UPPER CHESAPEAKE BAY OYSTER REEF RESTORATION PROJECT

Final Report
1995 Grant
Award No. NA56FU0443

Maryland Department of Natural Resources
Fisheries Service
Tawes State Office Building
Annapolis, Maryland 21401

John W.S. Foster, III
Project Officer

Upper Chesapeake Bay Oyster Reef Restoration

Objective

The objective of the Oyster Reef Restoration project was:

- to restore hard substrate, vertical profile and bottom roughness of historic oyster reefs to continue to provide suitable surfaces for the attachment and growth of the oyster reef community and associated fish assemblages.

Background

The economic significance of the oyster harvest in the Chesapeake Bay has long been recognized (Kennedy and Breisch 1981). What is only now becoming widely appreciated is the importance of the oyster in the natural functioning of the complex ecosystem that is the Chesapeake Bay. Historically, oysters may have been important in maintaining water quality by removing algae and silt from suspension. Furthermore, the hard bottom substrate formed by natural oyster reefs is essential to the existence of many other benthic organisms, and beneficial to many finfish (Newell and Breitburg 1991). Although soft mud bottom benthic communities

UNITED STATES
DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
State, Federal & Constituent Programs Division

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Final REPORT

Grantee: Maryland Department of Natural Resources, Fisheries Service

Project No:

Grant No: NA56FU0443

Project Title: Upper Chesapeake Bay Oyster Reef Restoration Project - 1995

Period Covered: July 1, 1995 - June 30, 1996

Prepared by: John W.S. Foster, III John W.S. Foster

Approved by: Ben Florence Ben Florence

Date: Dorothy Leonard Dorothy L. Leonard

Statutory Funding Authority: __Anadromous Fish Conservation Act (P.L. 89-304)

- X Chesapeake Bay Studies
- __Endangered Species Act
- __Interjurisdictional Fisheries Act (Title III of P.L. 99-659)
- __Magnuson Act
- __Oyster Disease Research
- __Saltonstall-Kennedy
- __Unallied Industry Projects
- __Unallied Science Projects

predominate within the Bay today (Holland et al. 1987), only 140 years ago oyster reef communities were extensive (Newell 1988). It is estimated that there has been a 25 to 38 fold decline in oyster stocks in the Bay (Newell 1988, Rothchild et al. 1991). These oyster reefs provide habitat and food resources for a number of mobile species that are ecologically important to the Chesapeake Bay ecosystem (Newell and Breitburg 1991). It was primarily the fishing gear, especially patent tongs and dredges, that spread the shell reduced the physical profile of the oyster reef to the characteristically flat bars found in the bay today (Rothchild et al. 1991, Winslow 1884).

The benefits of re-establishing the historic oyster reef communities to the Chesapeake Bay have been well documented in recent literature and management reports (Myatt and Myatt 1990, Newell 1988, Rothchild et al. 1991, Newell and Breitburg 1991, Chesapeake Bay Program Action Agenda, 1991). The rebuilding of these reefs will take more than just waiting for the oyster communities to naturally re-establish. Several restoration techniques to create siltfree bottom topography and suitable surface substrate will be constructed and evaluated.

The reconstruction of Chesapeake Bay oyster reefs is based on historic descriptions of Bay reefs. Winslow (1884) described a natural oyster rock as a well defined area where "oysters are crowded together so closely that they cannot lie flat but grow vertically upwards, side by side. They are long and narrow, are fastened together in clusters..." This description of subtidal oyster reefs in the Chesapeake is similar to oyster reefs in North Carolina (Grave 1905) and to intertidal oyster reefs observed today along the South Atlantic and Gulf coasts.

Based upon these historic characterizations and the recommendations of a 1990 review of Maryland's Chesapeake Bay artificial reef program (Myatt and Myatt 1990), Maryland Fisheries Division proposed to re-create the oyster reef complex by placing clusters of hard substrate for the attachment of a 'oyster reef community'. The initial requirements of such structure and area are:

height	- 0.5 - 2.0 m
slope	- 1:1 or greater
material	- suitable for the attachment of fouling community - interstitial spaces similar to oyster clusters
bottom	- bearing strength to artificial structures
location	- historical oyster growing area outside existing live bottom.

Habitat management has been on-going on the Chesapeake Bay since at least the 1880's. Winslow (1884) reported that oyster shell was placed on barren areas near natural oyster reefs to increase the harvestable quantity of oysters. Additionally, these new oysters were a more desirable flat product for the market than the traditional Bay oyster, due to less competition for space. Since the 1960's, Maryland's Oyster Repletion Program has been spreading fossil shell over depleted bars to provide new substrate for spat settlement. This program was not designed to restore historic oyster bars but to supplement the commercial oyster fishery with a harvestable product.

