Delaware Artificial Reef Plan

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INTRODUCTION

This 2011 edition of the Delaware Artificial Reef Plan is an update of the previous (1999) edition. Although in 1994, Delaware was the last mid-Atlantic state to initiate a state-sponsored artificial reef development and management program, the program has been very active since its inception. The growth of the program's size and scope necessitates periodic revision of the state reef plan. This revision of the Delaware Artificial Reef Plan includes additions to reef site materials, relevant information added from state, federal, and regional management agencies, as well as current and developing interests of the state as they pertain to artificial reefs and fisheries management. Original text and information have been maintained from the previous Delaware Artificial Reef Plan document, where appropriate.

BACKGROUND: ARTIFICIAL REEFS

The practice of purposely deploying structure to enhance fishing habitat is centuries old (Meier et al. 1989), and is known today as constructing an "artificial reef." The U.S. Army Corps of Engineers, which permits artificial reef structures, defines the term artificial reef in Code of Federal Regulations (CFR), Title 33, Volume 3 Sec. 322.2-as (g)"The term artificial reef means a structure which is constructed or placed in the navigable waters of the United States or in the waters overlying the outer continental shelf for the purpose of enhancing fishery resources and commercial and recreational fishing opportunities." Delaware employs artificial reefs to attract invertebrates such as oysters, blue mussels, and worm species, as well as local fish populations, to the benefit of both the organisms and recreational fishermen.

While the soft sand/mud sea floor that represents much of the bottom of the Delaware Bay and coastal areas does support some fish and shellfish, this near-uniformly flat habitat limits those fish and invertebrates that utilize structure. Several recreationally important species to Delaware are associated with firm substrate and structure, including black sea bass, tautog (these fishes are consistently among the top species, by number caught, for recreational fishermen), oyster, and blue mussel. The invertebrates seek structure and hard surfaces on which to attach. And the fishes utilize the reef structure for physical and psychological refuge, reproduction, and feeding.

Artificial reef development efforts were private, largely unregulated, and sporadic affairs in the United States until the latter half of the 20th century. State and federally sponsored artificial reef programs eventually grew out of these early pioneering efforts. The federal government's first official foray into artificial reef development was a funded a research program from 1966-1974, which focused on construction, costs, biology, and management aspects (Stone 1974). Government sponsored artificial reef program rules, regulations, and policies began to be implemented in the 1980s. The National Fishing Enhancement Act (PL-98-623) was enacted by

Congress in 1984. This act promoted state-managed effective and responsible artificial reef development. Because Section 205 of the act required that all artificial reef applicants had to demonstrate to the satisfaction of the Secretary of the Army, that they had the financial ability to assume liability for reef-related damages, most artificial reef efforts were left to be assumed by state-sponsored programs rather than local private efforts.

As a result of the National Fishing Enhancement Act, the National Oceanic and Atmospheric Administration (NOAA) produced the first National Artificial Reef Plan in 1985 (Stone, 1985). The National Artificial Reef Plan set national guidelines for reef development and provided direction for individual states to develop site-specific reef development plans; this Plan was revised in 2008 with the Atlantic States Marine Fisheries Commission (ASMFC) and the Gulf States Marine Fisheries Commission (GSMFC) jointly acting as the lead agencies. The process included extensive federal agency review and National Marine Fisheries Service (NMFS) approval.

Individual state-managed reef programs received strong financial support from the 1986 Wallop-Breaux Amendment to the Federal Aid in Sport Fish Restoration Act. The Federal Aid in Sport Fish Restoration Act uses angler and boater excise taxes to increase sport fishing and boating opportunities, including artificial reefs.

The federal financial support and encouragement, as well as the financial-liability exclusion of most private efforts, led all of the states between New York and Texas to develop artificial reef development programs. Delaware was the last of the mid-Atlantic states to initiate a state-sponsored artificial reef development and management program, being first permitted for development in December 1994. Delaware's artificial reef program is designed to enhance a generally featureless bay and ocean bottom habitat. The structure and profile of the reef material provide surface area and interstitial space for attachment, spawning, refuge, and feeding for many different organisms that are generally limited by the Delaware Bay and ocean environment. The increased diversity of the reef sites, increased abundance of structure-oriented fishes, and use of interesting reef materials benefit Delaware economically as well as environmentally by increasing hook and line fishing and diving opportunities. The economic benefits of a well-planned, executed and maintained artificial reef program extend to support associated industries (restaurants, hotels, charter boats, tourism, motor fuels, bait stores, equipment sales/repair, etc.). The fisheries management efforts behind artificial reefs are not a plan to change the native marine environment of Delaware waters, but an enhancement of the limited natural structure areas and associated marine organisms already present in the state. Delaware Bay and coastal waters already support important recreational fisheries for a variety of demersal and pelagic species that naturally favor structure. Delaware combines planning, monitoring, sampling, study and evaluation in order to benefit from its artificial reef program.

PREVIOUS HISTORY OF DELAWARE ARTIFICIAL REEFS

The history of artificial reef development activities in Delaware consists of relatively few efforts by private groups. The earliest anecdotal record involves the deployment of a barge load of concrete culvert pipe one mile east of Indian River Inlet by Desylva and Ritchie in 1959-60 (Kent Price, personal communication). Subsequent attempts to locate and monitor the site were unsuccessful.

During the period 1968-71, the Delaware Division of Public Health administered the overboard disposal of a large volume of waste surf clam shell, a by-product of the commercial surf clam processing industry. In addition to providing cultch for all oyster growing areas, shell was used to create two artificial reef sites in the Harbor of Refuge, near Lewes, Delaware. Information is not available as to the success or longevity of this effort.

During the period 1972-74, the Delaware Artificial Reef Association, Inc., a private, non-profit association of headboat captains, was active in artificial reef development along Delaware's ocean coast. A site 5.3 nautical miles east of Indian River Inlet, with two existing wrecks, was enhanced with seven derelict fishing vessels and over 8,000 automobile tires. A sidescan sonar survey of this site (now incorporated into site #10) during the 1994 permitting efforts showed one existing steel barge and no other vessels or tires.

