Chapter Five

REEFING

Artificial reefs have been a part of man's history for all recorded time. About 2000 years ago, the ancient Greek geographer Strabo recorded that the ancient (to him) Persian kingdoms built reefs across the mouth of the Tigris River to obstruct the passage of marauding naval pirates from India, the Vikings of the time. Many ancient naval battles involved blockading harbors with artificial reefs. About 200 years before Strabo, the Roman historian Polybius recorded that the Romans built a reef across the mouth of the Carthaginian harbor of Lilybaeum in Sicily during the First Punic War to trap the powerful enemy ships within and assist in driving the Carthaginians from the island. In modern times, mines are usually used to blockade harbors, and artificial reefs are relegated to more-benign tasks.

The first documented artificial reef in the United States dates from 1830, when log huts were sunk off the coast of South Carolina to improve fishing. Since then, and until the latter part of the 20th century, most artificial reefs were built by ad hoc volunteer groups for the same reason—to improve fishing. Like the 1830 reef, 80 percent of the reefs constructed off U.S. coasts have used materials of opportunity: trees, rocks, shells, ships, barges, and in very recent years unwanted oil and gas recovery structures.[1] All such reef materials have had one common feature: they were free to the volunteers, or nearly so.

Only since the mid-1970s have engineered structures been used for artificial reefs, and even today they remain in the minority. Recent years have seen increased interest in using artificial reefs to replenish or replace depleted fishing grounds and to serve the relatively new activity of recreational scuba diving.[2] In a survey recently completed for this study, Atlantic and Gulf Coast state reef

---

[1]Gulf States Marine Fisheries Commission, "Guidelines for Marine Artificial Reef Materials," No. 38, January 1997.

[2]Ibid., p. 55.

authorities reported that over 846 vessels have been used for reefs during the past 25 years—and that there is near-term demand for hundreds more.[3]

There are impediments to reef building with ships in U.S. territorial waters, however, all of which involve issues of cost and the environment. The Atlantic States Marine Fisheries Commission (ASMFC) reports that the reasons so few large U.S. government ships have been deployed as reefs are (1) lack of funds to prepare the ships, (2) uncertainties on how to handle pollutants such as PCBs and asbestos, (3) the question of state liability for the reef, and (4) unclear MARAD rules regarding ship availability.[4] The report voices no concerns specifically about the use of Navy ships, because Navy ships have not heretofore been available for reefs (other than Navy nonwarships transferred to MARAD upon their retirement).

We begin the rest of this chapter by discussing the demand for artificial reefs. We then describe the impediments to reefing programs, estimate the costs such programs would entail, and discuss the economic benefits that derive from artificial reefs.

THE DEMAND FOR ARTIFICIAL REEFS

In 1994, the ASMFC reported that at least 666 steel-hulled vessels had been sunk for reefs since 1974. Forty-one of these ships were donated to the states by MARAD pursuant to Public Law 92-402 of 1974, "The Liberty Ship Act," which was amended in 1984 by PL 98-623 to include ships other than Liberty ships. Although MARAD's 41 ships only amounted to 6 percent of the total, they constituted almost all of the 44 large ships sunk—i.e., those over 300 feet long. Nearly half of the 666 ships were very small fishing boats or tugboats no more than 75 feet long. Average ship size, then, was small, but the vessels were of many different types, including Navy landing craft, barges, dry docks, and different kinds of merchant ships. [5]

Reefs continue to be built with ships from a variety of sources. Florida and other states use ships from private or public sources, including on occasion a local Navy command. There is current demand among Atlantic and Gulf Coast states for over 540 ships just to meet needs for improved fish resources.[6]

---

[3]This survey was conducted by Mel Bell, Department of Natural Resources, State of South Carolina, and Tom Maher, Florida's Division of Marine Fisheries, Summer 2000.

[4]Atlantic States Marine Fisheries Commission, "The Role of Vessels as Artificial Reef Material on the Atlantic and Gulf of Mexico Coasts of the United States," Special Report 38, December 1994, pp. 4 and 6.

[5]Ibid.

[6]Survey conducted by Mel Bell and Tom Maher, Summer 2000.

We broke the current demand for artificial reefs into three parts: demand for reefs for the promotion of marine life and commercial fish–related activities, demand for reefs for sport diving, and demand for reefs for other uses.

Artificial Reefs for Promotion of Marine Life and Fishing Purposes

Artificial reefs, whether from ships or other forms of solid materials, are generally accepted as beneficial to the increase of sea life in sandy or mud-bottom coastal areas. Ocean bottom areas that have no solid surfaces but have other features needed for life (such as proper salinity, light, and nutrition) are generally poor in marine life except for transiting species at certain times of the year. With an anchor for fixed life and the creation of a food chain, however, the reef becomes a full "habitat for fish and other aquatic organisms" that allows the many species appropriate to the locale to thrive.[7] The demand for reef materials depends on the state's specific coastal environment. All southern Atlantic states and Gulf Coast states have ocean bottoms off their coasts that are largely barren sand or mud and therefore have developed artificial reef programs in recent decades. To the contrary, northern Atlantic states—Massachusetts, for example—have ocean bottoms off their coasts that are already largely rock, so artificial reefs would add little to the habitat for sea life.

In addition to increasing and benefiting sea life, artificial reefs can be used for research on how habitat influences marine life and how to restore endangered or at-risk species. For example, we learned that the state of South Carolina would consider constructing a nursery and habitat for Atlantic grouper if sufficient ships were available at low cost. Atlantic grouper are apparently at risk because of over-fishing, and a large deepwater reef (at approximately 400 ft) is needed off the coast of South Carolina to rebuild their population. Such a reef could consume up to 100 large vessels.

Most artificial reefs are not deep water reefs, however. Most are placed in shallower water for convenient use by fishermen. The construction of artificial reefs for fishing purposes has long been managed by quasi-governmental marine fishery organizations. We interacted with two such groups: the Atlantic States Marine Fisheries Commission (ASMFC) and the Gulf States Marine Fisheries Commission (GSMFC). These two groups primarily represent the marine fishery interests for all states bordering the Atlantic and Gulf coasts. A representative from Florida serves on both commissions. While nominally focused on fisheries, these two organizations also consider the promotion of diving reefs to be within their responsibilities.

---

[7]Gulf States Marine Fisheries Commission, "Guidelines," p. 1.

