	5	70	25
Foreign vessels								
Atlantic/Gulf/Pacific ports	5	95	0	0	5	5	70	25
Noncontiguous ports	5	95	0	0	5	5	70	25
Noncontiguous trade	5	95	0	0	5	5	80	15
Great Lakes vessels								
1,000 GT and over	100	0	25	50	25	25	50	25
Under 1,000 GT	100	0	25	50	25	25	50	25
Military Sealift Command charter	5	95	0	0	5	5	75	20
Temporarily inactive vessels	5	95	0	0	5	5	75	20
Coastal shipping								
Ships								
1,000 GT and over	25	60	40	0	0	10	75	15
Under 1,000 GT	5	95	5	0	0	15	75	10
Tow/tugboats								
Large (inspected)	20	80	20	0	0	50	45	5
Small	20	80	20	0	0	60	40	0

[a]Refers to storage of all garbage that vessels would not be permitted to dump. Assumes other garbage will be dumped where allowed under Annex V.

Table 6.--Final disposition of vessel-generated domestic waste, aggregated sector totals (annual quantities) (GT = gross tons; MT = metric tons).

Maritime sector	Total generated annually (MT)	Pre-Annex V: Off-loaded in port (MT)	Off-loaded in port (m^3)[a]	Incinerated at sea (MT)	Incinerated at sea (m^3)[a]	Dumped overboard (MT)	Dumped overboard (m^3)[a]
Merchant shipping	30,949	3,302	39,794	1,148	14,971	26,499	349,304
Commercial passenger vessels	258,074	232,121	3,026,799	638	8,322	25,315	330,095
Commercial fishing	233,177	0	0	0	0	233,177	3,040,564
Recreational boating	636,055	424,036	5,529,325	0	0	212,018	2,764,662
Offshore oil and gas operations	16,710	10,733	139,958	0	0	5,977	18,656
Miscellaneous vessel classes	1,637	5	60	0	0	1,633	20,778
U.S. Navy	57,596	0	0	0	0	57,596	751,040
U.S. Coast Guard	4,317	1,452	28,786	0	0	2,864	8,941
U.S. Army	490	0	0	0	0	490	6,388
NOAA	317	7	165	88	1,146	222	2,463
Total	1,239,322	671,656	8,764,887	1,874	24,439	565,791	7,292,892

Table 6.--Continued.

Maritime sector	Post-Annex V[b]							
	Off-loaded in port				Incinerated at sea		Dumped overboard	
	Plastics		Other					
	(MT)	(m^3)[a]	(MT)	(m^3)[a]	(MT)	(m^3)[a]	(MT)	(m^3)[a]
Merchant shipping	1,626	311,353	2,737	6,255	4,381	57,132	22,204	103,685
Commercial passenger vessels	22,490	2,304,400	233,340	1,060,557	1,117	14,564	1,128	5,265
Commercial fishing	15,373	1,352,768	0	0	3,723	48,542	214,081	999,660
Recreational boating	39,848	4,975,109	554,892	2,771,045	0	0	41,315	128,964
Offshore oil and gas operations	398	49,740	5,547	72,799	0	0	0	0
Miscellaneous vessel classes	109	5,372	0	0	306	3,986	1,223	5,709
U.S. Navy	3,859	2,409,124	0	0	0	0	53,737	250,929
U.S. Coast Guard	289	126,913	765	2,604	0	0	3,262	10,183
U.S. Army	33	9,143	0	0	0	0	199	621
NOAA	11	331	0	0	148	1,926	158	737
Total	84,037	11,544,253	797,282	3,913,261	9,674	126,150	337,306	1,505,752

[a]Weight-to-volume conversions reflect (1) the densities of the various types of garbage (see Table 4), (2) the composition of the vessel waste stream, and (3) the degree to which compaction equipment is used in each sector.

[b]Assumes full compliance with Annex V requirements.

quantities. Both the weight and volume of garbage are indicated. Weight-to-volume conversions reflect assumptions about the types of garbage generated and the use of compaction to reduce garbage volume. This table shows aggregated sector totals only. A set of more detailed disposition tables is found in the Appendix.

The first columns of Table 6 indicate the current disposition of vessel-generated domestic garbage. The relative quantities of garbage currently brought back to shore, incinerated, or dumped overboard vary from sector to sector. A small amount of at-sea incineration occurs in portions of the merchant shipping and cruise ship sectors as well as on some National Oceanic and Atmospheric Administration (NOAA) research vessels. The percentage of domestic garbage brought back to shore for disposal is relatively high in the commercial passenger and recreational boating sector. Of the 1.2 million metric tons (MT) generated in all of the sectors, however, 566,000 MT or 45% by weight is still dumped overboard.

Under Annex V, some increased use of marine incinerators will occur, but the percentage of domestic garbage disposed of via incineration at sea will remain below 1%. All plastics, with the exception of that destroyed in incinerators, will be returned to shore for disposal. The current methodology predicts that 84,037 MT of plastics will be brought ashore for disposal. This will account for only 9.5% of all garbage brought ashore on a tonnage basis. Because of its low density, however, in volume terms plastics will represent close to 75% of the waste. Restrictions on the disposal of other types of garbage for vessels operating close to shore or in special areas will also increase the quantity of nonplastics brought ashore. Overall, the net increase in plastics and nonplastics brought ashore under Annex V will be 209,663 MT.

SUPPORTING STATISTICAL ANALYSIS OF MARITIME SECTORS SUBJECT TO COAST GUARD ENFORCEMENT OF MARPOL ANNEX V REGULATIONS

This section provides supporting data on the populations of ships covered in this study and used to generate the estimates of aggregate garbage generation shown in Table 6. Seven separate maritime sectors are identified as falling under the jurisdiction of the Coast Guard under MARPOL Annex V. These sectors are: merchant shipping, commercial fishing, commercial passenger vessels, recreational boating, offshore oil and gas operations, research and other miscellaneous vessels, and vessels operated by the U.S. Government. Each of these is profiled below in terms of the number and types of ships, onboard employment, and the frequency and duration of voyages. This information is then combined with data from earlier sections to derive per voyage, per vessel, and aggregate annual garbage quantity estimates for each of the sectors.

Merchant Shipping

Merchant vessels are those ships involved in the waterborne transport of cargo and passengers over established transoceanic, coastwise, intercoastal, and inland water routes. Under the provisions of the Jones Act, domestic waterborne commerce (cargoes moving between U.S. ports) is

reserved exclusively for U.S. vessels. The U.S. import and export trade, however, is dominated by foreign vessels. The foreign and domestic trade sectors are discussed separately below.

Foreign Trade Vessels

According to the U.S. Maritime Administration (MARAD), the U.S. oceangoing merchant fleet numbers approximately 823 vessels of 1,000 gross tons (GT) and over. Of these, however, some 391 are inactive. Of the 432 active U.S. vessels, 122 or 28% are active in foreign trade. Another 54 vessels are active in Marine Sealift Command (MSC) operations, and will have voyage patterns comparable to foreign trade ships (see Table 7).

In addition to the vessels covered by MARAD, the Coast Guard's Marine Safety Information System (MSIS) data base shows there to be 43 vessels under 1,000 GT that are certificated for operation over open ocean routes. Thus, a total of 219 U.S.-flagged vessels operate over foreign trade routes.

The MARAD reports show that foreign-flagged vessels dominate the foreign trade sector, accounting for 95.6% of all U.S. import and export trade by tonnage (MARAD 1987b). The number of foreign vessels involved is commensurate. Data from the Coast Guard indicate that in 1987 a total of 6,751 foreign vessels, representing 110 different shipping nations, were inspected at U.S. ports (Coast Guard 1987b).

We assumed that vessels without incinerators will off-load all garbage in their final foreign port of call prior to setting sail for the United States. Under this assumption, vessels will retain on board all garbage they are prevented from dumping, and seek to off-load it upon return to the United States.

In order to estimate how much garbage is generated by these ships while en route to the United States, we examined data from the U.S. Customs Bureau's AE-975 file, Vessel Entrances and Clearances (U.S. Bureau of the Census 1987). This data base includes information on the final foreign port of call of vessels arriving at U.S. ports.

Four months of data (January, April, July, and October) were examined and used to derive annual estimates. In 1987, U.S. vessels made a total of 3,969 entrances to U.S. ports, while an estimated 33,087 entrances were made by foreign vessels. Table 8 shows a breakdown of these entrances by U.S. coastal area and foreign region of origin. Along the Atlantic and Gulf coasts, the largest number of entrances, 55 and 40%, respectively, were recorded by vessels clearing Customs from Caribbean ports. Entrances at Pacific coast ports were dominated by vessels arriving from Pacific Rim countries (46.6%) and from Pacific Canadian ports (28.8%).

A weighted average voyage length for foreign trade vessels arriving at U.S. ports was developed by calculating typical voyage lengths for each of the U.S.-foreign region pairings from Table 8. The estimated voyage lengths are based upon representative voyages from each foreign region to the U.S. coast and an assumed vessel speed of approximately 500 nmi per

Table 7.--Deployment status of U.S. flag merchant fleet, vessels 1,000 gross tons (GT) and over (U.S. Maritime Administration (MARAD), Merchant Marine Data Sheet, 1 March 1987).

Deployment status	Passenger/ combination		General cargo		Intermodel vessels		Bulk carriers		Tankers		Total	
	No.	Dwt	No.	Dwt	No.	Dwt	No.	Dwt	No.	Dwt	No.	Dwt
Active vessels												
Privately owned	2	15	36	531	112	2,694	22	934	192	11,772	364	15,946
Oceangoing												
U.S. foreign trade	--	--	26	380	69	1,703	13	684	14	806	122	3,573
Foreign-to-foreign	--	--	--	--	4	72	--	--	8	571	12	643
Domestic trade	2	15	1	18	20	358	7	188	146	9,671	176	10,250
Coastal	--	--	--	--	1	17	5	133	97	4,062	103	4,212
Noncontiguous	2	15	1	18	19	341	2	55	49	5,609	73	6,038
Military Sealift Command charter	--	--	9	133	19	561	2	62	24	724	54	1,480
Great Lakes[a]	--	--	--	--	--	--	55	1,819	3	20	58	1,840
Government-owned	4	32	3	26	--	--	--	--	1	17	8	75
BB charter and other custody	4	32	3	26	--	--	--	--	1	17	8	75
Subtotal--active fleet	6	47	39	557	112	2,694	22	934	193	11,789	372	16,021
Inactive vessels												
Privately owned	6	59	13	164	35	1,124	39	937	33	3,040	126	5,324
Oceangoing	6	59	13	164	35	1,124	4	336	33	3,040	91	4,723
Temporarily inactive	--	--	3	43	1	33	1	63	2	131	7	270
Laid up	6	59	7	82	32	1,085	3	273	29	2,841	77	4,340
Laid up (MARAD custody)	--	--	3	39	2	6	--	--	2	68	7	113
Great Lakes	--	--	--	--	--	--	35	601	--	--	35	601

Table 7.--Continued.