In 1980, the University of Delaware Sea Grant Program considered the local artificial reef situation and published Artificial Reefs for Delaware, (Jensen et al., 1980) which described materials and funding options available at that time. The use of scrap tires was endorsed as cost-effective and useful in attracting fish.

During the mid-1980s, the U.S. Army Corps of Engineers (COE) utilized 142 acres of wetland and shallow sub-tidal habitat in the Delaware River near the Wilmington harbor for a dredged material area. As partial mitigation for the loss of fish nursery habitat, a complex of prefabricated concrete reef structures was deployed near Brown Shoal in Delaware Bay in June of 1989. In preparation for this effort, the Delaware Division of Fish and Wildlife funded several studies including a Conceptual Plan for Siting and Developing Artificial Reef Sites in Delaware Bay and adjoining coastal waters, (Aquabio, 1984) and an Artificial Reef Feasibility Study (Aquabio, 1985). The COE off-site mitigation effort involved sixteen precast concrete structures 20'x20'x9' in size, placed in four clusters of four units each. Physical and biological monitoring of this effort was extensive and continued through 1994 (Battelle, 1994). Monitoring data showed that epifaunal populations approximated a thousand fold increase in the biomass of the displaced infaunal invertebrate community at this polyhaline site in lower Delaware Bay (Battelle 1994). This effort and the resulting recreational fishing opportunities created extensive interest among the fishing public in a state-sponsored artificial reef development and

management program. This mitigation site near Brown Shoal is now incorporated into the Delaware Artificial Reef Program (site #7).

In 1986, the University of Delaware received state and federal permits to site an experimental reef made from stabilized waste products (fly ash and bottom ash) resulting from combustion of eastern bituminous coal associated with electric power generation. A near-shore site southeast of Indian River Inlet was selected. Leaching of various metals was determined to be minimal and reef materials attracted typical epifaunal and fish communities (Price 1987). The residue, resulting from coal combustion, can exceed 25% of the original volume of coal. As a part of the process of evaluating the ashreef, Eklund and Targett (1990, 1991) described seasonality of fish catch rates, reproductive seasonality and species composition of the sea bass trap fishery in the middle Atlantic bight.

The state-sponsored artificial reef development efforts in Delaware started with the Department of Natural Resources and Environmental Control: Division of Fish & Wildlife's formation of the Delaware Artificial Reef Program in July 1992.

FEDERAL ENTITIES INVOLVED WITH ARTIFICIAL REEF PROGRAMS	STATE ENTITIES INVOLVED WITH ARTIFICIAL REEF PROGRAMS
U.S. Army Corps of Engineers	DNREC; Division of Fish and Wildlife
Environmental Protection Agency	DE State Div. of Historical and Cultural Affairs
Coastal Zone Management Act	DE Coastal Management Program
U.S. Coast Guard	DNREC; Division of Water Resources
National Ocean Survey	
U.S. Maritime Administration	

FEDERAL

A permit from the COE is the primary certificate of federal approval. All information regarding the COE permit program is summarized in the Federal Register, Vol. 51, No. 219, Nov. 13, 1986 under title 33 CFR 320-330, "Final Rule for Regulatory Programs." A permit to site a structure to be used as an artificial fishing reef is granted by the COE under Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403). Section 10 authorized the COE to prohibit the construction or alteration of any navigable waters of the United States. Section 4 of the Outer Continental Shelf Lands Act of 1953 (43 U.S.C. 1333(f)) extends this authority to the continental shelf. The Corps. also has authority under Section 404 of the Clean Water Act of

1972 (PL 92-500) to regulate any materials placed within navigable waters of the Territorial Sea and stipulates state certification of discharge projects.

The Environmental Protection Agency reviews comments on COE applications for compliance with Section 402 of the Clean Water Act. A major concern of the EPA is toxins introduced to the marine environment.

The National Marine Fisheries Service and the U.S. Fish and Wildlife Service also provide review and advisory comment on COE applications regarding fish stocks and habitat.

A state consistency certification is required under approved Coastal Zone Management Programs under Section 307 (c)(3) of the Coastal Zone Management Act of 1972 (PL-583; 16 U.S.C. 463).

An environmental assessment of all potential impacts must be prepared in order to comply with the National Environmental Protection Act, which requires an assessment for all projects using federal funding.

The United States Coast Guard (USCG) manages the Private Aids to Navigation Program. They determine which reef sites will require a buoy, and they provide minimum standards for buoying. The Delaware Artificial Reef Program will abide by Coast Guard recommendations for buoying, but purposefully seeks to site reefs in such a way as to minimize the requirements for buoying. Delaware strives to leave clearance above the reef structure such that it will not present a hazard to recreational or commercial shipping, and fishermen are able to locate the reefs with modern electronics. The USCG, as mandated by the Ports and Waterway Safety Act, maintains responsibility for the establishment of navigation channels and navigational clearances over reefs.

The National Ocean Survey (NOS) maintains reef site location boundaries on nautical charts. Delaware provides accurate navigational coordinates of all sites and informs NOS about the development of permitted reefs.

The United States Maritime Administration (MARAD) has the authority to transfer obsolete naval vessels to the state for reef deployment under the National Fishing Enhancement Act (P.L. 98-402: Section 207), should these vessels be acceptable in terms of cost, environmental cleanup capability, and suitable reef material/structure. The Navy transfers retired non-warships to MARAD for disposal either through scrapping or reefing.

The Navy leads a federal reefing effort to reef certain retired warships. There are two models for how the preparation and reefing is conducted. For very large vessels, such as aircraft carriers, the Navy contracts the clean-up and preparation of the vessel and donates it to a state or county reef program, after sinking on a permitted site. This was the process for the reefing of the

aircraft carrier "Oriskany," reefed in 2006 off the coast of Pensacola, FL. Smaller warships are transferred to state or county reef programs, who themselves are responsible for contracting the clean-up and preparation of the vessels. This was the process for the retired destroyer, Arthur. W. Radford, reefed in 2011 in a joint effort by the states of Delaware, New Jersey, and Maryland.