Of all Atlantic and Gulf Coast states, Florida has been the most active in constructing fishing reefs. Florida is in many ways an ideal state for engaging in reef building. Its coastal waters are warm and shallow for many miles out toward sea. Large areas of its coastal ocean have barren sand and mud bottoms with a surface climate suitable for nearly year-round marine activities. Florida has over 300 existing reef sites employing over 400 metal vessels of all kinds and has permitted reefs to be built by state, county, and local governments as well as private organizations. Recently, private programs were suspended to secure better environmental control over reef building. Texas, South Carolina, and other coastal states also have active reef-building programs, but none is yet on the scale of Florida's.

At RAND's request, Mel Bell, of the state of South Carolina Department of Natural Resources and Tom Maher of the state of Florida's Division of Marine Fisheries conducted a brief survey of interest in artificial reefs along the Atlantic and Gulf coasts during the summer of 2000. Seven states responded; the results are presented in Table 5.1. As the table shows, there is a demand for more than 540 ships of all the sizes listed. These sizes correspond to the sizes of the 358 ships in the fleet awaiting disposal (see Appendix A). The existing reef system offers sites of adequate water depth for all ships. It even appears that ships as large as aircraft carriers would be welcome.

Because of the large demand for ship reefs off the Atlantic and Gulf coasts—a demand sufficient to consume the entire inactive ship inventory—we did not formally investigate the demand for ships off the West Coast or off the coasts of Hawaii or the Pacific Ocean territories.

Artificial Reefs for Sport Diving

The use of reefs for recreational diving is a modern development coinciding with the development of reliable scuba equipment shortly after World War II and the subsequent popularization of the sport of scuba diving. There are approximately 8.5 million certified scuba divers in the world, and the Professional Association of Diving Instructors (PADI) reports that their annual certifications, representing about 70 percent of all certifications, have been increasing by about 50,000 per year since the mid-1980s. The number of certifications translates into a continually increasing demand for interesting diving targets.[8] For example, ex-U.S. Coast Guard vessels *Bibb* and *Duane*, sunk off the Florida Keys, are important scuba diving targets. In July 2000, the San Diego Oceans Foundation (SDOF) sunk a Canadian destroyer escort, the ex-HMCS *Yukon*, off the coast near San Diego, California, as a recreational diving and fishing attrac-

[8]Gulf States Marine Fisheries Commission, "Guidelines," p. 55.

Table 5.1

Survey Results of Reefing Practices Among Atlantic and Gulf Coast States

	State							
	FL	MA	NY	NJ	SC	GA	TX	Total
Existing state program?	Y	Y	Y	Y	Y	Y	Y	
Existing county, municipal, or private reef program?	Y	N	N	N	N	N	N	
State oversight agency	F&W Con. Com.	Div. Mar. Fish.	Dep. Env. Con.	Div. of F&W	Dep. Nat. Res.	Dep. Nat. Res.	Parks & Wild-life	
State management plan?	Y	Draft	Y	Y	Y	Draft	Y	
State construction guidelines?	Y	Draft	Y	Y	Y	Y	Y	
Total number of existing per-mitted artificial reefs	>300	3	11	14	42	19	36	>422
Number <30 ft of water	18	1	2	-	12	0	0	33
Number 31–60 ft of water	17	2	4	4	19	14	8	68
Number 61–75 ft of water	30	0	4	5	4	3	1	47
Number 76–100 ft of water	32	0	1	3	5	0	4	45
Number >100 ft of water	42	0	0	2	2	2	23	71
Reasons for reefs								
Recreational fishing	Y	Y	Y	Y	Y	Y	Y	
Recreational diving	Y	N	Y	Y	Y	N	Y	
Habitat enrichment	Y	Y	N	Y	Y	Y	Y	
Commercial fishing	N	Y	Y	N	N	N	Y	
Fisheries stock enhancement	Y	N	N	Y	Y	Y	Y	
Other		Mitiga-tion			Exp.			
Use metal vessels including ships, barges, and boats in past?	Y	N	Y	Y	Y	Y	Y	
Total no. of metal vessels in existing reefs	>400	0	65	100	230	33	18	>846
Ships <200 ft	112	0	0	7	166	1	0	286
Ships >200 ft	58	0	0	10	7	2	13	90
Ships of unknown length	15	0	0	0	0	0	0	15
Are metal vessels presently used?	Y	N	Y	Y	Y	Y	Y	
Would state use surplus ships in the future?	Y	Y	Y	Y	Y	Y	Y	
55–100 ft	Y	Y	Y	Y	Y	Y	Y	
101–200 ft	Y	Y	Y	Y	Y	Y	Y	
201–300 ft	Y	N	Y	Y	Y	Y	Y	
301–400 ft	Y	N	Y	Y	Y	Y	Y	
>400 ft	Y	N	Y	Y	Y	Y	Perhaps	
How many total?[a]	113	<12	15	>100	>100	>100	>100	>540
Limit on per-ship cost to state								
<$50K	Y	Y	Y	Y	Y	Y	Y	
$50–$100K	Y	N	N	Y	N	N	Y	
$100–$150K	N	N	N	N	N	N	Perhaps	
$150–$200K	N	N	N	N	N	N	N	
$200–$250K	N	N	N	N	N	N	N	
>$250K	N	N	N	N	N	N	N	
Minimum vertical profile of candidate ships	None	20 ft	None	5	None	None	20	
Maximum vertical profile of candidate ships	None	60 ft	35[b]	80	50[b]	70[b]	60	

[a]These states reported that they could use an unlimited number of ships. We entered >100.

[b]These states would create deeper sites if larger ships were available.

tion. By all reports, it was an instant success, swamping the diving and fishing businesses in the city during subsequent months. The Artificial Reef Society of British Columbia (ARSBC) has sunk five ships, including three sister ships of the *Yukon*, for the same purposes in different areas off the coast of British Columbia, Canada. The Lake Ontario Scuba Association is negotiating with the Canadian government to acquire the HMCS *Nipigon*, a frigate about the same size as the *Yukon*, which it wants to sink in Lake Ontario as a diving attraction. The government of Australia donated the ex-HMAS *Swan*, a destroyer escort, to the government of Western Australia for construction of a diving reef in 1997. A similar project involving the ex-HMAS *Hobart*, an ex-USS *Charles F. Adams* Class destroyer, is in progress off southern Australia. Diving vacation sites involving ships—whether they are wrecks or intentional for man-made reefs—are promoted in most if not all coastal nations.