Deployment status	Passenger/ combination		General cargo		Intermodel vessels		Bulk carriers		Tankers		Total	
	No.	Dwt	No.	Dwt	No.	Dwt	No.	Dwt	No.	Dwt	No.	Dwt
Government-owned (MARAD)	24	183	184	2,102	28	761	--	--	21	623	257	3,669
National defense Reserve fleet	21	166	184	2,102	23	593	--	--	18	401	246	3,262
Ready research force (RRF)	1	9	53	661	17	438	--	--	8	141	79	1,249
Other reserve	6	57	122	1,356	6	155	--	--	9	244	143	1,812
Special programs	1	5	3	28	--	--	--	--	--	--	4	33
Nonretention	13	95	6	57	--	--	--	--	1	16	20	168
In processing for RRF	--	--	--	--	4	152	--	--	--	--	4	152
Other government-owned	3	17	--	--	1	16	--	--	3	222	7	255
Subtotal--Inactive fleet	30	242	197	2,266	63	1,885	39	937	54	3,663	383	8,993
Total--Active and inactive	36	289	236	2,823	175	4,579	61	1,871	247	15,452	755	25,014

[a]Includes ships normally active but laid up due to the winter freeze.

Table 8.--Entrances to U.S. ports by U.S. and foreign vessels, and estimated days at sea by U.S. coastal area, 1987 (U.S. Bureau of the Census 1987; Eastern Research Group estimates).

U.S. coastal area	Vessel origin	Estimated number of entrances			Estimated voyage length[a] (days)
		Foreign vessels	U.S. vessels	Total vessels	
Atlantic	Caribbean	5,895	954	6,849	3
	Scandinavia and N. Europe	1,497	204	1,701	9
	Canada--Atlantic	963	3	966	3
	Mediterranean	765	45	810	9
	W. coast S. America	612	27	639	9
	E. coast S. America	465	36	501	8
	Pacific Rim	282	3	285	15
	W. coast Africa	267	9	276	11
	Australasia	126	--	126	17
	Indonesia and India	123	--	123	16
	Middle East	78	6	84	12
	E. coast Africa	39	9	48	16
	Canada--Great Lakes	39	--	39	4
	Total	11,151	1,296	12,447	
	Weighted average voyage length	5.7	4.6		
Gulf	Caribbean	3,264	474	3,738	3
	W. coast S. America	1,794	249	2,043	6
	Scandinavia and N. Europe	1,212	51	1,263	10
	Mediterranean	645	42	687	10
	Pacific Rim	435	9	444	13
	W. coast Africa	327	27	354	15
	E. coast S. America	267	15	282	8
	Canada--Atlantic	282	--	282	6
	Australasia	99	--	99	14
	Indonesia and India	72	3	75	13
	Middle East	63	3	66	12
	E. coast Africa	27	9	36	10
	Canada--Great Lakes	33	--	33	7
	Canada--Pacific	3	--	3	7
	Total	8,523	882	9,405	
	Weighted average voyage length	6.7	5.3		
Pacific	Pacific Rim	3,285	306	3,591	11
	Canada--Pacific	1,650	567	2,217	3
	Caribbean	708	195	903	10
	W. coast S. America	321	138	459	15

Table 8.--Continued.

U.S. coastal area	Vessel origin	Estimated number of entrances: Foreign vessels	U.S. vessels	Total vessels	Estimated voyage length[a] (days)
	Australasia	174	3	177	11
	Indonesia and India	150	15	165	15
	Scandinavia and N. Europe	120	3	123	15
	E. coast Africa	51	--	51	11
	Mediterranean	12	--	12	18
	Total	6,471	1,227	7,698	
	Weighted average voyage length	9.2	7.7		
Great Lakes	Canada--Great Lakes	1,716	156	1,872	1
	Scandinavia and N. Europe	96	9	105	10
	Mediterranean	27	--	27	10
	W. coast Africa	12	--	12	11
	Pacific Rim	6	--	6	16
	Middle East	3	--	3	13
	Total	1,860	165	2,025	
	Weighted average voyage length	1.7	1.5		
Noncon-tiguous areas (includes Alaska, Hawaii Puerto Rico, and Virgin Islands	Caribbean	3,891	354	4,245	(b)
	Pacific Rim	426	6	432	(b)
	W. coast S. America	195	27	222	(b)
	E. coast S. America	135	3	138	(b)
	Scandinavia and N. Europe	93	--	93	(b)
	Australasia	84	--	84	(b)
	Indonesia and India	75	6	81	(b)
	W. coast Africa	60	3	63	(b)
	Canada--Atlantic	54	--	54	(b)
	E. coast Africa	42	--	42	(b)
	Mediterranean	18	--	18	(b)
	Canada--Pacific	6	--	6	(b)
	Middle East	3	--	3	(b)
	Total	5,082	399	5,481	(b)

[a]The percentage of entrances from each vessel origin is used to derive the weighted average voyage lengths for each coastal area.

[b]Voyage lengths for entrances to noncontiguous ports are estimated as follows: Hawaii--6 days (60% of entrances are from Japan), Puerto Rico and the Virgin Islands--1 day (majority of entrances are from Caribbean countries).

As indicated above, the Jones Act excludes foreign vessels from competing for U.S. domestic trade. Consequently, all domestic trade moves aboard U.S. vessels. In 1987, the fleet of U.S.-flagged domestic trade vessels included the following:

- 176 vessels of 1,000 GT and over (MARAD 1987a). Of these, 103 or 59% are active in "coastal" trade or trade between ports in the contiguous United States (see Table 7). All but six of these are tankers. The remaining 73 vessels operate in "noncontiguous" trade or trade between the contiguous U.S. states and the noncontiguous states and properties. Included in this total are 49 tankers and 19 intermodal vessels, as well as 2 U.S. cruise ships (described in the next section);

- 12 freighters and 14 tankers under 1,000 GT designated for coastwise travel (Coast Guard 1987b);

- 14 freighters and 43 tankers designated for lakes, bays, and sounds operation (Coast Guard 1987b);

- 9 freighters and 6 tankers designated for river operation (Coast Guard 1987b); and

- ca. 5,000 tug and towboats (U.S. Army Corps of Engineers 1987), which operate predominantly over the inland waterways.

Great Lakes ships may operate in either domestic or foreign (United States-Canada) trade. No breakdown is reported for these ships based on trade status, hence they are analyzed in terms of the number of ships and annual operating ratios, rather than number of entrances. (Operating ratios or utilization rates refer to the percentage of days annually on which the ship is engaged in trading activities.) In 1987, there were estimated to be 58 active Great Lakes ships of 1,000 GT or over (MARAD 1987a) and 7 of under 1,000 GT (Coast Guard 1987b).

Domestic trade vessels operate exclusively within U.S. waters, and will hence be under Coast Guard jurisdiction whenever they are operating. One exception is noncontiguous vessels which may exit U.S. waters en route from the continental United States. The approach to estimating garbage quantities in the domestic sector is, therefore, somewhat different. Whereas the annual garbage quantities generated by foreign trade vessels are estimated based upon the number of voyages, in this case it is the number of ships, the crew size, and the annual ship utilization rate which are the determinants.

Crews aboard domestic trade ships also average 20-25 men. Large oceangoing tugs carry up to 10 men, while smaller tugs and motor barges carry 6-man crews.

Domestic ships over 1,000 GT are estimated to have average voyage lengths of 5 days, while those under 1,000 GT average 4 days. Trips of large tugboats are also assumed to average 4 days, while small tugs are estimated to average 2 days at sea.

All vessels in the merchant marine sector, with the exception of Great Lakes ships, are assumed to operate with 90% utilization rates. Due to the winter freeze-up, Great Lakes ships are limited to approximately 50% utilization.

Garbage Generation Estimates

Domestic garbage.--In Table 9 below, estimates of the amount and types of garbage generated over typical voyages are shown for each of the merchant shipping categories. The table shows both weight and volume estimates, and indicates that the greatest accumulation would occur on foreign trade and large domestic trade ships. Over a 7-day voyage these ships are estimated to generate 330 kg or 2.2 m^3 of garbage, of which only 22 kg is plastics. One cubic meter represents approximately 8-9 large 113.5 liter (30-gal) garbage bags.

Cargo wastes.--Table 10 presents estimates of the number of entrances to U.S. ports by U.S. and foreign general cargo vessels, and of the quantities and types of dunnage generated by such ships. In the Customs data base, dry cargo ships account for 56.1% of entrances by U.S. ships and 74.4% of entrances by foreign ships (Bureau of the Census 1987). The MARAD data indicate that 28 of the 101 dry cargo ships in the U.S. foreign trade fleet (27.7%) are general cargo-type ships (MARAD 1987a). Applying this percentage to the number of dry cargo entrances, it is estimated that U.S. and foreign break-bulk ships enter U.S. ports 617 ($0.277 \times 0.561 \times 3{,}969$ entrances) and 6,819 ($0.277 \times 0.744 \times 33{,}087$ entrances) times annually. These entrances are seen in Table 10 to generate potentially close to 20,000 m^3 of waste lumber, 3,815 m^3 of cardboard, and 2,981 m^3 of plastic.

Commercial Passenger Vessels

The category of commercial passenger vessels encompasses all for-hire passenger-carrying vessels, including cruise ships, ferries and excursion vessels, and charter boats.

Cruise Ships

The cruise ship category includes domestic ships which operate exclusively within U.S. waters and foreign ships which sail from U.S. ports on international voyages. The Customs data base identifies approximately 80 foreign cruise ships which operate regularly out of U.S. ports. In 1986, these vessels recorded an estimated 3,324 entrances to U.S. ports (see Table 11). A high proportion of these entrances (45%) was recorded by vessels entering the Miami and Tampa port districts from the Bahama Islands. Other origin and destination combinations which account for large numbers of entrances include Canada/Alaska, Mexico/Los Angeles, Mexico/Miami, and Bermuda/New York. Puerto Rico and the Virgin Islands also receive numerous cruise ships, which arrive primarily from other Caribbean or South American ports.