The sinking of the Arthur W. Radford on the Del-Jersey-Land reef

Photos: Z. Hense

STATE OF DELAWARE

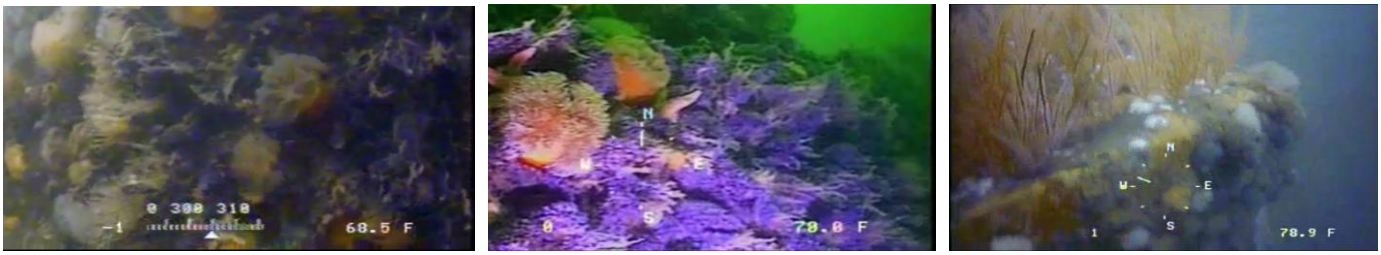
The overriding goals of Delaware's artificial reef program are to enhance habitat for fish and benthic organisms, and provide enhanced recreational fishing opportunities as part of a marine fisheries management program. In working toward these goals, Delaware bears the responsibility for the planning, siting, construction, and monitoring of state-managed reef sites. To this end, the Delaware Artificial Reef Program obtains all permits and authorization from state and federal regulatory agencies as sole permittee. The Division of Fish and Wildlife does solicit public involvement in this process and participates in interstate efforts to enhance fisheries habitat and manage fish populations.

The Delaware Artificial Reef Program Coordinator identifies all candidate artificial reef sites based on water quality and biological data, selecting applicable sites to attract and support target invertebrate and fish populations; sites are also selected with consideration of the targeted user's needs. The Delaware Artificial Reef Program approves reef materials appropriate for the environment, habitat, and attractiveness to invertebrates and fish. Delaware's Artificial Reef Program is also responsible for minimizing user conflicts with other bay/ocean users, including other fisheries and navigational interests. Post reef-placement, Delaware's Reef Program assumes the responsibility for coordinating research and monitoring efforts on the reef sites for permit compliance, biological productivity and angler use.

Before an artificial reef site can be established, a state sub-aqueous lease must be secured in accordance with Chapter 72, Title 7, Delaware Code. The State Division of Historical and Cultural Affairs has been authorized under Sections 106 and 110(F) of the National Historic Preservation Act to require remote sensing surveys of proposed reef sites by a certified marine archeologist. Sunken or buried materials of potential historic value must be avoided as a condition of the state's sub-aqueous lease.

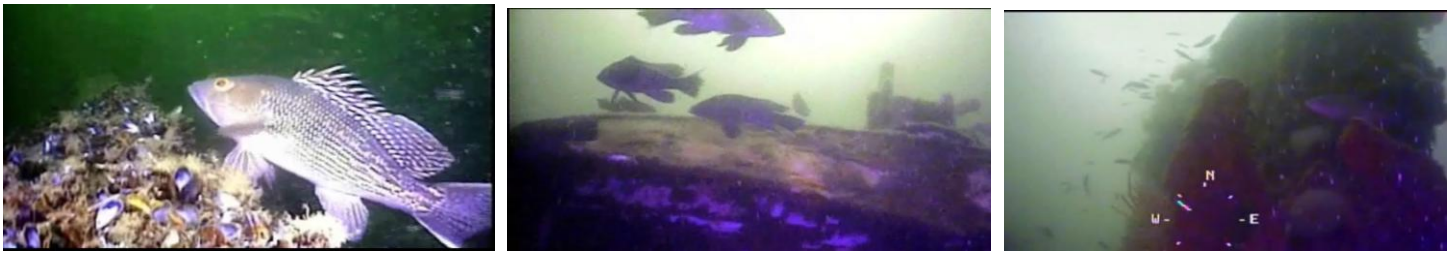
PURPOSE

Delaware's coastline, both in the Delaware Bay and Atlantic Ocean, is relatively flat and featureless. Such bottom benefits greatly from the enhancement of the artificial reefs, as they provide structure for invertebrate growth (micro/macroalgae, corals, sponges, mussels, oysters, etc.) and ocean relief for structure-oriented fishes. Among other benefits, the reef provides for fishes: physically, with shelter/optimal alignment from currents (Lindquist & Pietrafesa, 1989), biologically, with food resources (Bohnsack, 1989), and psychologically, as reefs supply social groups and space in which to hide from predators, both of which have been shown to reduce stress in fishes (Galhardo & Oliveira, 2009). Selected reef materials provide a hard base for sessile organisms to attach; settling invertebrates cannot be sustained on sand because of its instability and constant movement (Gratwicke and Speight 2005).



Invertebrate colonization on Delaware's reef sites. Still shots are taken from underwater DNREC video.

The invertebrate colonization is a valuable part of the food chain of the reef. Structure-oriented fishes utilize the reef as a food source, as well as employing the vertical and interstitial space for hiding and movement. The reef also provides surface space and edge to allow organisms to take advantage of multiple environments. In Gratwicke and Speight's study (2005), the amount of rugose substrata provided by artificial reefs was the most significant variable related to observed fish species richness. In the same study, the variety of growth forms on artificial reefs was the second most important habitat variable for fish species richness, indicating that varied voids, structures, and growth on an artificial reef provide a larger number of species with potential feeding, refuge, and breeding sites than more uniform structure might.


Fish on Delaware's reef sites. Still shots are taken from underwater DNREC video.