There are no projections available on the demand for additional diving resources. However, literally hundreds of "dive center" businesses are situated along the U.S. coasts (and inland as well, for diving in lakes, rivers, and ponds) and diving proponents are actively seeking more ships. The sponsor of the *Yukon* project off California (discussed above) wants five additional ships at the site. A project involving the ex-USS *Speigel Grove* for reefing off Key Largo, Florida, has been in progress for many years. A new dive project managed by Artificial Reefs for the Keys (ARK) is working toward reefing the ex-USS *Gen Hoyte S. Vandenberg* off Key West. This project plans to include features and hardware for distance learning so that marine science can be taught throughout the United States.

During public hearings held in preparation for the Navy's ongoing Ship Disposal Project (SDP), the comments were overwhelmingly in favor of using inactive ships to build reefs. Of the 118 public respondents, 91 urged that the ships be used for reefs instead of being recycled. (Only two of the remaining 27 respondents expressed opposition to reefs, and the balance expressed no opinion on reefs.) Most of the diving individuals and groups that we contacted emphasized that divers are especially interested in warships with guns or gunlike structures as dive targets.[9]

Other Uses

There are many other potential uses for artificial reefs. We have already mentioned the Atlantic grouper nursery suggested by South Carolina. Also as already mentioned, ARK is proposing to use the *Vandenberg* reef for educational

---

[9] The *Yukon* was fitted with gun-barrel-like metal pipes to replace the original gun barrels before being sunk.

purposes. There are more. Some people have suggested using artificial reefs to grow specific forms of marine life for cancer research. Others suggest that ships be used as artificial reefs to prevent the loss of beaches, to relieve diving and fishing pressures on natural reefs, and to serve as underwater memorials to those who served aboard them.

Adequacy of Demand for Artificial Reefs

The demand for reefs off U.S. coasts was emphasized in a 1996 GSMFC resolution in which it was found that "the demand for ships and ship hulls for artificial reef applications far exceeds the supply." Noting the potential availability of unneeded Navy and MARAD ships, the GSMFC resolved that the "Commission strongly encourages the Department of the Navy to develop a mechanism to identify appropriate decommissioned Navy vessels and ships and to make those vessels and ships available . . . to State artificial reef programs for application as artificial reefs."[10]

The demand for fishery reefs alone is more than 540 vessels, and the demand for diving reefs and for other purposes will increase this number. We thus conclude that the demand for ships for use as artificial reefs—whether it be to provide habitat for marine life, to promote sport or commercial fishing, to provide sites for sport diving, or to do all these activities and more—is more than adequate to consume all 358 ships in the Navy and MARAD inactive fleets.

IMPEDIMENTS TO REEFING PROGRAMS

The impediments to building reefs with ships stem from environmental standards and the costs associated with preparing ships to those standards. Two of the reasons the ASMFC reported for why few MARAD ships have been deployed as reefs in accordance with the Liberty ship program were (1) lack of funds to prepare the ships and (2) uncertainties on how to handle pollutants such as PCBs and asbestos.[11] These issues remain to this day.

Additional impediments may ultimately arise from factions within the environmental community should a Navy-MARAD reefing program be initiated. We are aware of some concerns that artificial reefs are "killing zones" for fish and that they just attract fish from elsewhere rather than creating more fish. Arguments of this nature do not have credence within the coastal marine fishery or-

[10]Quotation from Chris Nelson, Chairman, in Gulf States Marine Fisheries Commission, "Resolution on the Use of Retired Navy Ships and Artificial Reef Materials," October 17, 1996.

[11]Atlantic States Marine Fisheries Commission, "The Role of Vessels," pp. 4 and 6.

ganizations we consulted, but they could certainly come up during a more visible Navy-MARAD reefing program.

State and Federal Standards

Given the continuing reefing activity along many state shores, we assume that each state has adequate rules for matters under its cognizance. There are, however, no uniform federal standards for areas under federal cognizance. The standards employed for any specific reefing project are usually generated by the organization responsible for the project in consultation with local and regional state and federal environmental and/or coastal zone regulators. For example, the *Yukon* project used Canadian standards amended by requirements from California state authorities. The standards invoked by South Carolina are expressed in two sentences requiring artificial reef materials to be "free of all oils, hydraulic fluids, fuels refrigerants and [anything else] that might be harmful to the marine environment and free of floating debris."[12] Implementation details of the "free of all" requirement are left to the specific project.

Significantly lacking are standards specific to the remediation of the solid nonmetallic materials containing PCBs that were first found in 1989 in Navy ships and subsequently found in all manner of ships. This area of environmental law is primarily a Federal responsibility. The GSMFC has issued advisory guidelines in their 1997 report and called on the EPA to expressly address the PCB question so that the unfettered use of ships might continue.[13] The Navy, in concert with the EPA, is sampling for the presence of environmental pollutants in the vicinity of sunken ships in both deep and shallow waters and is conducting laboratory studies of PCB behavior in seawater. The Navy is also conducting an environmental risk assessment regarding PCBs in the marine environment. This work may lead to uniform rules. Until it does, each reef-building project must confront the issue independently and employ standards acceptable to the local authorities at the current time.

U.S. Coast Guard Standards

The U.S. Coast Guard (USCG) has overcome these difficulties by developing, in concert with New Jersey and Maryland authorities, its own standards for the

---

[12]South Carolina Department of Natural Resources, "South Carolina Marine Artificial Reef Management Plan," Section 9.2.3, 1991.

[13]Gulf States Marine Fisheries Commission, "Guidelines." The GSFMC also advised its member states to continue using ships as reefs in accord with state standards pending EPA action. Note that the GSFMC apparently has no authority to issue binding environmental standards for use of ships as reefs.

conduct of its ships-to-reefs program. The ships in the program are small, the largest to date being a buoy tender with a displacement of less than 1,000 tons. Vessels are prepared at the USCG Baltimore, Maryland, shipyard and subsequently donated to New Jersey and Maryland for construction of reefs. The yard developed a cleaning protocol it believes conforms to reasonable requirements, but the USCG advised us that no other national agency has passed judgment on its actions. The USCG plans to clean and provide up to 70 vessels for reefs over the next few years, which is essentially all of its unneeded ships that cannot be sold or donated for continued use elsewhere.[14] The standards being employed by the USCG are summarized in the following sections.