Based upon the predominance of short-haul trips represented by these data, an average voyage duration of 1 day (24 h) is assumed for cruise

Table 9.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated merchant shipping (Eastern Research Group estimates) (GT = gross tons, MT = metric tons).

Merchant shipping	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b] (MT)	Total garbage per year[b] (m^3)
Foreign trade																	
U.S. vessels																	
Atlantic/Gulf/Pacific	7	25	165	2.0	330	2	196	2	22	1	90	50	16,425	NA	3,405	1,124	7,326
Noncontiguous/foreign	2	25	53	2.0	105	1	62	1	7	0	90	156	16,425	NA	399	42	273
Foreign vessels																	
Atlantic/Gulf/Pacific	7	25	173	2.0	345	2	205	2	23	1	90	48	16,425	NA	26,145	9,020	58,809
Noncontiguous/Great Lakes	2	25	60	2.0	120	1	71	1	8	1	90	137	16,425	NA	6,942	833	5,431
Noncontiguous trade (U.S.--domestic)	7	25	175	2.0	350	2	208	2	23	1	90	47	16,425	71	NA	1,166	7,603
Great Lakes (domestic and foreign trade)																	
1,000 GT and over	2	25	53	1.5	79	1	47	0	5	0	50	87	6,844	58	NA	397	2,588
Under 1,000 GT	2	25	53	1.5	79	1	47	0	5	0	50	87	6,844	7	NA	48	312
United States																	
Military Sealift charter	7	25	175	2.0	350	2	208	2	23	1	90	47	16,425	54	NA	887	5,783
Temporarily inactive vessels	7	25	175	2.0	350	2	208	2	23	1	90	47	16,425	7	NA	115	750
Coastal shipping																	
Ships																	
1,000 GT and over	5	25	125	1.5	188	1	111	1	13	1	90	66	12,319	103	NA	1,269	8,273
Under 1,000 GT	4	25	100	1.5	150	1	89	1	10	1	90	82	12,319	98	NA	1,207	7,871
Tow/tugboats																	
Large (inspected)	4	10	40	1.5	60	0	36	0	4	0	90	82	4,928	12	NA	59	386
Small	2	6	12	1.5	18	0	11	0	1	0	90	164	2,957	5,000	NA	14,783	96,380
Total garbage per year																30,949	201,785

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.

[b]Total garbage weight per year is equal to the product of either (1) per vessel annual garbage quantity and the vessel population, or (2) garbage quantity per voyage and the number of entrances.

[c]Refers to the percentage of days annually operating in U.S. waters.

Table 10.--Estimates of annual quantities of cargo waste (dunnage) currently dumped and quantities dumped under MARPOL Annex V (Eastern Research Group estimates).

Basis of estimate	U.S. vessels	Foreign vessels
Number of entrances to U.S. ports per year	3,969	33,087
Dry cargo as percentage of all entrances	56.1%	74.4%
Dry cargo entrances	2,227	24,617
General cargo as percentage of all dry cargo ships	27.7%	27.7%
General cargo entrances	617	6,819
Dunnage generated per clearance from U.S. port		
Lumber		
Quantity (m^3)	48.6	48.6
Percent of entrances	66.7%	66.7%
Cardboard		
Quantity (m^3)	23.6	23.6
Percent of entrances	33.3%	33.3%
Plastic		
Quantity (m^3)	0.12	0.12
Percent of entrances	10.0%	10.0%
Total dunnage quantities generated per year		
Lumber (m^3)	19,983.4	220,930.2
Cardboard (m^3)	130,979	130,979
Plastic (m^3)	7.20	7.20
Incidence of dumping	50.0%	50.0%
Total dunnage quantities dumped in U.S. waters per year		
Current practice		
Lumber (m^3)	9,991.7	110,465.1
Cardboard (m^3)	1,768,214	1,768,214
Plastic (m^3)	3.602	3.602
Under MARPOL Annex V		
Lumber (m^3)	9,991.7	110,465.1
Cardboard (m^3)	1,768,214	1,768,214
Plastic (m^3)	0.00	0.00

Table 11.--Cruise ships entering U.S. ports (Bureau of the Census 1987; Eastern Research Group estimates).

Vessel origin	U.S. port of entrance	Estimated number of entrances (1987)	Percent of total
Bahamas	Miami	1,232	37.1
Bahamas	Tampa	276	8.3
Canada (Pacific coast)	Anchorage	244	7.3
Mexico (Pacific coast)	Los Angeles	228	6.9
Mexico (Gulf coast)	Miami	168	5.1
Bermuda	New York	152	4.6
French West Indies	Virgin Islands	116	3.5
Leeward/Windward Islands	Virgin Islands	84	2.5
Netherlands Antilles	Virgin Islands	80	2.4
French West Indies	San Juan, Puerto Rico	72	2.2
Netherland Antilles	Miami	72	2.2
Haiti	Miami	56	1.7
Netherland Antilles	San Juan, Puerto Rico	56	1.7
Bahamas	San Juan, Puerto Rico	52	1.6
Haiti	San Juan, Puerto Rico	44	1.3
Jamaica	Miami	44	1.3
Dominican Republic	Virgin Islands	40	1.2
Dominican Republic	San Juan, Puerto Rico	32	1.0
Venezuela	San Juan, Puerto Rico	32	1.0
All other origins	All other destinations	244	7.3
Total		3,324	100.0

ships arriving in the United States. While examples of much longer voyages may be found within the data, short voyages are much more typical.

Foreign cruise ships entered U.S. ports with an average passenger complement of 786. Crew-to-passenger ratios are approximately 1:2 (J. Ruers, International Committee of Passenger Liners, pers. commun. 1988), hence an average of approximately 1,000 persons are assumed to be on board such ships.

Coast Guard data indicate that approximately two dozen U.S.-flagged vessels are used in domestic cruise operations (L. Stanton, Coast Guard, pers. commun. 1988). These include two large vessels of over 1,000 GT which operate in the Hawaiian interisland trade as well as several smaller vessels active on coastal routes along both the east and west coasts. Average time between ports is estimated at 1 day, as the vessels are usually in port each night. Such vessels are estimated to carry an average of 200 passengers and crew members (E. Scharfe, Director, Small Passenger Vessel Association, pers. commun. 1988) during typical cruises.

Other Passenger-Carrying Vessels

Additional categories of passenger-carrying vessels include ferries and charter fishing and pleasure vessels, of which there are a large number. In 1987, the Coast Guard's MSIS data base contained some 49 U.S.-flagged passenger vessels of 1,000 GT and over, and 4,774 vessels under 1,000 GT.

Among the larger passenger vessels, four are ocean-designated and include the two Hawaiian cruise ships discussed above as well as two converted hospital ships that are part of the MSC. These are covered in the merchant vessel data. Ten larger passenger vessels operate with river designations (e.g., Mississippi River cruises), while the remaining 34 are designated for operation in lakes, bays, and sounds. These vessels offer ferrying services and excursion or sightseeing cruises of short duration. Thus, a total of 44 additional large ferries and riverboats operate domestically. They are assumed to carry up to 1,000 passengers on voyages averaging 1 day in duration.

Approximately 75% of the 4,774 passenger-carrying vessels under 1,000 GT are charter fishing boats, with ferries, yachts, and other small boats accounting for the remaining 25% (Stanton pers. commun. 1988). Charter fishing boats are assumed to carry an average of 20 persons, while ferries and other commercial passenger vessels are assumed to carry 200 people. Voyage lengths of 1 day or less are assumed for all vessels in this category.

Large cruise ships generate substantial quantities of garbage even on overnight voyages. Table 12 indicates that 1,000 passengers on a luxury cruise will generate over 2 MT of garbage each day. Smaller ships carrying 200 passengers may generate close to 500 kg per day.

Commercial Fishing

United States Vessels

Fishing vessels may be classified according to whether they operate in onshore, offshore, or inland fisheries. Onshore fishing, defined as fishing which takes place within 12 nmi from shore, is conducted by smaller boats making primarily day-long trips. Data sources distinguish between fishing boats, which are under 5 net tons in size, and fishing vessels, which include all craft of 5 net tons or more (see Table 13).

Boats under 5 net tons generally do not exceed 7.6 m (25 ft) in length (T. Willis, Coast Guard Documentation Branch, pers. commun. 1988), and are not eligible for Coast Guard documentation. Normally, therefore, they do not operate at significant distances from shore. For convenience, all fishing boats (i.e., <5 net tons) are assumed to operate in the onshore fisheries. The NMFS estimates there to be approximately 105,500 boats active in the U.S. fisheries (NMFS 1987). These are assumed to carry an average of three crew members, and to return to port each night.

Table 12.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated commercial passenger vessels (Eastern Research Group estimates) (GT = gross tons, MT = metric tons).

Commercial passenger ships	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b]: (MT)	Total garbage per year[b]: (m^3)
Cruise ships																	
U.S. vessels																	
>1,000 GT	1	1,000	1,000	2.4	2,400	16	1,426	14	161	10	90	329	788,400	2	NA	1,577	10,281
Under 1,000 GT	1	200	200	2.4	480	3	285	3	32	2	90	329	157,680	24	NA	3,784	24,673
Foreign vessels	1	1,00	1,000	2.4	2,400	16	1,426	14	161	10	90	NA	NA	NA	3,324	7,978	52,013
Excursion vessels	1	200	200	2.4	480	2	285	3	32	2	90	329	157,680	1,194	NA	188,270	1,227,495
Charter boats	1	20	20	2.4	48	0	29	0	3	0	90	329	15,768	3,581	NA	56,465	368,148
Total garbage per year																258,074	1,682,608

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.
[b]Total garbage weight per year is equal to the product of either (1) per vessel annual garbage quantity and the vessel population, or (2) garbage quantity per voyage and the number of entrances.
[c]Refers to the percentage of days annually operating in U.S. waters.

Table 13.--Employment and craft in the U.S. commercial fisheries ([U.S.] National Marine Fisheries Service 1987).

Size	Number
Vessel >5 tons	24,300
Motor boats	104,000
Other boats	1,500
Total craft	129,800
Fishermen	238,800

While some larger craft also operate close to shore, fishing vessels (5 net tons and over) are assumed to operate beyond 12 nmi from shore. These vessels are capable of longer voyages, and are frequently equipped with sophisticated navigational and fish locating equipment. They also have greater onboard storage and processing capacity.