The artificial reef program does not introduce wholly new habitat or species to the waters of Delaware. Artificial reefs instead develop a small area of the seafloor to enhance the habitat-limited endemic reef fishes and organisms, not changing the overall community structure, but encouraging the fish species attracted to the reefs (Simonsen & Cowan, 2007). The potential of the artificial reef in attracting or producing target species of fish or invertebrates are related, among other factors, to the limiting environmental factors (Guidelines for Marine Artificial Reef, 2004); however, there is evidence that artificial reefs in Delaware enhance benthic productivity (Steimle et al., 2002).

Recent studies suggest that the positive effects of artificial reefs to the environment extend beyond the physical reef structure. Reef placement may positively alter adjacent habitat. The fish and invertebrate organisms that are attracted to the reefs, can fall off of the reef, or leave organic detritus, such as fecal matter, and dead organisms in the benthos surrounding the reef (Wilhemsson et al., 2006), thus enriching not only the actual reef site, but a larger area as well. Oysters on reef structure can provide essential fish habitat for different life stages fish and invertebrate species, as well as affect the ecosystem beyond the limits of the reef structure itself (Coen et al., 2007).

The Delaware Artificial Reef Program has permitted 14 artificial reef sites that meet pertinent criteria. Reef sites have a hard, stable bottom of sand or clay, which will support the reef structure, without subsequent smothering by shoaling or subsidence. The site must have a flat or gently sloping bottom. Sites are also chosen by their proximity to one or more fishing ports. The depth of the reef sites must ensure that adequate clearance over reef structures for safe navigation, as required by permits, is provided. Water quality and hydrography for prospective reef sites must be such that they will attract target populations of invertebrates and fish. Existing scattered wrecks provide some information about the preferences of pelagic and demersal target species in the area. Delaware has placed some reef sites around existing wrecks, enhancing the habitat development of the area. In most cases, Delaware has chosen to place reef sites in new, habitat-limited areas to encourage invertebrate and target fishes to inhabit the area. In the past, Delaware has also solicited opinions from fishing captains and the fishing public as to their preference for future reef construction candidate sites, to which the site criteria and exclusion list was then applied.

SITING CONSIDERATIONS

Prospective reef site areas are to be avoided if they do not meet the selection criteria or have further disqualifying factors; this forms the exclusion list (Myatt & Ditton, 1985). Areas of possible conflict with navigation channels, anchorage areas, waste dump sites, outfalls, and areas reserved for military use or commercial fisheries are eliminated. High energy areas with

excessive current and/or wave height are excluded. Already highly productive zones, including shellfish beds and submerged aquatic vegetation, are left undisturbed. Shallow near-shore areas, shoals, steeply sloping bottom, and soft bottom areas are not good reef site candidates. Known archeological sites are to be avoided, as are designated beach replenishment borrow sites.

Areas that are too far from ports or shore access points are often not applicable to reef sites. Reef sites are constructed for the benefit of both marine organisms and sportfishing. Because many anglers are limited by time and distance from port, most of Delaware's reef sites are located just a few miles from a public access point so that fishermen and charter boats can reach them quickly and easily. Having reef sites throughout the Delaware Bay, as well as a few ocean sites, means that a large variety of fishermen can use the reef sites; both small boats and large boats have access to some reefs. The distribution of Delaware's reef sites throughout the Bay and ocean also allows for different habitats and marine organism/fish colonization on the reef sites due to differences in salinity, temperature, depth, current, light, and other environmental aspects.

Delaware's Artificial Reef Program has sited more reefs in the Delaware Bay than the Atlantic Ocean (Figure 1), as the majority of Delaware's coastline and ports are along the Delaware Bay. The artificial reefs in the Delaware Bay are represented by four broad habitat zones, differentiated by distinct epifaunal communities and fish populations.

The permitted site near Reedy Island is in an area of very low salinity (0.5-5ppm). This oligohaline site is not currently developed, but concrete structure is expected to be placed on the site in the near future. The invertebrate epifaunal community is expected to include barnacles, hooked mussels, amphipods, tubificid and other polychaetes. Fishes that utilize oligohaline areas include striped bass, white perch, and various catfish.

The area from Collins Beach to Port Mahon is of mesohaline moderate salinity (8-18%). Natural oyster beds are found in this zone. Previous studies have found natural oyster beds capable of supporting a diverse invertebrate community (Watling & Maurer, 1973). The oyster beds here have been managed by Delaware's Division of Fish & Wildlife for years, when funds have been available. Shell cultch is planted, allowing for attachment and growth of oyster larvae. Additionally, the deployment of low-profile reef materials adjacent to existing natural beds provides substrate for further oyster spat settlement. The natural beds and artificial reefs in these waters support the pelagic species weakfish, bluefish, and striped bass. Artificial reefs constructed in these waters have been kept smaller than lower bay and ocean sites, due to limited availability of suitable hard bottom and conflicting water uses of these areas.

The lower Delaware Bay has a polyhaline salinity regime (18-30%), similar to Delaware coastal waters. The epifaunal community in polyhaline waters is dominated by blue mussels, barnacles, hydroids, and the tube worms *Sabellaria* as well as hydroids. In the Delaware Bay,

the area from Bowers Beach to Indian River Inlet provides polyhaline waters (reef sites 3-10). Fish species utilizing the artificial reefs in these waters include black sea bass, bluefish, weakfish, tautog, summer flounder, scup, trigger fish, among others.

Delaware's permitted ocean reef sites include the Redbird Reef (site #11) and the Del-Jersey-Land inshore and offshore reefs. These are euhaline sites with the salinity of full ocean water (about 35 ppt). These areas support blue mussels, soft and Northern corals and anemones.

CONSTRUCTION OF ARTIFICIAL REEFS

During the design and construction of an artificial reef, many aspects of the reef are evaluated. Considerations include the vertical profile, the quantity and quality of interstitial spaces, the amount of surface area provided, and the qualities of the materials used to build the reef itself. The height of vertical relief that the artificial reef provides is a consideration when designing a reef to benefit certain species. A study of artificial reefs, found that height was a significant predictor of fish abundance, but not a significant predictor of observed species (Gratwicke and Speight 2005). Demersal species are believed to be more attracted to low profile reefs, while pelagic fishes are more often associated with high profile reefs. High profile structure intercepts the tide currents, creating eddies where some fishes schooling near the reef can exploit the physical break from the water's force (Lindquist & Pietrafesa, 1989).