Maryland's Artificial Reef Program built a series of 'state of the art' reefs (fiberglass, preformed concrete and quarry rock) to determine an appropriate Bay reef design for estuarine species. This work indicated the effectiveness of low profile (0.5 - 2m) hard substrate reefs to simulate oyster reefs. It also became evident that traditional marine reefs built strictly for sport fish harvest were not economically justified due to the behavioral characteristics of estuarine fish species, though oyster reef restoration is justifiable when based on environmental enhancement of the predominating benthic habitat structures which have been lost (Myatt and Myatt 1990).

In 1968 Maryland DNR built a series of fish reefs from concrete pipe and concrete ballasted tire units. The concrete pipe survived about 10 years before it began to sink into the mud substrate. At least one tire reef survives and is still functioning in Eastern Bay. After 24 years the units are intact, in their original location and are covered with oysters(102 on an eight tire unit) and associated fouling organisms. Additionally, oyster shells that have fallen off the units have provided substrate for the development of a reef community up to 2 meters outward from each unit.

Approach

The approach to this project was divided into two parts:

1. construction and placement of structures on reef sites, and
2. evaluation and monitoring of materials used in the construction of reefs.

The former included predeployment surveys of each site and the construction and deployment of the reef structures. The latter part was the biological evaluation of community development on materials used in the construction of reefs.

Deliverables

The deliverables proposed for this project included:

1. a description of the construction activities,
2. location of the reef construction,
3. monitoring activities to include an evaluation oyster reef growth and physical monitoring of the reef sites, amd
4. budget summary.

The criteria for Chesapeake Bay artificial oyster reef structures was previously noted.

The structure design used in this project, which met this criteria at a reasonable cost, was oyster shell piles designed to maximize slope and surface area for added habitat diversity.

Shell

Maryland has dredged fossil oyster shell for use as cultch in the Oyster Repletion Program since the 1960's. The state has a negotiated contract with C. J. Langenfelder and Son, Inc. of Stevensville, Md. to dredge shell from deposits in the upper Chesapeake Bay, haul and plant the shell onto oyster seed areas. The following year part of this shell and attached spat are transplanted to more favorable growing areas. It was determined that utilizing this contract would be the more cost effective means of having oyster shell structures constructed on reef sites. In a contract modification, the contractor agreed to place mounds of oyster shell at several reef sites in the Bay. The specifications called for fossil shell piles of 'normal planting quality' to have:

slope	1:1 or greater
height	> 3 ft., < 6 ft.
base	less than 3 X height
shape	conical
distribution	20 to 30 piles per acre, random placement.

The volume of each pile was to be 8 to 10 cubic yards and would have affected structure restoration on 200 to 300 acres of barren Bay bottom. A cost adjustment within the contract limits was made for the increased effort necessary to meet the specifications.

The contract called for the work to occur immediately following the 1995

Repletion Program's shell planting in August 1995. The contractor delayed the work until June 1996 requiring an additional grant extension. When the work was started, the mechanism the contractor designed to construct the specified pile design was not effective and it became necessary to modify the design specifications so that construction could be completed in a timely This modification permitted the contractor to anchor the barges and use a front end loader to dump shell directly overboard and to wash a quarter of the shell overboard to create large piles. The piles created varied in size, and averaged about 300 ft. long, 100 - 500 ft. wide and had elevations of 4 to 12 ft. off the bottom. Up to 3,500 cy was used to create a pile.

The primary design objective of the steep slope and surface area to volume ratio was not met as a result of the alteration in off loading methods. The high slope was specified to reduce sediment buildup and maximize the life expectancy of the structures.

A total of 34,749 cubic yards (cy) was placed at four locations creating 153 acres of potential oyster reef and sport fish habitat:

Hacketts	6183 cy	53 acres
Old Fort, Severn R.	1907 cy	12 acres
Ulmstead Point	2039 cy	12 acres
Plum Point	24620 cy	76 acres

Figures 1 and 2 indicate the areas of habitat enhancement on each reef site.

Reef personnel directed the placement and monitored the results of the shell placement. The area of placement for each barge load of shell was marked with buoys. The location of the barges was monitored with GPS during off loading activities and the elevations of the piles were recorded after construction.

The cost of the shell placement was $217,887, or $1,424 and 227 cy per acre.

<u>Monitoring</u>

The monitoring was broken into two activities:

1. An evaluation study of growth and survival of oyster spat on several different cultch materials; and
2. An investigation of the feasibility of using acoustics to differentiate bottom sediments in the Bay.

Spat growth study

The evaluation study of the growth and survival of oyster spat on several different substrates types was concluded in August 1996. The draft study report is included in Appendix A.