The NMFS estimates that in 1986 there were 24,300 fishing vessels of 5 net tons or more in the United States. While these may range up to 1,000 GT and over in size, relatively few are this large. Table 14 indicates that over 60% of fishing vessels are both smaller than 25 net tons in size, and <15.2 m (50 ft) in length.

Inland fishing covers commercial activity taking place on the inland waterways. At present, small commercial fisheries operate on the Great Lakes and along the Mississippi River (S. Koplin, NMFS, Statistics Branch, pers. commun. 1988), and account for only a small percentage of the national catch. States bordering the Great Lakes, for example, accounted for only 1.7% of the 1987 U.S. commercial catch (NMFS 1987). As boats active in the inland fisheries will be contained within the data presented above, the craft involved will be assumed to operate in a fashion similar to those in the saltwater fisheries. Assumptions regarding crew sizes and voyage lengths of fishing vessels are shown in Table 15, which derives the per voyage, per vessel, and aggregate annual garbage quantities.

Foreign Fishing Vessels

Foreign fishing vessels granted access to fishing stocks within the U.S. exclusive economic zone (EEZ) will also be expected to comply with MARPOL Annex V. While some restrictions on vessel discharges already apply, the requirements do not address specifically the problem of garbage dumping.

In the recent past, foreign fishing activity in U.S. waters has centered around the eastern Bering Sea and Aleutian Islands areas, where

Table 14.--Documented U.S. fishing vessels,[a] by length and gross tonnage (U.S. Coast Guard, Marine Safety Information System 20 April 1986; [U.S.] National Marine Fisheries Service 1987).

	Vessel length				
Gross tonnage	<15.2 m (<50 ft)	15.2-19.8 m (50-65 ft)	19.8-24.1 m (65-79 ft)	>24.1 m (>79 ft)	Total
Less than 25	14,703	112	2	2	14,815
25-49	2,774	1,152	33	--	3,959
50-99	340	1,511	1,107	45	3,003
100-199	18	117	1,418	674	2,227
200-299	--	--	--	69	69
300-399	--	--	--	32	32
400-499	--	--	--	49	49
500-599	--	--	--	45	45
600-699	--	--	--	15	15
700-799	--	--	--	10	10
800-899	--	--	--	10	10
900-999	--	--	--	23	23
1,000-1,999	--	--	--	34	34
2,000-2,999	--	--	--	2	2
3,000-3,999	--	--	--	2	2
4,000-4,999	--	--	--	2	2
More than 5,000	--	--	--	--	--
Total	17,835	2,891	2,560	1,015	24,300

[a]Vessels are defined as craft of 5 net tons or over.

the most significant target species has been Alaskan pollock. The country most active in this fishery is Japan. Other fisheries with considerable foreign participation include the Pacific whiting and Atlantic mackerel fisheries.

Direct access to U.S. fishing stocks by foreign vessels has been cut back considerably in recent years. At present, foreign access is obtained primarily through joint venture permits (J. Kelley, NMFS, Office of Fishery Conservation and Management, pers. commun. 1989). Under joint venture agreements, U.S. vessels deliver their catch to large foreign motherships or other factory trawlers, which process the fish at sea.

Data on the number of foreign fishing vessel permits issued in 1987, by type of vessel, flag of vessel, and fishery, were requested from the NMFS, but were not available in time for this report. In general, though, activity by foreign fishing vessels within U.S. waters has been decreasing in recent years with the "Americanization" of the U.S. EEZ. Direct fishing

Table 15.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated: commercial fishing (Eastern Research Group estimates) (GT = gross tons, MT = metric tons).

Commercial fishing	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b] (MT)	Total garbage per year[b] (m^3)
Undocumented	1	3	3	1.5	5	0	3	0	0	0	66	241	1,084	105,500	NA	114,367	745,660
Documented																	
5-25 GT	7	7	49	2.0	98	1	58	1	7	0	66	34	3,373	14,815	NA	49,965	325,766
25-300 GT	15	15	225	2.0	450	3	267	3	30	2	66	16	7,227	9,258	NA	66,908	436,229
300-1,000 GT	15	15	225	2.0	450	3	267	3	30	2	66	16	7,227	188	NA	1,359	8,858
Over 1,000 GT	30	30	900	2.0	1,800	12	1,069	11	121	8	66	8	14,454	40	NA	578	3,770
Foreign vessels[b]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0
Total garbage per year																233,177	1,520,282

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.

[b]Total garbage weight per year is equal to the product of either (1) per vessel annual garbage quantity and the vessel population, or (2) garbage quantity per voyage and the number of entrances.

[c]Refers to the percentage of days annually operating in U.S. waters.

by foreign vessels has been almost completely phased out, while joint ventures between U.S. catcher vessels and foreign processing vessels are declining. More and more, foreign access to U.S. fishery products will be in the form of exported products processed on U.S. soil. According to a report to the Alaska Department of Environmental Conservation, "it is generally assumed that there will be little, if any, joint venture activity in the North Pacific EEZ by 1991" (Pacific Associates 1988).

Garbage Generation Estimates

Domestic garbage.--Table 15 shows the derivation of the per voyage and annual domestic waste estimates. The largest ships may generate up to 1,800 kg of garbage overall per voyage. Of this amount, however, they would likely have to retain only the plastics. Small fishing boats are estimated to generate only 4.5 kg of total garbage per day at sea.

Commercial wastes.--As indicated, it is assumed that most fishing craft will generate an additional 0.028 m^3 (1.0 ft^3) of plastic gear waste per week (0.004 m^3 (0.14 ft^3) per day). Longliners and boats in the herring fisheries are assumed to generate twice this amount. Such vessels are assumed to represent 5% of all vessels in the 5-25 and 25-300 GT categories. Table 16 shows the estimated quantities of fishing wastes generated annually.

Recreational Boating

All recreational boats operating over the navigable waters of the United States are also required to comply with Annex V. Potentially, therefore, most of the approximately 14 million recreational boats in the United States might be included in an analysis of Annex V. For this study, we limit the analysis to numbered boats in coastal states or in states bordering the Great Lakes. Still, some 7.3 million recreational boats fit this criterion (see Table 17).

The majority of recreational boats are used on inland waters or, when used in the ocean, within 3 nmi from shore. When operating in these waters, boaters are prohibited from disposing of any garbage overboard. Beyond 3 nmi from shore, limited dumping may occur.

In order to identify those boats prohibited from any overboard disposal, several assumptions were made. First, only boats registered in coastal states are assumed to operate in the ocean. Secondly, only larger boats are assumed to operate beyond 3 nmi from shore. Within coastal and Great Lakes states, the size breakdown of the registered boating fleet is as follows:

- 56.3% are under 4.9 m (16 ft) long,
- 39.6% are between 4.9 and 7.9 m (16 and 26 ft) in length, and
- 3.7% are greater than 7.9 m (26 ft) in length (see Table 17).

Table 16.--Estimates of annual quantities of plastic fishing gear wastes generated in the U.S. fisheries (Eastern Research Group estimates) (GT = gross tons, MT = metric tons).

Vessel category	Number of vessels	Annual quantities of fishing waste generated: Vessels generating normal quantities[a] (MT)	Vessels generating normal quantities[a] (m^3)	Vessels generating additional quantities[b] (MT)	Vessels generating additional quantities[b] (m^3)
Undocumented	105,500	1,779	131,781	0	0
Documented					
5-25 GT	14,815	216	12,570	23	1,323
25-300 GT	9,258	135	7,855	14	827
300-1,000 GT	188	3	160	0	0
Over 1,000 GT	40	1	34	0	0
Foreign vessels	NA	NA	NA	NA	NA
Total	129,801	2,133	152,400	37	2,150

[a]Vessels using trawls, set nets, or pots. Plastic waste in these fisheries is essentially gear-related.

[b]Vessels active in bait fisheries (i.e., longlining) or herring fisheries which generate additional quantities of plastic waste in the form of bait wrappings or salt bags.

According to the Boat Owner's Association of the U.S. (BOATUS), recreational boats under 4.9 m (16 ft) in length "are most likely confined to inland lakes, rivers, and bays," and of those over 4.9 m (16 ft), only 10% are estimated to venture beyond 3 nmi from shore (Schwartz 1987). Based on this, approximately 219,000 boats are estimated to operate in areas where some overboard disposal of garbage is permitted. The remaining 13.1 million operate in areas where no garbage disposal may occur.

Garbage Generation

Voyage lengths and onboard complements for recreational boats of various sizes are shown in Table 18, which derives the per voyage and annual garbage quantities generated.

Offshore Oil and Gas Operations

Offshore oil and gas operations such as exploratory drilling, development drilling, and oil and gas production from offshore platforms are also covered by MARPOL Annex V. The restrictions which apply to such operations are different from those applicable to commercial and recreational vessels. Under Annex V, ocean disposal of all types of garbage, with the exception of ground food wastes, is prohibited. For operations located within 12 nmi from shore, even the disposal of ground food wastes is prohibited.

Table 17.--Recreational boats in coastal and Great Lakes states (U.S. Coast Guard 1987a).

Region	Class and size					
	Class A <4.9 m (<16 ft)	Class 1 4.9-7.9 m (16-26 ft)	Class 2 7.9-12.2 m (26-40 ft)	Class 3 12.2-19.8 m (40-65 ft)	Class 4 >19.8 m (>65 ft)	Total
Coastal states						
Number	2,548,709	1,955,105	212,458	22,754	1,806	4,740,832
Percent of total	53.8	41.2	4.5	0.5	0.0	100.0
Great Lakes states						
Number	1,540,340	916,301	55,846	4,540	232	2,517,259
Percent of total	60.7	37.2	1.9	0.3	0.0	100.0
Coastal and Great Lakes						
Number	4,089,049	2,871,406	268,304	27,294	2,038	7,258,091
Percent of total	56.3	39.6	3.7	0.4	0.0	100.0

Table 18.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated: recreational boats (Eastern Research Group estimates) (GT = gross tons, MT = metric tons).