Structural complexity of reef sites has been shown to increase species richness and biomass, and fish abundance as compared to reefs with greater void space (Sherman et al., 2002, Gratwicke & Speight, 2004, Charbonnel et al., 2002). Reef sites that provide a variety of holes, crevices, walls, and overhangs can result in a generally more diverse community than what might develop with less structural complexity. A reef structure can intercept the current, and cause water to swirl around/through it, either depositing material on and around the reef or carrying it away, thus supplying more resources for feeding and reproduction, or habitat for juvenile fishes. The structure of a reef can determine the type and diversity of biological community developing in and around it.

Surface area is an important predictor of total biomass found on an artificial reef. The reef's surface provides a secure anchor for both sessile and motile invertebrates and algal growth. As invertebrates and algae are a significant food source for many fishes, it follows that the more area available for food source colonization, the greater the potential for recruitment of feeding fish communities.

Not only is the design of the artificial reef important to the successful recruitment of target fishes, the material used in an artificial reef is an important consideration as well. Reef materials must offer suitable openness for water circulation, such that portions of the reef are not

lost to stagnant dead zones. Openness throughout the reef is also important for allowing organisms to use as much of the physical structure of the reef as possible, both outside of the reef's structure, inside the reef's structure, and access between the two.

ARTIFICIAL REEF MATERIALS AND DESIGN (materials criteria, types of materials, and materials transfer)

Materials utilized in reefing activities are varied, and appropriateness must be considered when designing an artificial reef (Luckens & Selberg, 2004). The marine environment is a harsh one, with constant wind and wave action, storm surge, and many chemical properties at work; even natural materials like rocks, shell, and coral can be damaged or buried, so artificial reef structures are not expected to last forever. However, artificial reefs should be built with stability and durability in mind, and placed so that movement and sinking is minimal and slow. Artificial reefs are of two general types, designed structures and materials of opportunity. Delaware's Program has utilized the latter. Materials of opportunity are more cost effective and available locally. Using proper materials, and deploying them in an optimal orientation and configuration within a reef site, it is possible to incorporate many of the desirable characteristics into a reef site using materials of opportunity. Delaware's program has included concrete, stabilized tires, marine cable, vessels, and subway cars as materials of opportunity.

Concrete proves suitable for artificial reef material as it is durable, stable, and provides an excellent firm substrate for epifaunal invertebrates. Construction second-quality precast culvert pipe, junction boxes, and man-holes have structural complexity and habitat advantages such as large surface areas for attachment of organisms, openness within the structure to aid water circulation, and within water profile to attract and protect targeted species. Other forms of concrete used in reefing include demolition waste from buildings, road surfaces or bridge decks. When free of hydrocarbons and exposed steel reinforcing bars, this material can be deployed in piles, which will provide optimal profile and complex interstitial spaces. In its artificial reef program, Delaware has utilized over 78,067 tons of concrete, mostly in the form of concrete culvert. In the Delaware Artificial Reef Program, the concrete is pushed off of an anchored barge, forming piles that generally extend from 5 to 15 feet off of the bottom. This helps to avoid loss of surface area, which occurs when scattered pieces of culvert scour into the sand bottom.

Complex concrete materials being deployed in the Delaware Bay.

Photos: Z. Hense

Automobile and truck tires have been used in every reef program along the Atlantic Coast, and are one of the more controversial material being used in reef programs. Advantages that tires provide to a reef include complex structure, high amount of surface area, excellent durability, local availability, and usefulness in supporting a rich epifaunal community in the mid-Atlantic region. The disadvantages of tire reef include lack of density requiring considerable ballasting with concrete, which increases handling and costs, and the potential toxicity of tires at low salinity levels (Hartwell, et al, 1994). Most of the problems with tires relate to the stability of the tire piles, as many early efforts used little or no ballast. As a result of tire reefs breaking apart, some states no longer permit the use of tire units as reef materials. Delaware has used truck tires (no automobile tires) ballasted for strength and stability, as recommended by a New Jersey study (Myatt et al, 1989). The tires are compressed and banded together, and concrete is poured inside. In order to maximize stability, the units are deployed in no less than 60 feet of water. In order to eliminate potential low-salinity toxicity concerns, no tire deployments are made at estuarine sites (Delaware Bay). Currently, Delaware has utilized over 5,575 tons of ballasted tire on its artificial reefs. Sidescan sonar is used to periodically assess movement of tire units to ensure stability on the ocean bottom.

Still shots are taken from 2009 DNREC ROV footage of encrusted concrete ballasted tires on a Delaware reef.

Marine cable is a donated material in artificial reef construction. At this time, Delaware has utilized 5.6 nautical miles of marine cable. The benefits of marine cable include that it is available at no-cost, and that it is a durable, stable, and non-toxic material. The cable can be piled/looped/snarled to provide greater structure and interstitial space. However, marine cable, by nature of its relatively thin and solid nature, does not provide as great a surface area for attachment and growth of invertebrates as do other, more substantial materials.

Most states have included the use of scrapped commercial or military vessels in their artificial reef programs. Vessels are usually the most popular material with fishermen and SCUBA divers. Not all boats are suitable reef candidates. Wooden and fiberglass vessels have proven unsatisfactory due to their poor durability and stability. Properly ballasted steel hulls provide high profile structure more likely to attract and hold both pelagic and demersal fish species. Delaware has utilized commercial vessels on its reef sites such as the Gregory Poole, a Minesweeper/Menhaden harvesting vessel (175’), steel barge “Bucchannon” (120’x40’), a 40’

steel hull pilot boat, the tug boats “Delilah” (90’), “Margie Ann” (90’), “Margaret” (85’), “William C. Snow” (55’), “Fels Points” (110’), “Cittie Point” (95’), “Bay Tide” (110’), “Mr. G” and “Rusty Pusher” (small tug and push boat), “Golden Eagle” (70’), steel vessels “P3” (35’), “Dolphin” (42’), and the trawler “Crazy Horse” (77’) .The life expectancy of a steel vessel is often many decades, with fishing often improving as the vessel deteriorates. One problem with motor vessels is that all toxics must be removed prior to sinking. Commercial vessels, especially non-motor vessels (barges) have the advantage in having fewer toxics. Toxic substances commonly found on scrapped vessels include bilge sludge, hydrocarbons, toxic heavy metals, asbestos and PCBs. PCBs are a common problem on military vessels. Because the EPA maintains a zero discharge policy for PCBs, this sometimes makes the cost of vessel clean-up prohibitive. Delaware has also used properly cleaned military vessels on its reefs, including military track vehicles, YC 1479 (160’ Navy barge), and Yon 80 (Navy barge). The retired 563’ Navy destroyer, Arthur W. Radford was reefed August 10, 2011 on DelJerseyLand, a Delaware permitted reef site.