PCB Removal. The USCG yard removes all material contaminated with PCBs above 50 ppm. This includes felt gasket and faying material, electric power cables, paints, rubber gaskets, and other materials. The yard has developed several eyeball tests for materials based on the results of about 2,000 analyses of samples performed over the past 2 years. The eyeball tests include

1. Remove and dispose of (as PCB waste) electric power and signal cables dating from 1980 and earlier; retain all cables dating from 1984; and test all cable dating from 1980 to 1984 if the amount warrants, otherwise remove.
2. Remove and dispose of all potential PCB-felt products, including joinerwork bulkheads assembled with felt, faying materials between engine mounts and the ship's hull, faying material between deckhouse and hull, and others.
3. Remove and dispose of plastic foam hull insulation and fiberglass insulation located close to felt joinerwork materials. (Fiberglass insulation is thought to be contaminated by migration of PCBs in the PCB-felt in contact with joinerwork panels.)
4. Leave plastic gaskets in place if there is reason to believe they were new in 1985 or later. Thus, for example, door gaskets, which are replaced annually on vessels in service, are left in place—provided the ship was operational after 1984 (and all have been so far).

Water blasting is the primary tool for removal of PCB surface contamination, which occurs largely in PCB-laden felt. The acceptance criterion is the same as in federal regulations regarding spills of liquid PCBs (49 CFR 761): less than 10 micrograms per 100 cm^2. The yard finds that water blasting is effective for removal of felt-contaminated paints and surface residues and permits the solid residues to be easily filtered out. The water used in blasting is disposed of as ordinary industrial effluent.

[14]Personal interview with Cohen and Petagno, USCG Shipyard, Baltimore, MD, by Hess and Rushworth, RAND and MSCL, Inc., January 13, 2000.

The yard has not found PCBs in paints, oils, hydraulic fluids, and greases used in USCG vessels, although with the exception of paints, most of these materials are removed as oils.

All electronic systems—whether or not they contain PCBs—are removed, primarily for continued use. The USCG uses the same radars and communications and navigation equipment in many classes of vessels, so equipment removed from one can be used in others.

Asbestos Removal. The yard removes all asbestos-containing products. The usual approach is to remove the entire part or component that has asbestos on or in it and dispose of that part or component in a landfill as asbestos waste. The yard has found this approach to be less expensive than attempting to remove asbestos and leave the part/component behind. All vessels prepared for reefing to date have been diesel powered, which means they will have little propulsion system thermal insulation compared to steam-powered vessels.

Many USCG vessels use "Marinite" joinerwork bulkheads throughout. Older Marinite that contained asbestos is removed; newer, asbestos-free Marinite is left in place. Note that Marinite is common in MARAD ships but that the Navy has seldom used it (because it is brittle and will not withstand shock).

Removal of Oil, Weapons, and Debris. Fuels and lubricants are removed and the tanks flushed. Engines are removed either for reuse or to assure that all oil is removed before reefing. The yard has found that it is less expensive to remove and dispose of the engines than to try to clean the oil from them. The USCG is very sensitive to the possibility of an oil slick following a reefing and thus is very careful to ensure that all oil is removed from every tank, component, part, and all nooks and crannies.

The yard removes all weapons from ships. It also removes all loose debris and broom-sweeps all decks and bilges clean.

The resulting hulks are virtually stripped of everything. Two photographs of the buoy tender, USCG *Red Beach*, which was being converted for reefing early in 2000, are shown in Figures 5.1 and 5.2. The engine room shown had not yet had all of its debris removed.

Note that the USCG standards do not explicitly include actions to make ships safe for divers. However, ships are essentially made safe for divers by having their machinery, cables, and nearly everything else except bulkheads and overheads removed before they are sunk.

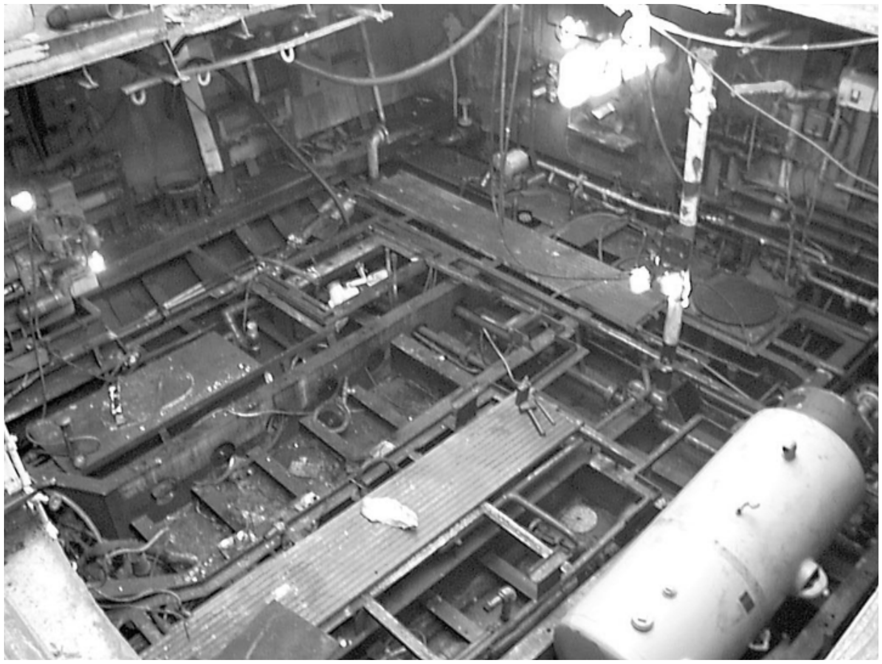

Figure 5.1—*Red Beach* Engine Room Stripped of Machinery and Ready for Final Cleaning

Figure 5.2—*Red Beach* Bulkhead Stripped of Joinerwork and Water Blasted

Canadian Standards

Canadian organizations have prepared and sunk several ships for reefs during the past decade. To support Canadian programs, Environment Canada, the equivalent of the U.S. EPA, has developed rules for preparation of ships.[15] The rules and their draft predecessors were used to prepare the Canadian ships HMCS *Columbia*, *Saskatchewan*, and *Mackenzie*, naval frigates all roughly 2,300 tons in displacement. The Environment Canada rules were also used for the *Yukon* project, although we were informed that the Southern California Water Resources Board required additional cleaning of oil residues from the ship's machinery. The Canadian rules are comparable to the USCG practice with the following exceptions:

1. PCB-containing components must be removed, but PCB-bearing paint, plastics, and rubber may remain in place. (California authorities allowed such materials to remain in place in the *Yukon*.)
2. Intact, undisturbed asbestos insulation need not be removed, but any loose or unsealed asbestos must be sealed or removed to protect workers.
3. Machinery need not be removed if it is cleaned so as to be visually free of oil.