Recreational boats	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b] (MT)	Total garbage per year[b] (m^3)
Coastal states																	
Under 4.9 m	1	4	4	1.0	4	0	2	0	0	0	6	22	88	2,548,709	NA	223,267	1,455,671
4.9-7.9 m	1	4	4	1.0	4	0	2	0	0	0	6	22	88	1,955,105	NA	171,267	1,116,640
7.9-12.2 m	1	4	4	1.0	4	0	2	0	0	0	6	22	88	212,458	NA	18,611	121,343
12.2-19.8 m	1	4	4	1.0	4	0	2	0	0	0	6	22	88	22,754	NA	1,993	12,996
Over 19.8 m	2	6	12	1.5	18	0	11	0	1	0	6	11	197	1,806	NA	356	2,321
Subtotal																415,495	2,708,971
Great Lakes states																	
Under 4.9 m	1	4	4	1.0	4	0	2	0	0	0	6	22	88	1,540,340	NA	134,934	879,751
4.9-7.9 m	1	4	4	1.0	4	0	2	0	0	0	6	22	88	916,301	NA	80,268	523,337
7.9-12.2 m	1	4	4	1.0	4	0	2	0	0	0	6	22	88	56,105	NA	4,915	32,044
12.2-19.8 m	1	4	4	1.0	4	0	2	0	0	0	6	22	88	4,540	NA	398	2,593
Over 19.8 m	2	6	12	1.5	18	0	11	0	1	0	6	11	97	232	NA	46	298
Subtotal																220,560	1,438,022
Total garbage per year																636,055	4,146,994

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.

[b]Total garbage weight per year is equal to the product of either (1) per vessel population, or (2) garbage quantity per voyage and the number of entrances.

[c]Refers to the percentage of days annually operating in U.S. waters.

Mobile Offshore Drilling Units

Data from the Department of the Interior's Minerals Management Service (MMS) for February 1988 showed there to be 124 mobile offshore drilling units (MODU's) active in U.S. Federal waters (L. M. Tracey, Department of the Interior, Minerals Management Services, pers. commun. 1988). All but one of these were reported to be operating beyond 12 nmi from shore. Approximately 78 MODU's were active in state waters (J. Dees, Ocean & Oil Weekly, Houston, TX, pers. commun. 1988). State waters extend out to 3 nmi from shore, except off Florida and Texas, where the state-federal boundary occurs at 3 leagues or approximately 10.35 nmi. All activity in state waters is subject to the complete ban on disposal within 12 nmi of shore, while MODU's in Federal waters would be able to dispose of ground food wastes. The MMS data indicate that MODU's in Federal waters have an average of 40 beds. This figure has been used as an estimate of the number of men aboard MODU's on a 24-h basis. Active MODU's are assumed to operate at 100% utilization.

Platforms

Approximately 3,500 production platform "complexes," consisting of one or more platforms in a single location, actively operate in U.S. Federal waters. Of these, however, only 779 are manned. A total of 124 manned platforms are situated within 12 nmi from shore, while the remaining 655 are located beyond 12 nmi. Dees (pers. commun. 1988) estimates that a maximum of 40 additional manned platforms are active in state waters.

The MMS data indicate that platform complexes have an average of 15 beds each.

Offshore Service Vessels

Service vessels employed in petroleum support activities are also covered by Annex V prohibitions. This category includes supply ships, tugs, anchor-handling vessels, crew ships, and research and survey vessels. Coast Guard data indicate that there are 484 offshore service vessels (OSV's) operating in the Federal Outer Continental Shelf region. Most crew and supply ships fall in the 50-200 dwt range. These are assumed to carry crews of five persons, and to make trips lasting an average of 1 day.

No data are available to indicate how many OSV's operate in state waters. Assuming the same ratio of structures (MODU's and platforms) to OSV's exists in state waters as in Federal waters, it is estimated that there are 63 additional OSV's active in state waters (484 + 903) × 118).

Garbage Generation

Garbage quantities for the offshore oil and gas sector are calculated in Table 19 on a per day, rather than a per voyage basis, since the structures are stationary and relatively permanent. Currently, all garbage with the exception of food wastes is required by the MMS to be transported to shore for disposal.

Table 19.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated: offshore oil and gas (Eastern Research Group estimates) (GT = gross tons, MT = metric tons).

Offshore oil and gas operations	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b] (MT)	Total garbage per year[b] (m^3)
Mobile offshore drilling units																	
Within 12 nmi	1	40	40	2.0	80	1	48	0	5	0	100	365	29,200	74	NA	2,161	14,088
Outside 12 nmi	1	40	40	2.0	80	1	48	0	5	0	100	365	29,200	123	NA	3,592	23,417
Offshore oil and gas production platforms																	
Within 12 nmi	1	15	15	2.0	30	0	18	0	2	0	100	365	10,950	655	NA	7,172	46,762
Outside 12 nmi	1	15	15	2.0	30	0	18	0	2	0	100	365	10,950	655	NA	7,172	46,762
Offshore service vessels	1	5	5	2.0	10	0	6	0	1	0	100	365	3,650	545	NA	1,989	12,970
Total garbage per year																16,710	108,945

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.
[b]Total garbage weight per year is equal to the product of either (1) per vessel population, or (2) garbage quantity per voyage and the number of entrances.
[c]Refers to the percentage of days annually operating in U.S. waters.

Research and Other Miscellaneous Vessels

Several categories of miscellaneous vessels have also been included in this analysis. These include vessels operated by universities and other oceanographic research institutions, maritime academy training ships, and various "industrial" vessels such as dredges and cable-laying ships.

Research Vessels

Numerous universities as well as private and nonprofit groups (e.g., Greenpeace, the Cousteau Foundation), operate oceanographic research vessels. The Coast Guard's MSIS data base indicates that in 1987 there were 26 vessels actively involved in oceanographic research (Coast Guard 1987b).

A 1978 profile of the world's oceanographic research fleet indicated that a typical research cruise might involve 20-25 crew members and 10-20 scientists (Trillo 1978; cited in Parker et al. 1987). These estimates were deemed appropriate by individuals connected with two major oceanographic research institutes, the Woods Hole Oceanographic Institute (J. Colburn, Woods Hole Oceanographic Institute, pers. commun. 1988) and the Scripps Institution of Oceanography (G. Schorr, Associate Director, Scripps Institution of Oceanography, La Jolla, CA, pers. commun. 1987).

School Training Vessels

Seven maritime academies in the United States operate a total of 14 ships used for training (Coast Guard 1987b). Seven of these are ocean-designated, six are authorized for coastwise travel, and one carries a Great Lakes designation. Only five of the vessels are greater than 1,000 GT in size.

Training ships of 1,000 GT or over are estimated to carry 150 men, while those under 1,000 GT are estimated to carry a crew of 50. Voyage lengths are estimated at 15 and 7 days, respectively. These estimates are based on discussions with officials at the Massachusetts Maritime Academy, who are familiar with the sizes and operations of vessels used at their and other maritime academies (D. Kan, Massachusetts Maritime Academy, Buzzard's Bay, MA, pers. commun. 1987).

Industrial Vessels

The category of industrial vessels comprises an assortment of vessel types including dredges, cable-laying ships, and drilling ships. Their common characteristic is that they carry crews who perform functions other than operating the vessel. The Coast Guard's MSIS data base indicates that in 1987 there were a total of 85 such vessels. Of these, 57 were greater than 1,000 GT, while 22 were under 1,000 GT. Furthermore, 69 were ocean-designated, while 17 were designated for coastal operation only.

While it is difficult to generalize about these vessels as a group, voyage lengths and crew complements on board have been approximated.

Oceangoing industrial vessels of 1,000 GT or over are estimated to carry an average of 30 persons on board and have voyage lengths averaging 15 days. Coastal vessels of 1,000 GT are also assumed to carry crews of 30 men, but are at sea for an average of 7 days. Both oceangoing and coastal vessels under 1,000 GT are estimated to carry 15 persons and to operate over 7-day voyages.

Garbage Generation

Domestic garbage.--Estimates of garbage generation in these sectors are shown in Table 20. School training ships and research vessels over 1,000 GT generate substantial quantities of garbage and plastics. Large research vessels, for example, may generate over 10 m^3 of plastics from domestic sources alone. This would be sufficient to fill an average commercial garbage dumpster.

Research vessel wastes.--The additional quantities of plastics associated with oceanographic research wastes are derived in Table 21.

U.S. Navy

Data from the Jane's Fighting Ships (1986) indicate that the U.S. Navy fleet currently numbers approximately 679 active vessels (see Table 22). Normal operational cycles for Navy vessels involve one 6-month tour of duty outside of U.S. waters every 18 months (D. Steigman, Jane's Publishing Co., pers. commun. 1988). Consequently, at any given time approximately one-third of the Navy fleet is operating outside of U.S. waters.

Crew complements on board Navy vessels range from 25 men up to as many as 5,000 on board the largest aircraft carriers. Where a range of crew sizes was reported, crew complements shown in Table 22 represent the average. Utilization factors while in U.S. waters range from 20 to 75%, depending on the vessel's strategic importance and its re-fit cycle (Mullenhard, pers. commun. 1988). Steigman (pers. commun. 1988) provided separate estimates of operating ratios for each class of Navy vessel, which are used to derive garbage quantity estimates for these ships while in U.S. waters.

Garbage Generation

Because of the large crew sizes and extended periods at sea, several categories of Navy ships are seen in Table 23 to generate extremely large quantities of wastes. Aircraft carriers with 5,000 men aboard, for example, could generate as much as 200 MT of garbage over a 20-day cruise. Several other categories of ships may generate 10 to 20 MT as well. Clearly, the Navy has particular garbage handling problems.

U.S. Coast Guard

The Coast Guard operates a large fleet of vessels, ranging from small harbor patrol boats to a pair of 121.9-m (400-ft) icebreakers. Table 24 provides a summary of the Coast Guard's fleet and indicates the number of

Table 20.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated: miscellaneous vessel categories (Eastern Research Group estimates) (GT = gross tons, MT = metric tons).

Miscellaneous vessels	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b] (MT)	Total garbage per year[b] (m^3)
School training																	
1,000 GT and over	15	150	2,250	2.0	4,500	29	2,673	26	302	19	35	9	38,325	5	NA	192	1,249
Under 1,000 GT																	
Ocean	7	50	350	2.0	700	5	416	4	47	3	35	18	12,775	2	NA	26	167
Coastal	7	50	350	1.5	525	3	312	3	35	2	35	18	9,581	5	NA	48	312
Industrial vessels																	
1,000 GT and over																	
Ocean	15	30	450	2.0	900	6	535	5	60	4	75	18	16,425	52	NA	854	5,569
Coastal	7	30	210	1.5	315	2	187	2	21	1	75	39	12,319	11	NA	136	883
Under 1,000 GT																	
Ocean	7	15	105	2.0	210	1	125	1	14	1	75	39	8,213	17	NA	140	910
Coastal	7	15	105	1.5	158	1	94	1	11	1	75	39	6,159	5	NA	31	201
Research vessels																	
Inspected																	
1,000 GT and over	25	50	1,250	2.0	2,500	16	1,485	15	168	10	35	5	12,775	2	NA	26	167
300-1,000 GT	15	50	750	1.5	1,125	7	668	7	75	5	35	9	9,581	15	NA	144	937
Uninspected																	
Under 300 GT	10	25	250	1.5	375	2	223	2	25	2	35	13	4,791	9	NA	43	281
Total garbage per year																1,637	10,676

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.
[b]Total garbage weight per year is equal to the product of either (1) per vessel population, or (2) garbage quantity per voyage and the number of entrances.
[c]Refers to the percentage of days annually operating in U.S. waters.