A fully cleaned and prepared tug boat, in the process of sinking, on a Delaware reef site.

Photos: Z. Hense

Subway cars make ideal reef material in the mid-Atlantic region because the stable outer structure provides both inside the car and outside the car surface area for invertebrates, and the voids within the cars provide reef fish with good water circulation, and different sized openings and voids for feeding and refuge areas. Both “Redbird,” the first generation of subway cars released for reef purposes from the New York City Transit Authority, and the later stainless steel cars weigh approximately 18,000 pounds apiece. Because in their originally designed use, they were made to stand up to much movement, weight loading, and use, subway cars are engineered for great strength and stability, relative to their size. Thus, subway cars have a projected marine reef lifespan of 25-30 years (Luckens & Selberg, 2004). Delaware has thus far utilized 1,329 subway cars in populating its Atlantic Ocean artificial reef sites. Before the cars are approved for reef use, undercarriages are removed, doors and windows are removed, and the entire car is cleaned of oil, grease, and debris. Each car is individually inspected before it is accepted into the reef program. Some environmental groups have voiced concern about using subway cars in artificial reefs because the cars contain small levels of asbestos in floor panel glue and wall insulation. However, both federal and Delaware environmental officials approved subway cars

for reef use because the asbestos fibers are contained within the glue epoxy and would not be free in the water column. And asbestos is only dangerous when airborne, not in an underwater environment.

Stainless steel cars have proven to be less durable than the earlier carbon steel cars, and have tended to collapse in many deployment locations. The pieces appear to be stable. The collapsed cars still provide low-profile structure, which supports invertebrates and structure-oriented fish.

Subway cars (stainless steel) being deployed on a Delaware reef site.

Photos: Z. Hense

REEF CONFIGURATION

Within a permitted reef site, the distribution of materials is important in maximizing habitat benefits to reef fishes (Turgeon et al., 2010). A "reef site" is not a single placement of material; rather the site determines the borders of an area and may contain multiple deployments. Reef material is deposited in patches within the permitted reef site. The deployments are designed to be clustered instead spread equally across the given area. Surface area and edge effect can be maximized by aggregating materials in groups throughout the reef site. Since 1995, deployments in Delaware of concrete, tire, cable, and subway car reef material have been made from an anchored barge in order to concentrate material to the maximum degree. The height and spaces between groups of material can impact reef effect (Walker et al., 2007, Turgeon et al., 2010). The "edge effect," or transitional zone between distinct habitat types, is an area that typically yields greater species diversity and abundance than that found in either habitat. Interspersing structure and sand habitats within the permitted reef site allows mobile fishes to utilize both habitats, and provides some form of each type of habitat for stationary organisms to utilize across the reef. It also tends to disperse fishing effort over wider areas, as there is not a single pile to cluster fishermen.

MANAGEMENT (general, monitoring, maintainence)

Physical

The Division of Fish and Wildlife maintains ownership of the artificial reefs, and periodically evaluates the habitat enhancement activities to ensure that management goals are being met. Permits issued by the U.S. Army Corps of Engineers require a periodic check on physical reef condition, including location and condition of any buoys located at the site, and an evaluation of deployed reef materials. Delaware's reef program purchased an Outland 1000 ROV to help monitor the reef sites. The ROV, with multiple attached cameras and sonar, allows the Division of Fish and Wildlife to investigate seasonal fish composition on the reef sites and to observe reef fishes/invertebrates in a non-intrusive manner. The fishes do not seem to be disturbed by the presence of the ROV, as they sometimes are by SCUBA divers [*personal observations*]. The reef itself is examined with by the Division of Fish & Wildlife, using side scan sonar, GPS, shipboard fathometer readings, SCUBA divers, and a camera-equipped remotely operated vehicle. The reef sites are inspected for movement of materials and minimum clearance above the structure, and judgments made about the durability and stability of the reef construction materials used.

Biological

Delaware also completes biological monitoring of its reef sites through assessment of epifaunal invertebrate populations and fish populations. This information is used to determine whether the target species for each reef are being supported, and provides a quality assessment for feedback for future enhancement and reef site development decisions.

Since 1997, bi-weekly randomized aerial flight survey has been conducted to estimate charter boat and private boat angler use of reef sites (Figure 2). Counts are taken of the numbers of boats utilizing the permitted reef sites during the flyovers. These data are used to compute estimates of angler effort on each site. Angler use, participation, catch, effort, catch-per-unit-of-effort, size and species targeted/caught has been tracked on the reef sites over time, and compared to regulations, fishing restrictions, and sociological information to complete a picture of artificial reef use in Delaware. While the reefs differ in their locations, environments, reef materials, biological communities, targeted months, and years, the times series of sampling did show some similarities among all of Delaware's reef sites. Black sea bass and tautog are two of the species most targeted by anglers on DE's reef sites. While the number of angler trips to reef sites did not correspond directly with DE harvest of black sea bass and tog, there is some correlation between them. Many factors influence fishing effort, like season, weather, wind, the economy, and fish availability

State monitoring efforts are coordinated with regional artificial reef efforts supported by the Atlantic States Marine Fisheries Commission (ASMFC) Artificial Reef Committee. Sharing

information with other states and regional reef programs helps to avoid redundancy, allows studies and efforts to be combined, and facilitates the sharing of knowledge and understanding of reef function in the mid-Atlantic region.