Navy SINKEX Standards

The Navy occasionally uses unneeded ships as targets for military exercises termed *sinking exercises*, or *SINKEX*. The Navy holds general permit for this activity from the EPA. Among the requirements is that ships be sunk in 6,000 feet or more of water and that they be cleaned to Navy SINKEX standards, which require removal of oils and greases, PCB-containing electrical and electronic equipment, and other "readily removable" PCB-containing equipment. As is appropriate for deep-sea sinking, the standards are less restrictive than the Environment Canada standards for shallow-water reef building.

THE COST OF A DOMESTIC REEFING PROGRAM

Funding for reef building has always been tight. Among the six states discussed in the 1994 ASMFC report, the average annual expenditure for preparing ships was only $25,000, of which 8 percent was state funding, 13 percent federal funding (from the Federal Aid in Sportfish Restoration Program), and the bal-

[15]Environment Canada, "Cleanup Guideline for Ocean Disposal of Vessels" and "Cleanup Standard for Ocean Disposal of Vessels," Pacific and Yukon Region, February 1998.

ance came from private or unknown sources.[16] Six states reported building reefs with ships without spending any state money. The information presented earlier in Table 5.2 suggests that at least some states would be willing to spend as much as $100,000 to prepare a ship for reefing. This amount is significantly more than the $25,000, but it is also significantly less than the full cost of such a program for anything other than the smallest vessels, as is discussed below. Clearly, cost is the weak point in many reefing programs.

Notionally at least, a reefing program should have cost elements comparable to those of the domestic recycling program discussed in Chapter Three—i.e., the cost to prepare the ship for use as a reef, the cost for tow preparation and towing, the cost of storage of ships awaiting reefing, and revenue from the sale of materials removed from the ship for reefing. During our search for information on reefing matters, we could find no consistent information on revenues from the sale of materials removed from ships to be reefed. Information from commercial and nonprofit organizations shows such revenues as an important source of funds for supplementing these organizations' usually meager budgets, but the USCG reported no revenues for their program. As a consequence, we have omitted such revenues from our overall program cost estimate.

Estimating the Cost of Preparing Ships for Reefing

The USCG provided us with return and budgeted costs for preparing 16 types of vessels in accordance with its standards. These costs are for all work at the shipyard, including local towing and docking, preparation work, and all incidental overhead items. They do not include the cost to tow the vessel to the sinking site. The vessels have all been small, ranging from 44-foot motor lifeboats displacing 13 tons to 180-foot buoy tenders displacing 935 tons. The incentive for this program is strictly cost: the USCG says it is much less expensive to clean a ship for reefing than to recycle it.

Both the SDOF, which sponsored the *Yukon* project, and the ARSBC, which sponsored the sinking of the *Yukon*'s three sister ships, also provided us with cost information for preparation of their ships.[17] The costs reported by these organizations are for storage at the preparation site, towing, preparation work, insurance, and other elements of doing business. In addition to being environmentally cleaned, these ships were prepared to be "safe for divers" according to standards set by the local diving groups involved in the project. Making

---

[16] Atlantic States Marine Fisheries Commission, "The Role of Vessels."

[17] San Diego Oceans Foundation letter dated October 11, 2000, to Denis Rushworth, MSCL, Inc.; and Artificial Reef Society of British Columbia letter of September 27, 2000, to Denis Rushworth, MSCL, Inc.

these ships “safe for divers” meant such things as opening large holes in the hull’s side and top to provide divers free access to the ship’s interior, sealing off via welding or filling with concrete all areas that could not be made safe, and removing cables from the deck overheads to prevent them from falling on divers when the cable trays ultimately fail. To achieve a uniform cost comparison across all options, we made some adjustments to the cost data provided. The ARSBC costs included 75 man-months of donated labor per ship. We converted these donations to costs at the rate of $45 per hour. The SDOF costs included promotional costs, which while essential for the program (because it was not government supported), were not truly costs for ship preparation. We struck these. We also struck towing costs because they are accounted for separately in our final cost estimate figures, and we struck all revenues from sales.

The National Steel and Shipbuilding Company (NASSCO) provided us with return costs from prior ship preparation programs and an estimate for the environmental preparation of CG16, CG26, and DDG 2 Class ships, not including diver-safe preparations. These ships are all roughly 5,000 tons light ship weight. The NASSCO estimate focuses on removing oils and lubricants from the ships, cleaning bilges, and removing oil-containing piping. It does not include costs for removing electric and electronic PCB-bearing equipment, electric cables, and asbestos or for the other items subject to the Canadian standards, nor does it include costs for towing the ships to the yard for preparation work or to the sinking site. Finally, the SDOF provided us with a rough order-of-magnitude cost estimate (with a high- and a low-cost boundary) for non-diver-safe preparation of ships according to the Canadian standards that the Foundation had received from a consortium of San Diego shipyard representatives.[18]

Table 5.2 presents the cost information from the different organizations, and Figure 5.3 presents the same information as a graph. The figure reflects all of the data and estimates but does not discriminate between diver-safe projects, such as *Yukon*, and non-diver-safe projects because there was not enough fine structure in the data to permit this. As can be seen, the data fall on a tightly clustered line. Note that the low data point, at about 5,000 tons, is the NASSCO estimate, which includes the cost for environmental preparation and focused on oil removal. The other data represent more-comprehensive environmental preparations and in many cases include diver-safe preparation. Using the equation in Figure 5.3, one sees that preparation of a 5,000-ton ship would cost about $1.0 million (substantially higher than NASSCO’s estimate of $0.6 million) whereas preparation of a 15,000-ton ship would cost about $1.7 million.

---

[18]Estimate provided by Dick Long of SDOF in interview by Hynes (RAND) and Rushworth (MSCL, Inc.), Summer 2000.