Table 21.--Estimates of annual quantities of additional plastic wastes generated by oceanographic research vessels (Eastern Research Group estimates) (GT = gross tons).

Vessel category	Number of vessels	Voyage length (days)	Voyages per year[a]	Additional waste per year (m^3)
Private vessels				
1,000 GT and over	2	25	5	1.17
300-1,000 GT	15	10	13	22.78
Under 300 GT	9	10	13	13.67
National Oceanic and Atmospheric Administration vessels				
Large deepwater vessels	4	25	5	2.34
Small coastal vessels	20	10	13	30.37
Total	50			70.32

[a]Annual vessel utilization of 35% is assumed.

vessels in each class, the crew complement, and typical voyage durations. This table is based upon discussions with Coast Guard operations personnel.

Coast Guard vessels are assumed to operate entirely within U.S. waters. Utilization factors for Coast Guard vessels are similar to those of Navy ships, and are assumed to average 50%.

Garbage Generation

Several categories of Coast Guard cutters as well as the large polar icebreakers are estimated to generate substantial quantities of garbage over representative voyages. The relevant quantities are shown in Table 25.

U.S. Army

The U.S. Army reports a fleet of approximately 580 crafts (G. Danish, U.S. Army, pers. commun. 1988). Of these, only a small number are "sea deployable." As shown in Table 26, these include four logistic support vessels approximately 91.4 m (300 ft) in length, 35 utility class landing craft capable of extended trips at sea, and 10 large oceangoing tugs.

The rest of the Army's fleet is made up of approximately 490 "ship-to-beach" craft of various types, used mainly for shuttling troops and supplies to and from larger vessels anchored offshore. In addition, the

Table 22.--U.S. Navy vessels by type and status (Jane's Fighting Ships 1986; Navy League of the United States 1987).

Vessel type	Active	Building/ reactivating conversion	Approximate onboard complement	[a]Estimated manpower total
Strategic missile submarines	38	5	150	5,700
Attack submarines	101	15	140	14,140
Aircraft carriers	13	3	5,000	65,000
Battleships	2	2	1,500	3,000
Cruisers	31	13	500	15,500
Destroyers	68	1	350	23,800
Frigates	100	4	300	30,000
Light forces	7	0	25	175
Light amphibious warfare ships	57	7	700-2,800	99,750
Mine warfare ships	3	6	70	210
Auxiliary ships	79	3	100-1,000	35,550
Military Sealift Command	72	18	25-120	5,220
Ready reserve force	73	0	40-1,200	45,260
Naval reserve	35	0	NA	NA
Total	679	77		343,305

[a]Where crew complements vary within a class, the arithmetic mean of the range is used. Total estimated complement is derived by dividing average complement by the number of active vessels.

Army maintains 15 small harbor tugs and about 25 small outboard motor-powered J boats.

These craft are used only intermittently during peacetime in logistics exercises. A utilization rate of 35% is assumed for all vessels.

Garbage Generation

The largest Army ships, the logistic support vessels, carrying 40 persons on board for up to 30 days, may generate close to 2 MT of garbage and 10 m^3 of plastics alone. Other vessel classes generate considerably smaller quantities of garbage.

National Oceanic and Atmospheric Administration Research Vessels

The NOAA operates a fleet of approximately two dozen vessels which are engaged in atmospheric and oceanographic research (B. Cunningham, Office of NOAA Corps, NOAA, pers. commun. 1988). These vessels range in size from 250 to 4,000 GT. Smaller vessels are estimated to carry approximately 10 persons on board, and to remain at sea for periods of approximately 1 week.

Table 23.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated: U.S. Navy vessels (Eastern Research Group estimates) (GT = gross tons, MT = metric tons).

U.S. Navy vessels	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b] (MT)	Total garbage per year[b] (m^3)
Strategic missile submarines	3	150	450	2.0	900	6	535	5	60	4	3	3	2,973	38	NA	113	737
Attack submarines	7	140	980	2.0	1,960	13	1,164	12	131	8	6	3	6,624	101	NA	669	4,362
Aircraft carriers	20	5,000	100,000	2.0	200,000	1,304	118,800	1,177	13,400	837	22	4	811,111	13	NA	10,544	68,748
Battleships	20	1,500	30,000	2.0	60,000	391	35,640	353	4,020	251	33	4	243,333	2	NA	487	3,173
Cruisers	20	500	10,000	2.0	20,000	130	11,880	118	1,340	84	22	4	81,111	31	NA	2,514	16,394
Destroyers	20	350	7,000	2.0	14,000	91	8,316	82	938	59	22	4	56,778	68	NA	3,861	25,172
Frigates	20	300	6,000	2.0	12,000	78	7,128	71	804	50	22	4	48,667	100	NA	4,867	31,730
Light forces	15	25	375	2.0	750	5	446	4	50	3	22	5	4,056	7	NA	28	185
Light amphibious warfare ships	5	1,750	8,750	2.0	17,500	114	10,395	103	1,173	73	22	16	283,889	57	NA	16,182	105,502
Mine warfare ships	15	70	1,050	2.0	2,100	14	1,247	12	141	9	22	5	11,356	3	NA	34	222
Auxiliary ships	15	500	7,500	2.0	15,000	98	8,910	88	1,005	63	22	5	81,111	79	NA	6,408	41,778
Military Sealift Command	15	75	1,125	2.0	2,250	15	1,337	13	151	9	22	5	12,167	72	NA	876	5,711
Ready reserve force	15	620	9,300	2.0	18,600	121	11,048	109	1,246	78	33	8	150,867	73	NA	11,013	71,805
Naval reserve	15	620	9,300	2.0	18,600	121	11,048	109	1,246	78	0	0	0	35	NA	0	0
Total garbage per year																57,596	375,520

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.
[b]Total garbage weight per year is equal to the product of either (1) per vessel population, or (2) garbage quantity per voyage and the number of entrances.
[c]Refers to the percentage of days annually operating in U.S. waters.

Table 24.--U.S. Coast Guard fleet by type and status (Jane's Fighting Ships 1986; Navy League of the United States 1987).

Vessel type	Active	Reserve	Under construction	Approximate complement
Cutters, high endurance	15	--	--	171
Cutters, medium endurance	34	--	7	82
Icebreakers	6	--	--	161
Icebreaking tugs	8	--	1	17
Surface effect craft	3	--	--	18
Large patrol craft	83	--	8	11
Training cutter	1	--	--	245
Buoy tenders, seagoing	28	--	--	53
Buoy tenders, coastal	12	--	--	20
Buoy tenders, inland	6	--	--	20
Buoy tenders, river	18	--	--	20
Construction tenders, inland	17	--	--	20
Harbor tugs, medium	4	--	--	10
Harbor tugs, small	14	--	--	10
Total	249	--	16	--

Larger vessels make voyages of up to 1 month and typically carry some 20 officers, 55 to 60 crewmen, and up to 30 scientists.

Approximately half of these vessels operate out of the NOAA base in Seattle, while the other half are stationed in Newport News. Other bases maintained by NOAA include Woods Hole, Miami, Pascagoula, and San Diego, as well as one each in Alaska and Hawaii.

Garbage Generation

The largest NOAA ships may generate as much as 4 MT of garbage over a typical 20-day voyage, and close to 20 m^3 of plastics from domestic sources alone, as shown in Table 27.

Wastes associated with the research activities of these ships are derived along with those of private research vessels in Table 21.

Other Government Vessels

Other Federal Government agencies such as the Customs Bureau and the U.S. Army Corps of Engineers, as well as numerous state and local government departments and agencies, may operate modest fleets of boats. No large craft, however, are estimated to be operated by agencies other than those discussed above. Smaller boats are included in the data presented in the section on recreational boats, but are not separately analyzed here.

Table 25.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated: U.S. Coast Guard vessels (Eastern Research Group estimates) (GT = gross tons, MT = metric tons).

U.S. Coast Guard vessels	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b] (MT)	Total garbage per year[b] (m^3)
Icebreakers																	
Polar class 121.9 m	90	140	12,600	2.0	25,200	164	14,969	148	1,688	105	50	2	51,100	2	NA	102	666
Mackinaw class 73.2 m	6	75	450	2.0	900	6	535	5	60	4	50	30	27,375	1	NA	27	178
Bay class 42.7 m	6	17	102	2.0	204	1	121	1	14	1	50	30	6,205	9	NA	56	364
High endurance cutters																	
115.2 m	60	156	9,360	2.0	18,720	122	11,120	110	1,254	78	50	3	56,940	12	NA	683	4,455
82.3 m	60	109	6,540	2.0	13,080	85	7,770	77	875	55	50	3	39,785	10	NA	398	2,594
Medium endurance cutters																	
64.0 m	30	71	2,130	2.0	4,260	28	2,530	25	285	18	50	6	25,915	16	NA	415	2,703
61.9-64.9 m	30	75	2,250	2.0	4,500	29	2,673	26	302	19	50	6	27,375	10	NA	274	1,785
Patrol boats																	
33.5 m	10	16	160	2.0	320	2	190	2	21	1	50	18	5,840	23	NA	134	876
29.0 m	3	13	39	1.5	59	0	35	0	4	0	50	61	3,559	15	NA	53	348
25.0 m	2	10	20	1.5	30	0	18	0	2	0	50	91	2,738	15	NA	41	268
Buoy tenders																	
Seagoing	5	50	250	1.5	375	2	223	2	25	2	50	37	13,688	27	NA	370	2,409
Coastal	4	32	128	1.5	192	1	114	1	13	1	50	46	8,760	12	NA	105	685
River	5	18	90	1.0	90	1	53	1	6	0	50	37	3,285	18	NA	59	386
Inland	3	14	42	1.0	42	0	25	0	3	0	50	61	2,555	6	NA	15	100
Construction	5	8	40	1.0	40	0	24	0	3	0	50	37	1,460	16	NA	23	152
Harbor tugs																	
Medium	1	4	4	1.0	4	0	2	0	0	0	50	183	730	4	NA	3	19
Small	1	4	4	1.0	4	0	2	0	0	0	50	183	730	2,120	NA	1,548	10,090
Search and rescue <19.8 m	1	4	4	1.0	4	0	2	0	0	0	50	183	730	2,120	NA	1,548	10,090
Total garbage per year																4,317	28,146

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.
[b]Total garbage weight per year is equal to the product of either (1) per vessel annual garbage quantity and the vessel population, or (2) garbage quantity per voyage and the number of entrances.
[c]Refers to the percentage of days annually operating in U.S. waters.