LIABILITY

The National Fishing Enhancement Act of 1984 (P.L. 98-623, Title II), Section 205 C, addresses the legal liability of the artificial reef permittee, the materials donor, and the federal government. These liability considerations can be summarized as follows:

1) A Federal government decision to permit a reef in a particular place or to require certain materials for construction would not create liability, even if there were some risks involved, assuming that the explicit requirements of the National Fishing Enhancement Act of 1984 (NFEA) have been satisfied

2) A donor of materials for reef construction, once title has transferred, is immune from liability if materials meet the requirements of the National Artificial Reef Plan.

3) The NFEA does not address the transporting of reef materials. All maritime accidents, injury to crew, grounding, premature discharge, collision or sinking would have a liability situation similar to any other maritime context.

4) While the permittee is liable for failure to place and mark reefs (PL 998-633 Section 205 (C)(2)), strict adherence to the requirements of the permit will immunize the permittee from liability for injuries resulting from those activities required in the permit.

5) Once properly located and marked and periodically monitored by the permittee as required by permit, there is little potential for liability and it is each vessel owner's responsibility to avoid collision.

6) The liability of the permittee in cases of diving accidents associated with artificial reefs is similar to a municipality's liability for accidents in a public park. Liability in each case would involve determination of comparative negligence of the diver and the permittee.

The State of Delaware will utilize the following policy to ensure compliance with the liability conditions of the National Fishing Enhancement Act of 1984 and thereby minimize liability:

A. The Division of Fish and Wildlife or authorized representatives will monitor and inspect all reef construction activities to insure compliance with all permits.

B. Vessels or material donated to the Delaware Artificial Reef Program will be the responsibility of the donor until the vessel is sunk or the materials placed on the reef site,

with the exception of Navy owned vessels, which required Delaware to take title before the material is transported for sinking. If such time occurs, as the Navy alters their requirements to allow them to retain title through the sinking or placement of reef materials, the State of Delaware will not assume title until vessel/material are reefed.

C. Marine contractors will assume full responsibility and liability for all donated materials being transported until properly deployed on permitted sites in accordance with permit specifications. The marine contractor will also assume responsibility for the safety of his personnel and equipment and have in place, prior to commencement of work, insurance appropriate to cover this liability.

D. Artificial reef users will be advised through public announcements that they may use a state artificial reef at their own risk.

E. No portion of this document is intended to imply that the State of Delaware shall or intends to waive sovereign immunity as described in the State constitution.

FUNDING

Support for artificial reef development and management in Delaware takes many forms. The support sources include federal, state, and local governments, as well as industry and private sector donations. The Division of Fish and Wildlife also utilizes donated materials, donated labor or services, and mitigation funds.

Federal funding for the reef program is provided through the Federal Aid in Sport Fishing Restoration Act. Monies are collected from anglers and boaters through an excise tax on fishing and boating equipment, motorboat fuel, and import duties. These monies are allocated the next year to state fisheries agencies, specifically for use in sport-fish restoration, wetlands conservation, boating safety, and boating access projects.

The Division of Fish and Wildlife must generate one non-federal dollar for every three dollars requested of Federal funds. Therefore, the State of Delaware is both monetarily and environmental committed to responsible program development and long-term management. The State of Delaware funds the artificial reef program through a variety of sources to match federal aid including: general or specific appropriations, allocations from the unrebated state tax on boating motor fuel, and allocation of special funds (e.g. boat ramp certificate) dedicated to fish restoration projects.

Private donations have enhanced the Delaware Artificial Reef Program. These donations can take several forms, including: donations of money, value of donated labor or services, donated materials,

MITIGATION

Mitigation represents another source of funding that the Delaware Artificial Reef Program has utilized. Artificial reef mitigation is the development of artificial reefs in return for the loss of aquatic resources due to conflicting land and water uses. The COE constructed artificial reef structures near Brown Shoal are off-site mitigation for the loss of fish nursery habitat and loss of fishing opportunity for a dredged material storage area that was expanded in the Delaware River at Wilmington Harbor, South.