Table 5.2

Costs to Prepare Ships for Reefing

Vessel	Cleanup Standards	LSW Tons	Preparation Cost Minus Ship Purchase (US$)	US$/ LSW Ton	Reefing Date	Source
USCG 55’ ANB	USCG	22	82,500	3,750	NR	USCG
USCG 44’ MLB	USCG	13	46,000	3,538	NR	USCG
USCG 82’ WPB	USCG	55	120,000	2,182	NR	USCG
USCG 65’ WLI	USCG	54	97,500	1,806	NR	USCG
USCG 65’ WYTL	USCG	57	97,500	1,711	NR	USCG
USCG 100’ WLI	USCG	141	150,000	1,064	NR	USCG
USCG 100’ WLIC	USCG	141	150,000	1,064	NR	USCG
USCG 75’ WLR	USCG	111	112,500	1,014	NR	USCG
USCG 115’ WLR	USCG	230	230,000	10,000	NR	USCG
USCG 75’ ANVIL	USCG	114	112,500	987	NR	USCG
USCG 75’ WLIC	USCG	114	112,500	987	NR	USCG
USCG 65’ WLR	USCG	103	97,500	947	NR	USCG
USCG 157’ WLM	USCG	471	340,000	722	NR	USCG
USCG 133’ WLM	USCG	435	266,000	611	NR	USCG
USCG 180’ WLB	USCG	935	500,000	535	NR	USCG
USCG 180’ WIX	USCG	935	500,000	535	NR	USCG
HMCS *Columbia*	Canadian	2,390	241,662	338	1996	ARSBC
HMCS *Saskatchewan*	Canadian	2,380	223,496	331	1997	ARSBC
HMCS *Mackenzie*	Canadian	2,380	148,665	299	1995	ARSBC
HMCS *Yukon* environment and diver safe	Canadian	2,380	799,136	336	2000	SDOF
2300-ton frigate, U.S. yard estimate, environment and diver safe, low	Canadian	2,300	500,000	217	N/A	San Diego Consortium
2300-ton frigate, U.S. yard estimate, environment and diver safe, high boundary	Canadian	2,300	700,000	304	N/A	San Diego Consortium
CG16, CG26, DDG2 average ship, environment but not diver safe	NASSCO	5,050	579,051	115	N/A	NASSCO ROM
Project *Vandenberg* low, environment safe, diver safe	Local	14,300	1,700,000	119	NR	Jeff Dey, ARK
Project *Vandenberg* high, environment and diver safe	Local	14,300	2,000,000	140	NR	Jeff Dey, ARK

NOTES:

(1) In the case of the HMCS *Columbia*, *Saskatchewan*, and *Mackenzie*, the costs were provided in Canadian dollars. We used a 0.70 conversion factor to convert to the U.S. dollar amount shown.

(2) NR, in Reefing Date column, indicates no record.

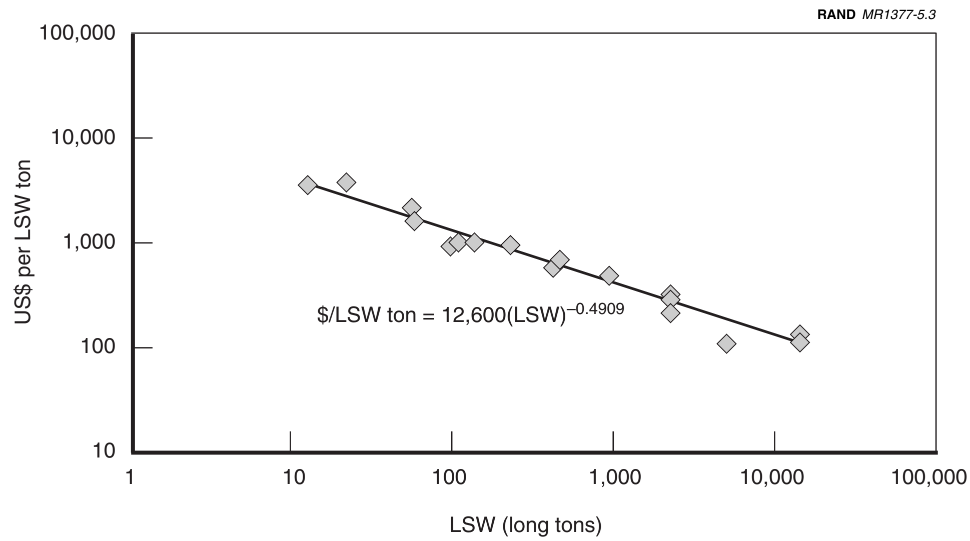

Figure 5.3—Cost per LSW Ton of Preparing Ships for Reefing

Estimating the Error in the Reef Preparation Cost

Our statistical regression analysis of the data shown in Figure 5.3 indicated excellent correlation between cost per ton and ship tonnage. The standard error from the analysis is ±16 percent. We also allowed for an escalation in labor costs similar to that for domestic recycling. This amounts to a ±30 percent error band. We applied these errors to the costs in calculating the best-case and worst-case estimates.

Estimating the Cost of a Reefing Program

Using the equation in Figure 5.3 to calculate the cost to prepare all 358 ships in the inactive fleet (see Appendix A, Table A.2) for reefing, we arrive at a total cost of $393 million in FY00 undiscounted constant dollars. This is, however, just the cost to prepare the ships. We must also consider tow preparation and towing, storage, the learning curve, and the various other factors we used to estimate the cost of a domestic recycling program in Chapter Three. To compute the total program cost, we used a cost model similar to the one we used for domestic recycling. Table 5.3 shows the baseline inputs to this model.

Table 5.3

Baseline Inputs to Reef Program Cost Model

Towing cost ($/mile of tow distance)	224
Outfitting cost ($/ship/tow)	100,000
Average recycle tow distance (miles/ship)	525
Average dismantling cost ($/ton)	142
Navy annual O&M per ship designated for scrap	57,000
MARAD annual O&M per ship designated for scrap	20,000
Weighted average annual storage O&M per ship designated for scrap	33,431
Annual storage O&M aging factor (%/year)	0.5
Discount factor (decimal) for discounted cost calculation	0.041
Preparation improvement curve slope (decimal) (log-linear unit)	0.95
Number of preparation sites	4

These inputs yield a baseline cost estimate of $500 million in undiscounted FY00 dollars, or $370 million discounted. For the best-case cost estimate, we used a 90 percent learning curve, and the lower end of the error envelope for ship complexity (-16 percent) and labor costs (-30 percent). The result is $320 million in undiscounted FY00 dollars, or $240 million discounted. For the worst-case cost estimate, we used a flat learning curve and the upper end of the error envelope for both ship complexity and labor costs. The result for this cost is $760 million in undiscounted FY00 dollars, or $560 million discounted.

In terms of annual average cost spread over a 20-year program, the budget would start at about $35 million per year and then fall to about $20 million per year in the last years as the learning curve reached maximum effect and the storage cost for the remaining ships declined. Figure 5.4 shows the annual budget for a 20-year reefing program.