Table 26.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated: U.S. Army vessels (Eastern Research Group estimates) (GT = gross tons; MT = metric tons).

U.S. Army vessels	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b] (MT)	Total garbage per year[b] (m^3)
Logistic support vessels	30	40	1,200	2.0	2,400	16	1,426	14	161	10	35	4	10,220	4	NA	41	267
Landing craft, utility class 2000	20	10	200	2.0	400	3	238	2	27	2	35	6	2,555	35	NA	89	583
Large oceangoing tugs	20	8	160	2.0	320	2	190	2	21	1	35	6	2,044	10	NA	20	133
Other small landing craft	2	5	10	1.0	10	0	6	0	1	0	35	64	639	491	NA	314	2,045
Small harbor tugs	2	5	10	1.0	10	0	6	0	1	0	35	64	639	15	NA	10	62
J-boats	2	5	10	1.0	10	0	6	0	1	0	35	64	639	25	NA	16	104
Total garbage per year																490	3,194

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.
[b]Total garbage weight per year is equal to the product of either (1) per vessel annual garbage quantity and the vessel population, or (2) garbage quantity per voyage and the number of entrances.
[c]Refers to the percentage of days annually operating in U.S. waters.

Table 27.--Derivation of per voyage, per vessel, and annual domestic garbage quantities generated: National Oceanic and Atmospheric Administration (NOAA) research vessels (MT = metric tons, NA = not applicable). (Source: Eastern Research Group estimates.)

NOAA research vessels	Voyage length (days)	Crew size	Person days per voyage	Per capita generation rate (kg/day)	Domestic garbage generation per voyage[a]: Total garbage (kg)	Total garbage (m^3)	Dry garbage (kg)	Dry garbage (m^3)	Plastic garbage (kg)	Plastic garbage (m^3)	Annual ship utilization rate[c] (%)	Voyages per year	Garbage per year per vessel (kg)	No. of vessels	No. of entrances	Total garbage per year[b] (MT)	Total garbage per year[b] (m^3)
Large deepwater vessels	20	110	2,200	2.0	4,400	29	2,614	26	295	18	35%	6	28,105	10	NA	281	1,832
Coastal research vessels	5	10	50	2.0	100	1	59	1	7	0	35%	26	2,555	14	NA	36	233
Total garbage per year																317	2,066

[a]Dry garbage is calculated as 59.4% of total garbage by weight. Plastic garbage is 6.7% of dry garbage by weight. See Table 4.
[b]Total garbage weight per year is equal to the product of either (1) per vessel annual garbage quantity and the vessel population, or (2) garbage quantity per voyage and the number of entrances.
[c]Refers to the percentage of days annually operating in U.S. waters.

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APPENDIX

Detailed Garbage Generation Tables for 10 Maritime Sectors

(ERG estimates)

Appendix Table 1.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (GT = gross tons, MT = metric tons). Merchant shipping.

Merchant shipping	Total MT generated	Before MARPOL Annex V						After MARPOL Annex V*							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
		MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Foreign trade															
U.S. vessels															
Atlantic/Gulf/Pacific	1,124	0	0	56	733	1,067	13,919	46	1,459	0	0	323	4,212	754	3,523
Noncontiguous	42	0	0	2	27	40	519	2	54	0	0	12	157	28	131
Foreign vessels															
Atlantic/Gulf/Pacific	9,020	0	0	451	5,881	8,569	111,738	370	11,708	0	0	2,593	33,815	6,057	28,282
Noncontiguous/Great Lakes	833	0	0	42	543	791	10,319	34	1,081	0	0	239	3,123	559	2,612
Noncontiguous trade (U.S.)	1,166	0	0	58	760	1,108	14,446	55	1,705	0	0	224	2,927	886	4,139
Great Lakes vessels															
1,000 GT and over	397	298	970	99	1,294	0	0	7	3,014	93	147	99	1,294	198	927
Under 1,000 GT	48	36	117	12	156	0	0	1	364	11	18	12	156	24	112
Military Sealift charter (U.S.)	887	0	0	44	578	843	10,987	39	1,224	0	0	213	2,776	635	2,965
Temp. inactive vessels (U.S.)	115	0	0	6	75	109	1,424	5	159	0	0	28	360	82	384
Coastal shipping															
Ships															
1,000 GT and over	1,269	0	0	317	4,136	952	12,409	12	429	0	0	460	5,998	797	3,723
Under 1,000 GT	1,207	0	0	60	787	1,147	14,955	61	2,542	0	0	175	2,283	971	4,535
Tow/tugboats															
Large (inspected)	59	12	154	0	0	47	632	4	1,035	10	22	2	31	42	198
Small	14,783	2,957	38,552	0	0	11,826	157,955	990	286,579	2,623	6,068	0	0	11,169	52,154
Total	30,949	3,302	39,794	1,148	14,971	26,499	349,304	1,626	311,353	2,737	6,255	4,381	57,132	22,204	103,685

*Assumes full compliance with Annex V requirements.

Appendix Table 2.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (GT - gross tons, MT = metric tons). Commercial passenger ships.

Commercial passenger ships	Total MT generated	Before MARPOL Annex V						After MARPOL Annex V[a]							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
		MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Cruise ships															
U.S. vessels															
>1,000 GT	1,577	1,577	20,561	0	0	0	0	106	13,191	1,471	6,870	0	0	0	0
Under 1,000 GT	3,784	3,595	46,879	0	0	189	2,467	254	31,025	3,531	16,157	0	0	0	0
Foreign vessels	7,978	5,744	74,899	638	8,322	1,596	20,805	5,733	267,957	0	0	1,117	14,564	1,128	5,265
Excursion vessels	188,270	178,856	2,332,241	0	0	9,413	122,750	12,614	1,543,483	175,656	803,829	0	0	0	0
Charter boats	56,465	42,349	552,219	0	0	14,116	184,073	3,783	448,745	52,682	233,701	0	0	0	0
Total	58,0742	232,121	3,026,799	638	8,322	25,315	330,095	22,490	2,304,400	233,340	1,060,557	1,117	14,564	1,128	5,265

[a]Assumes full compliance with Annex V requirements.

Appendix Table 3.--Final disposition of vessel-generated gargage before and after MARPOL Annex V (annual quantities) (GT = gross tons, MT = metric tons). Commercial fishing.

		Before MARPOL Annex V						After MARPOL Annex V[a]							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
Commercial fishing	Total MT generated	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Undocumented	114,367	0	0	0	0	114,367	1,491,320	7,663	880,206	0	0	0	0	106,705	498,263
Documented															
5-25 GT	49,965	0	0	0	0	49,965	651,532	3,348	317,669	0	0	0	0	46,617	217,682
25-300 GT	66,908	0	0	0	0	66,908	872,457	4,259	151,124	0	0	3,345	43,623	59,304	276,921
300-1,000 GT	1,359	0	0	0	0	1,359	17,717	77	3,092	0	0	204	2,658	1,077	5,031
Over 1,000 GT	578	0	0	0	0	578	7,539	27	677	0	0	173	2,262	378	1,763
Foreign vessels[b]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total for sector	233,177	0	0	0	0	233,177	3,040,564	15,373	1,352,768	0	0	3,723	48,542	214,081	999,660

[a]Assumes full compliance with Annex V requirements.
[b]Data unavailable in time for this report. See Section 2.3 for discussion.

Appendix Table 4.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (MT = metric tons). Recreational boating.

Recreational boating	Total MT generated	Before MARPOL Annex V: Off-loaded in port		Before MARPOL Annex V: Incinerated at sea		Before MARPOL Annex V: Dumped overboard		After Annex V[a]: Off-loaded in port: Plastics		After Annex V[a]: Off-loaded in port: Other		After Annex V[a]: Incinerated at sea		After Annex V[a]: Dumped overboard	
		MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Coastal states															
Under 4.9 m	223,267	148,845	1,940,895	0	0	74,422	970,447	14,959	1,867,751	208,308	972,704	0	0	0	0
4.9-7.9 m	171,267	114,178	1,488,853	0	0	57,089	744,427	10,327	1,289,470	43,813	746,158	0	0	17,127	53,461
7.9-12.2 m	18,611	12,408	161,791	0	0	6,204	80,896	1,122	140,125	15,628	81,084	0	0	1,861	5,809
12.2-19.8 m	1,993	1,329	17,328	0	0	664	8,664	120	15,007	1,674	8,684	0	0	199	622
Over 19.8 m	356	237	3,094	0	0	119	1,547	19	2,219	269	1,509	0	0	68	211
Subtotal	415,495	276,996	3,611,961	0	0	138,498	1,805,981	26,548	3,314,573	369,692	1,810,140	0	0	19,255	60,103
Great Lakes states															
Under 4.9 m	134,934	89,956	1,173,001	0	0	44,978	586,500	8,137	1,015,916	113,304	587,865	0	0	13,493	42,119
4.9-7.9 m	80,268	53,512	697,782	0	0	26,756	348,891	4,840	604,337	67,401	349,703	0	0	8,027	25,055
7.9-12.2 m	4,915	3,277	42,725	0	0	1,638	21,363	296	37,004	4,127	21,412	0	0	491	1,534
12.2-19.8 m	398	265	3,457	0	0	133	1,729	24	2,994	334	1,733	0	0	40	124
Over 19.8 m	46	30	398	0	0	15	199	2	285	35	194	0	0	9	27
Subtotal	220,560	147,040	1,917,363	0	0	73,520	958,682	13,299	1,660,537	185,200	960,906	0	0	22,060	68,860
Total for sector	636,055	424,036	5,529,325	0	0	212,018	2,764,662	39,848	4,975,109	554,892	2,771,045	0	0	41,315	128,964

[a]Assumes full compliance with Annex V requirements.

Appendix Table 5.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (MT = metric tons). Offshore oil and gas operations.