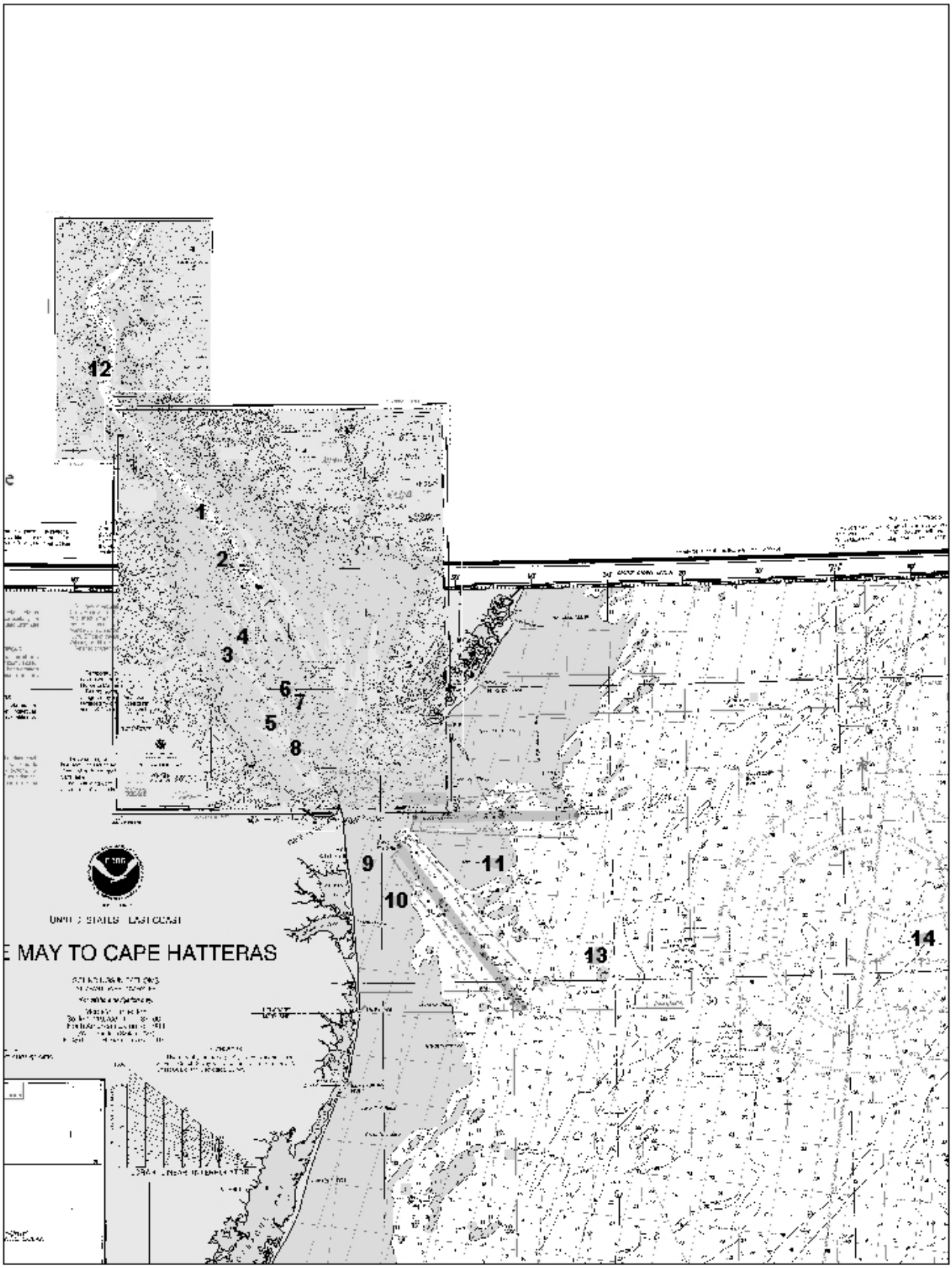


Figure 1: The locations of Delaware's 14 permitted reef sites.

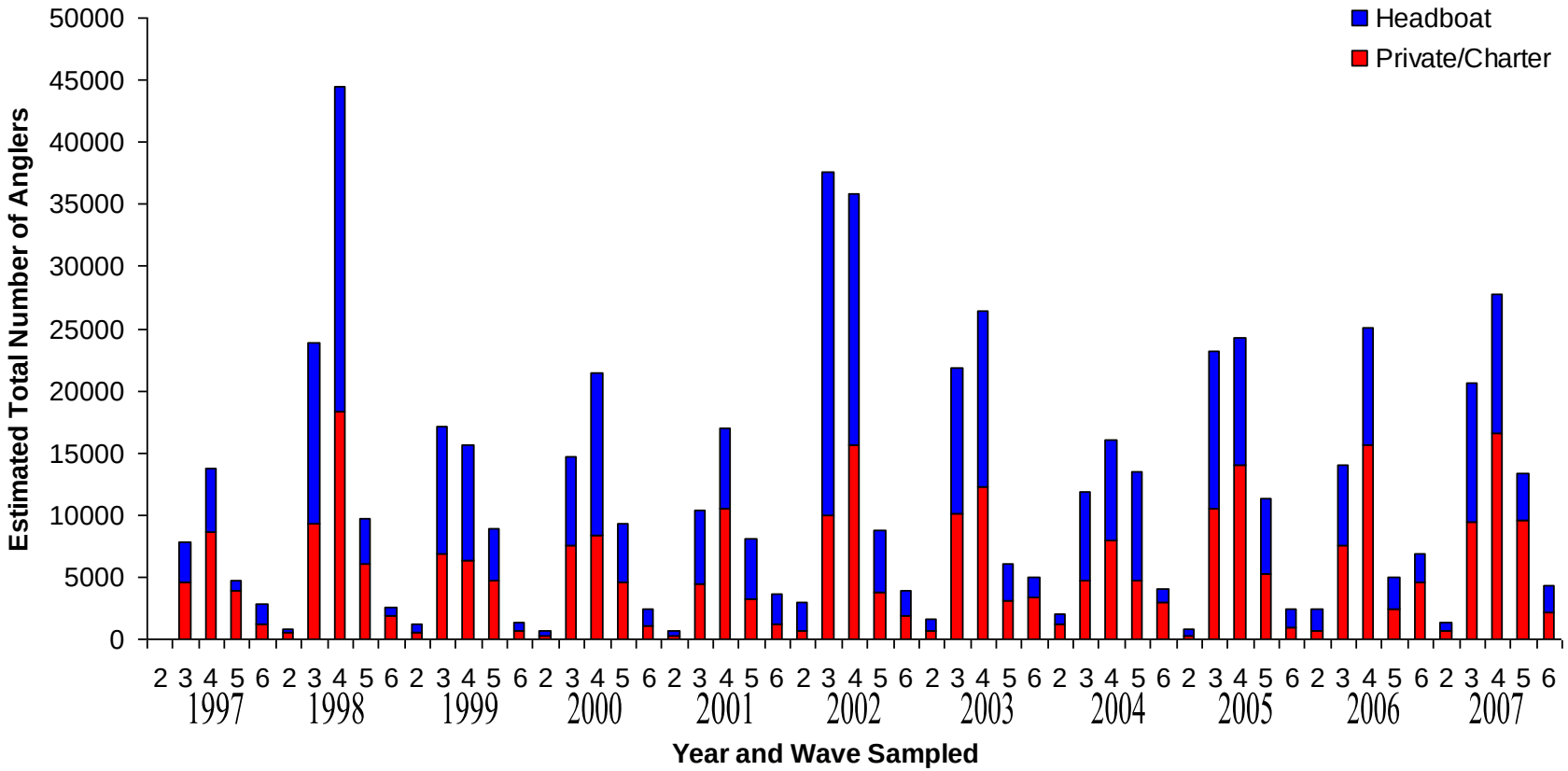


Figure 2. The estimated total number of anglers on headboat and private/charter boats that fished all reefs (reef estimates summed) by wave and by year sample

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