As discussed in Chapter Three, the separate Navy and MARAD annual budgets are affected by how many ships each agency holds title to. Figure 5.5 shows the separate Navy and MARAD annual budgets for the reefing program, based on the baseline cost estimate, if title to the 358-ship inventory remains as it is now. Figure 5.6 shows the separate annual budgets (baseline cost estimates again) that would result if the Navy were to transfer 47 ship titles to MARAD. Note that these estimates include ship storage costs, which amount to about one-third of the total cost of the reefing program. We did not examine the current Navy and MARAD budgets, but we presume they include ship storage. Budget additions beyond the current levels thus would have to be only about two-thirds of the estimated total costs given above.

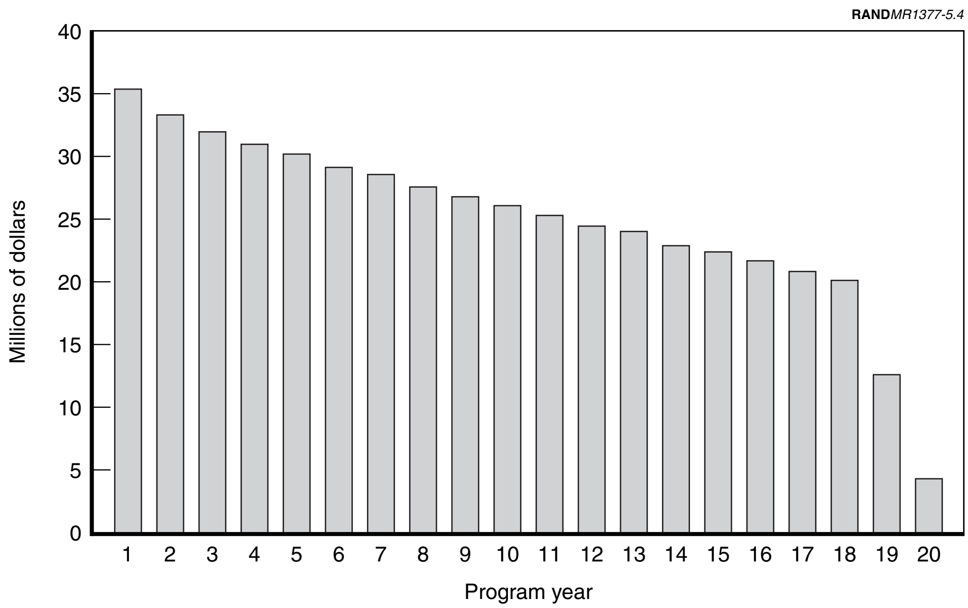

Figure 5.4—Annual Budget for Reefing

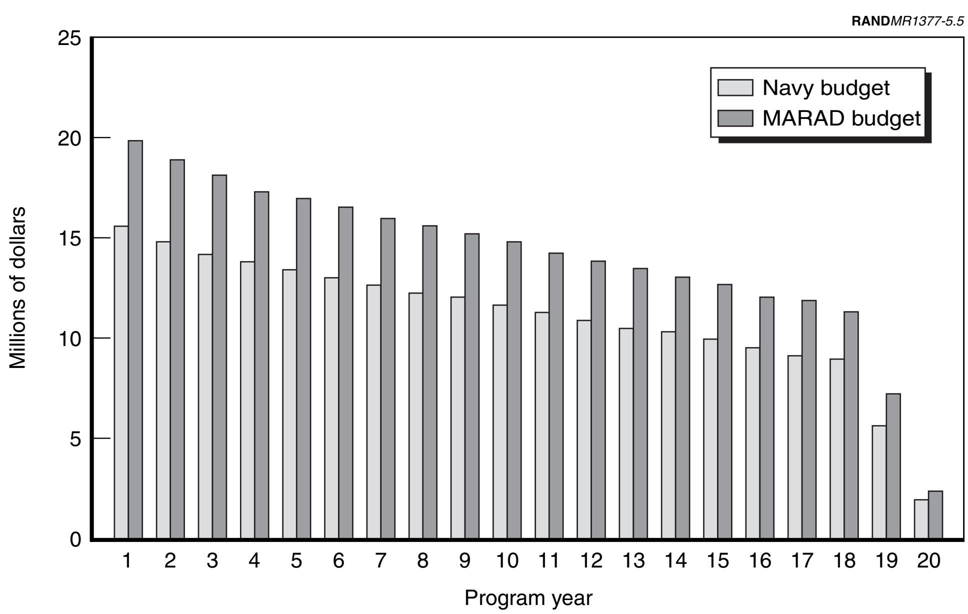

Figure 5.5—Annual Navy and MARAD Budgets for Reefing, Without Additional Title Transfers

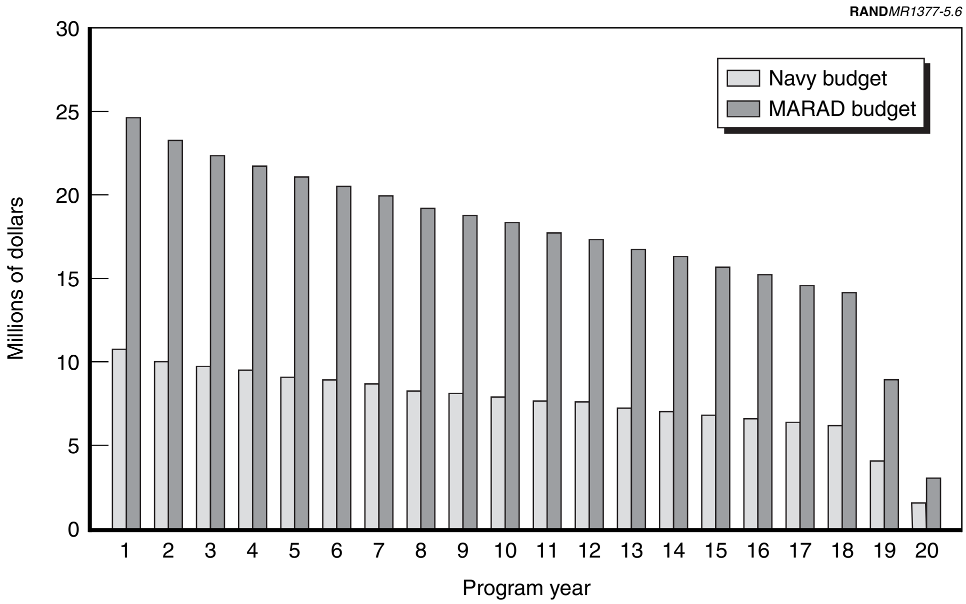

Figure 5.6—Annual Navy and MARAD Budgets for Reefing, With Additional Title Transfers

One issue we did not analyze is whether each agency should run its own reefing program with its own ships or whether one of the agencies should manage all the ships. It seems logical that the latter arrangement would be chosen for the sake of efficiency, in which case total program cost will remain the same but the entire budget will fall to the one agency. The government thus could achieve a small savings over our estimates by storing reef-program ships at MARAD rather than Navy facilities.