Offshore oil and gas operations[b]	Total MT generated	Before MARPOL Annex V						After MARPOL Annex V[a]							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
		MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Mobile offshore drilling units (MODU's)															
- within 12 nmi	2,161	1,284	16,737	0	0	877	2,738	145	18,076	2,016	9,414	0	0	0	0
- outside 12 nmi	3,592	2,133	27,819	0	0	1,458	4,552	0	0	0	15,647	0	0	0	0
Offshore oil and gas production platforms															
- within 12 nmi	1,796	1,067	13,910	0	0	729	2,276	120	15,023	1,675	7,824	0	0	0	0
- outside 12 nmi	7,172	4,260	55,553	0	0	2,912	9,090	0	0	0	31,247	0	0	0	0
Offshore service vessels (OSV's)	1,989	1,989	25,939	0	0	0	0	133	16,641	1,856	8,667	0	0	0	0
Total for sector	16,710	10,733	139,958	0	0	5,977	18,656	398	49,740	5,547	72,799	0	0	0	0

[a]Assumes full compliance with Annex V requirements.
[b]The MODU's, platforms, and OSV's are assumed to currently off-load all dry garbage in accordance with MMS and EPA requirements, hence only food wastes are shown as being dumped.

Appendix Table 6.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (GT = gross tons, MT = metric tons). Miscellaneous vessels.

Miscellaneous vessels	Total MT generated	Before MARPOL Annex V						After MARPOL Annex V[a]							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
		MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
School training															
1,000 GT and over	192	0	0	0	0	192	2,499	9	224	0	0	57	750	125	584
Under 1,000 GT															
Ocean	26	0	0	0	0	26	333	1	51	0	0	5	67	19	89
Coastal	48	0	0	0	0	48	625	3	96	0	0	10	125	36	167
Industrial vessels															
1,000 GT and over															
Ocean	854	3	37	0	0	851	10,780	60	3,255	0	0	128	1,665	667	3,112
Coastal	136	0	6	0	0	135	1,710	10	516	0	0	20	264	106	494
Under 1,000 GT															
Ocean	140	0	6	0	0	139	1,762	10	625	0	0	14	181	116	541
Coastal	31	0	1	0	0	31	389	2	138	0	0	3	40	26	119
Research vessels															
Inspected															
1,000 GT and over	26	0	1	0	0	25	322	2	45	0	0	13	166	11	51
300-1,000 GT	144	0	6	0	0	143	1,814	10	324	0	0	43	560	91	423
Uninspected															
Under 300 GT	43	0	2	0	0	43	544	3	97	0	0	13	168	27	127
Total for sector	1,637	5	60	0	0	1,633	20,778	109	5,372	0	0	306	3,986	1,223	5,709

[a]Assumes full compliance with Annex V requirements.

Appendix Table 7.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (MT = metric tons). U.S. Navy.

U.S. Navy vessels	Total MT generated	Before MARPOL Annex V						After MARPOL Annex V*							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
		MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Strategic missile submarines	113	0	0	0	0	113	1,473	8	4,725	0	0	0	0	105	492
Attack submarines	669	0	0	0	0	669	8,724	45	27,984	0	0	0	0	624	2,915
Aircraft carriers	10,544	0	0	0	0	10,544	137,497	706	441,051	0	0	0	0	9,838	45,939
Battleships	487	0	0	0	0	487	6,346	33	20,356	0	0	0	0	454	2,120
Cruisers	2,514	0	0	0	0	2,514	32,788	168	105,174	0	0	0	0	2,346	10,955
Destroyers	3,861	0	0	0	0	3,861	50,345	259	161,492	0	0	0	0	3,602	16,821
Frigates	4,867	0	0	0	0	4,867	63,460	326	203,562	0	0	0	0	4,541	21,203
Light forces	28	0	0	0	0	28	370	2	1,187	0	0	0	0	26	124
Light amphibious warfare ships	16,182	0	0	0	0	16,182	211,005	1,084	676,843	0	0	0	0	15,097	70,498
Mine warfare ships	34	0	0	0	0	34	444	2	1,425	0	0	0	0	32	148
Auxiliary ships	6,408	0	0	0	0	6,408	83,556	429	268,023	0	0	0	0	5,978	27,917
Military Sealift Command	876	0	0	0	0	876	11,423	59	36,641	0	0	0	0	817	3,816
Ready reserve force	11,013	0	0	0	0	11,013	143,610	738	460,660	0	0	0	0	10,275	47,981
Naval reserve	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	57,596	0	0	0	0	57,596	751,040	3,859	2,409,124	0	0	0	0	53,737	250,929

*Assumes full compliance with Annex V requirements.

Appendix Table 8.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (MT = metric tons). U.S. Coast Guard.

U.S. Coast Guard vessels	Total MT generated	Before MARPOL Annex V						After MARPOL Annex V[a]							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
		MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Icebreakers															
Polar class 400 ft	102	0	0	0	0	102	319	7	4,275	0	0	0	0	95	298
Mackinaw class 240 ft	27	16	322	0	0	11	35	2	1,145	9	29	0	0	17	53
Bay class 140 ft	56	33	657	0	0	23	71	4	467	17	59	0	0	35	108
High endurance cutters															
378 ft	683	0	0	0	0	683	2,133	46	28,580	0	0	0	0	638	1,990
270 ft	398	0	0	0	0	398	1,242	27	16,641	0	0	0	0	371	1,159
Medium endurance cutters															
210 ft	415	0	0	0	0	415	1,294	28	17,343	0	0	0	0	387	1,208
203-213 ft	274	0	0	0	0	274	855	18	11,450	0	0	0	0	255	797
Patrol boats															
110 ft	134	80	1,581	0	0	55	170	9	5,618	42	143	0	0	83	260
95 ft	53	32	628	0	0	22	68	4	2,233	17	57	0	0	33	103
82 ft	41	24	483	0	0	17	52	3	1,718	13	44	0	0	25	79
Buoy tenders															
Seagoing	370	220	4,351	0	0	150	468	25	15,458	116	394	0	0	229	715
Coastal	105	62	1,238	0	0	43	133	7	4,397	33	112	0	0	65	203
River	59	35	696	0	0	24	75	4	2,473	19	63	0	0	37	114
Inland	15	9	180	0	0	6	19	1	641	5	16	0	0	10	30
Construction	23	14	275	0	0	9	30	2	977	7	25	0	0	14	45
Harbor tugs															
Medium	3	2	34	0	0	1	4	0	122	1	3	0	0	2	6
Small	10	6	120	0	0	4	13	1	427	3	11	0	0	6	20
Search and rescue boats <65 ft	1,548	919	18,219	0	0	628	1,961	104	12,947	484	1,648	0	0	959	2,995
Total	4,317	1,452	28,786	0	0	2,864	8,941	289	126,913	765	2,604	0	0	3,262	10,183

[a]Assumes full compliance with Annex V requirements.

Appendix Table 9.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (MT = metric tons). U.S. Army.

U.S. Army vessels	Total MT generated	Before MARPOL Annex V						After MARPOL Annex V[a]							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
		MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Logistic support vessels	41	0	0	0	0	41	533	3	1,710	0	0	0	0	17	52
Landing craft, utility class 2	89	0	0	0	0	89	1,166	6	3,740	0	0	0	0	36	113
Large oceangoing tugs	20	0	0	0	0	20	267	1	855	0	0	0	0	8	26
Other landing craft	314	0	0	0	0	314	4,090	21	2,624	0	0	0	0	127	397
Small harbor tugs	10	0	0	0	0	10	125	1	80	0	0	0	0	4	12
J-boats	16	0	0	0	0	16	208	1	134	0	0	0	0	6	20
Total	490	0	0	0	0	490	6,388	33	9,143	0	0	0	0	199	621

[a]Assumes full compliance with Annex V requirements.

Appendix Table 10.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (MT = metric tons). National Oceanic and Atmospheric Administration (NOAA) research vessels.

		Before MARPOL Annex V						After MARPOL Annex V[a]							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
NOAA research vessels	Total MT generated	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Large deepwater vessels	281	6	141	84	1,099	191	2,144	9	235	0	0	141	1,832	131	612
Coastal research vessels	36	1	24	4	47	31	319	2	96	0	0	7	93	27	125
Total	317	7	165	88	1,146	222	2,463	11	331	0	0	148	1,926	158	737

[a]Assumes full compliance with Annex V requirements.

Appendix Table 11.--Final disposition of vessel-generated garbage before and after MARPOL Annex V (annual quantities) (MT = metric tons). Summary table.

Sector	Total MT generated	Before MARPOL Annex V						After MARPOL Annex V[a]							
		Off-loaded in port		Incinerated at sea		Dumped overboard		Off-loaded in port				Incinerated at sea		Dumped overboard	
								Plastics		Other					
		MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3	MT	m^3
Merchant shipping	30,949	3,302	39,794	1,148	14,971	26,499	349,304	1,626	311,353	2,737	6,255	4,381	57,132	22,204	103,685
Commercial passenger ships	258,074	232,121	3,026,799	638	8,322	25,315	330,095	22,490	2,304,400	233,340	1,060,557	1,117	14,564	1,128	5,265
Commercial fishing	233,177	0	0	0	0	233,177	3,040,564	15,373	1,352,768	0	0	3,723	48,542	214,081	999,660
Recreational boating	636,055	424,036	5,529,325	0	0	212,018	2,764,662	39,848	4,975,109	554,892	2,771,045	0	0	41,315	128,964
Offshore oil and gas operations	16,710	10,733	139,958	0	0	5,977	18,656	398	49,740	5,547	72,799	0	0	0	0
Miscellaneous vessels	1,637	5	60	0	0	1,633	20,778	109	5,372	0	0	306	3,986	1,223	5,709
U.S. Navy	57,596	0	0	0	0	57,596	751,040	3,859	2,409,124	0	0	0	0	53,737	250,929
U.S. Coast Guard	4,317	1,452	28,786	0	0	2,864	8,941	289	126,913	765	2,604	0	0	3,262	10,183
U.S. Army	490	0	0	0	0	490	6,388	33	9,143	0	0	0	0	199	621
National Oceanic and Atmospheric Administration research vessels	317	7	165	88	1,146	222	2,463	11	331	0	0	148	1,926	158	737
Total	1,239,322	671,656	8,764,887	1,874	24,439	565,791	7,292,892	84,037	11,544,253	797,282	3,913,261	9,674	126,150	337,306	1,505,752

[a]Assumes full compliance with Annex V requirements.