THE ECONOMIC BENEFITS OF ARTIFICIAL REEFS

Artificial reefs already provide returns to the government, and new reefs created with unneeded Navy and MARAD ships will provide more. Artificial reefs promote recreational and commercial fishing and recreational diving, activities that are of economic benefit to local and more-distant economies. Studies of how beneficial these activities are have been done, but they have not been well controlled and therefore provide only incomplete estimates. The state of Florida is now performing what is intended to be a definitive study, but its results are not yet available.

Table 5.4 summarizes the available data on the benefits of artificial reefs. As can be seen, some data reflect estimates of revenue from sport diving only, some from recreational fishing from private boats only, and some from all fish-

Table 5.4

Economic Benefits of Artificial Reefs

Geographical Area	Site	Months/ Year in Use	Local Annual Gross Receipts (US$M) Rec. Diving	Rec. Fishing	No. of Sites	No. of Ships Planned	Actual	Millions of US$/ site/ yr	Millions of US$/ ship/ yr	Sources	Comments
San Diego, CA	Wreck Alley	2	11.4		1	6	1	1.4	0.9	SDOF, 3/97	Diving estimate projected for a 6-ship site
Scapa Flow, UK	Scapa Flow	5	2.5		1	10	0	0	0.6	SDOF, 3/97	Est. SDOF of Scapa Flow diving revenue in US equiv.
Dunsborough, WAU, AU	HMAS *Swan*	0	1.48		1	1	1	0.8	0.8	Geoff Paynter, Geography Bay, ARSBC	
Sidney BC, Canada	G.B. Church & HMCS *Mackenzie*	9	2		1	2	2	0.7	0.3	ARSBC financial report, 1996	
Sechelt BC, Canada	HMCS *Chaudiere*	9	1		1	1	1	0.3	0.3	ARSBC	
Campbell River, BC, Canada	HMCS *Columbia*	9	1		1	1	1	0.3	0.3	ARSBC, 1996	
Nanaimo BC, Canada	HMCS *Saskatche–wan*	9	1		1	1	1	0.3	0.3	ARSBC, 1998	
Various SC, USA	South Carolina	9		18	2	173	73	0.58	0.1	R. J. Rhodes et al., 3/94	
Florida	Dade County, FL[a]	2		0.16	1			0.16		J.W. Milon, 12/87	Private recreational fish, low, per site
Florida	Dade County, FL	2		0.94	1			0.94		J.W. Milon, 12/87	Private recreational fish, high, per site
Various SC, USA	South Carolina	9		18	8			0.87		R. J. Rhodes et al., 3/94	Recreational fish, all SC sites
Port San Luis, CA	San Luis Obispo County	2		1.2	1			0.2		D.B. Rockland, 1990	Party boat fishing only
Florida	5 Counties, NW Florida[a]	2		414	8		9	6	0	F. W. Bell et al., 1998	Recreational fish NW Florida
						Avg.	**2.7**	**1.9**			

[a]Number of sites and ships for this location provided by Tom Maher, Florida Fish and Wildlife Commission, in personal interview.

ing but no diving. We chose to list and average all data so that we could develop a rough estimate of how much local business revenue could be realized per ship and per site. We also chose to express the results as if the sites/ships were located in coastal areas where fishing or diving activities would be year round—i.e., off the coasts of the southeastern and Gulf Coast states, California, and Hawaii. As shown in the table, we estimate the average annual gross revenue to be $2.7 million per reef site and $1.9 million per ship. There are over 400 existing artificial reef sites (see Table 5.2), some of which are ready to accept additional ships. If 100 such sites were to consume all 358 available Navy and MARAD ships (just under 4 ships per site), these sites would, we estimate, yield $270 million per year in gross business revenue. If the estimate were based on the number of ships, then the gross business revenue would exceed $680 million per year.

Federal receipts have for many decades averaged about 19 percent of gross national product (GNP) almost regardless of tax rates or tax policy.[19] Allowing an additional 6 percent for state and local income, sales, and other taxes, a total of about 25 percent of gross business revenue ends up in local, state, or federal coffers. Thus, from a fully developed reef program with all ships in place, federal, state, and local governments together can expect from $68 million to $170 million per year in receipts. Total government receipts will be sufficient to compensate for the entire program cost by midway through the twelfth year using the per-ship revenue estimates.[20]

CONCLUSIONS

The use of inactive Navy and MARAD ships for artificial reefs is a viable option. The overall program is estimated to cost $495 million, with a range of $320 million to $760 million. These costs represent a program to prepare ships for reefing in accordance with modern environmental requirements—criteria that seem high compared with the standards of state and local reef-building interests. Therefore, the demand for large U.S. government ships has been low. But if a ship preparation program funded by the Navy and MARAD could resolve the cost issue, there is sufficient reef-building demand to consume all 358 ships in the inventory. The average annual budget for a reef-building program will run from $10 million to $15 million in the Navy and from $20 million to $25 million in MARAD, depending on the number of Navy-to-MARAD ship title transfers that take place and how the program is administered. Additionally,

[19]Joint Committee on Taxation, U.S. Congress, 1986.

[20]The government will also derive tax revenues from the sale of scrap metals and equipment for a domestic recycling program, as discussed in Chapter Three.

federal, state, and local government receipts from the fishing and diving businesses that will use the reefs will be sufficient to compensate for the entire average cost of the program after about 12 years and, thereafter, will yield a net "profit" to the government.

To begin a Navy and MARAD reef-building program, the U.S. government will need to develop a uniform set of rules for ship preparation that covers all federal environmental responsibilities and meshes properly with state environmental responsibilities. In addition the Navy and MARAD will need to work out the details of how to administer such a program so that ships are fairly distributed among the many parties likely to request them.