Acoustic bottom classification investigation

The future of oyster reef restoration was recognized to be dependent upon suitable, cost effective cultch and substrate sources. One such material is oyster shell buried on historic natural oyster bars. The state of Virginia has established that such resurrection is possible and possibly cost effective if fossil shell becomes less available, (Chesapeake Bay Program, Aquatic Reef Committee reports, 1995). Before such shell resurrection is performed, the location and availability of the resource needs to be determined. It was with this objective that the initial enquiries into the feasibility of remote acoustic sensing of the bottom was initiated.

The existing surveys of Bay bottom types performed by the Maryland Geological Survey were done on a one kilometer grid sampling. The resolution of this scale is far too gross to determine the feasibility of resurrecting buried shell, if any appreciatable quantities actually exist. In an effort to increase the resolution of existing bay bottom surveys and to reduce the effort and expense of physical geological sampling that lead to the refinement of an acoustic bottom classification system being developed by the Naval Research laboratory at Bay St. Louis, Ms. The NRL Seafloor Classification System uses 30 and 50 kilohertz frequencies to probe the top four meters of the bottom with a resolution sufficient to identify a one inch layer of shell. The hardware was developed in the 1970's in Germany, though the abilities of recent computer and software development have allowed for the refinement in differentiation and interpretation of the acoustic signal.

The Navy system was developed to identify bottom types where mines can be readily identified, hence increased ship safety. Experimental work in Lake Pontchartrain, Ms. found what appeared to be buried oyster reefs. All development work had occurred in high salinity waters. NRL staff was interested in investigating how the system would function in oligo- and mesohaline waters and volunteered to bring their equipment to the Chesapeake Bay for an experimental evaluation. The work was jointly supported by NRL, Maryland Fisheries Division, and MGS.

Initial results of the acoustic surveys over several areas of the Bay which MGS had detailed data included the mouth of the Patuxent River Hog Island Bar, Choptank River at Cook Point Bar, and a reef site off Plum Point. Copies of several tracts and

Don Walters are included in Appendix B.

The Seafloor classification System development is still underway. Results of the Bay cruises indicated a promise of an economical, remote means of high resolution means of mapping upper bottom sediments and identifying potential oyster shell resurrection areas.

All monitoring activities were performed as matching activities by the Maryland Reef Program staff.

Budget

The table of expenditures are attached in Table 1. It should be noted that a new category of match, fossil shell royalty value, has been included in this project. This is the first time Maryland has considered using the value of this natural resource for matching federal funds. This inclusion was requested as a budget amendment and approval was received in February, 1996. A copy of the request and approval are included in Appendix C.

Table 1. Oyster Reef Restoration Project fund expenditures for 1995 grant, NA56FU0443.

	Federal	State
Shell reefs		
C.J. Langenfelder	$237,000	$17,351
Shell depletion allowance		88,750
Monitoring and administration		
J. Foster 84%		45,110
D. Myatt		37,697
K. Holder		22,736
S. Alspach		25,356
Totals	$237,000	$237,000

Citations

Grave, C. 1905. Investigations for the promotion of the oyster industry of North Carolina. U.S. Comm. of Fish and Fisheries Rpt. XXIX:247-341.

Holland,A.F., A.T.Shaughnessy, and M.H.Hiegel. 1987. Long-term variation in mesohaline Chesapeake Bay macrobenthos: Spatial and temporal patterns. Estuaries 10:227-245.

Kennedy,V.S. and L.L.Breisch. 1981. Maryland's oysters: Research and Management. Maryland Sea Grant Publication UM-SG-TS-81-04 pp 286.

Myatt,E.N. and D.O.Myatt. 1990. A study to determine the feasibility of building artificial reefs in Maryland's Chesapeake Bay. Report to Maryland Department of Natural Resources by International Weighmaster, Inc. pp95.

Newell, R.I.E. 1988. Ecological Changes in Chesapeake Bay: Are they the result of overharvesting the American oyster (Crassostrea virginica)? Pages 536-546 in: M.Lynch, (ed.) Understanding the Estuary: Advances in Chesapeake Bay Research. Chesapeake Research Consortium Publication 129, Gloucester Point, VA.

Newell,R.I.E. and D.Breitburg. 1991. Oyster reefs. Appendix to draft Chesapeake Bay Strategies for restoration and protection of ecologically valuable species. Living Resources Subcommittee of Chesapeake Bay Program, Annapolis, MD.

Rothchild,B.J., J.S.Ault, P.Goulletquer, W.P.Jensen and M.Heral. 1991. The decline of Chesapeake Bay oyster population: A century of habitat destruction and overfishing. in report to Maryland Department of Natural Resources, (UMCESS) CBL 091-049, pp239.

Winslow, F. 1884. Report to the Oyster Commission of the State of Maryland. Annapolis, MD pp183.

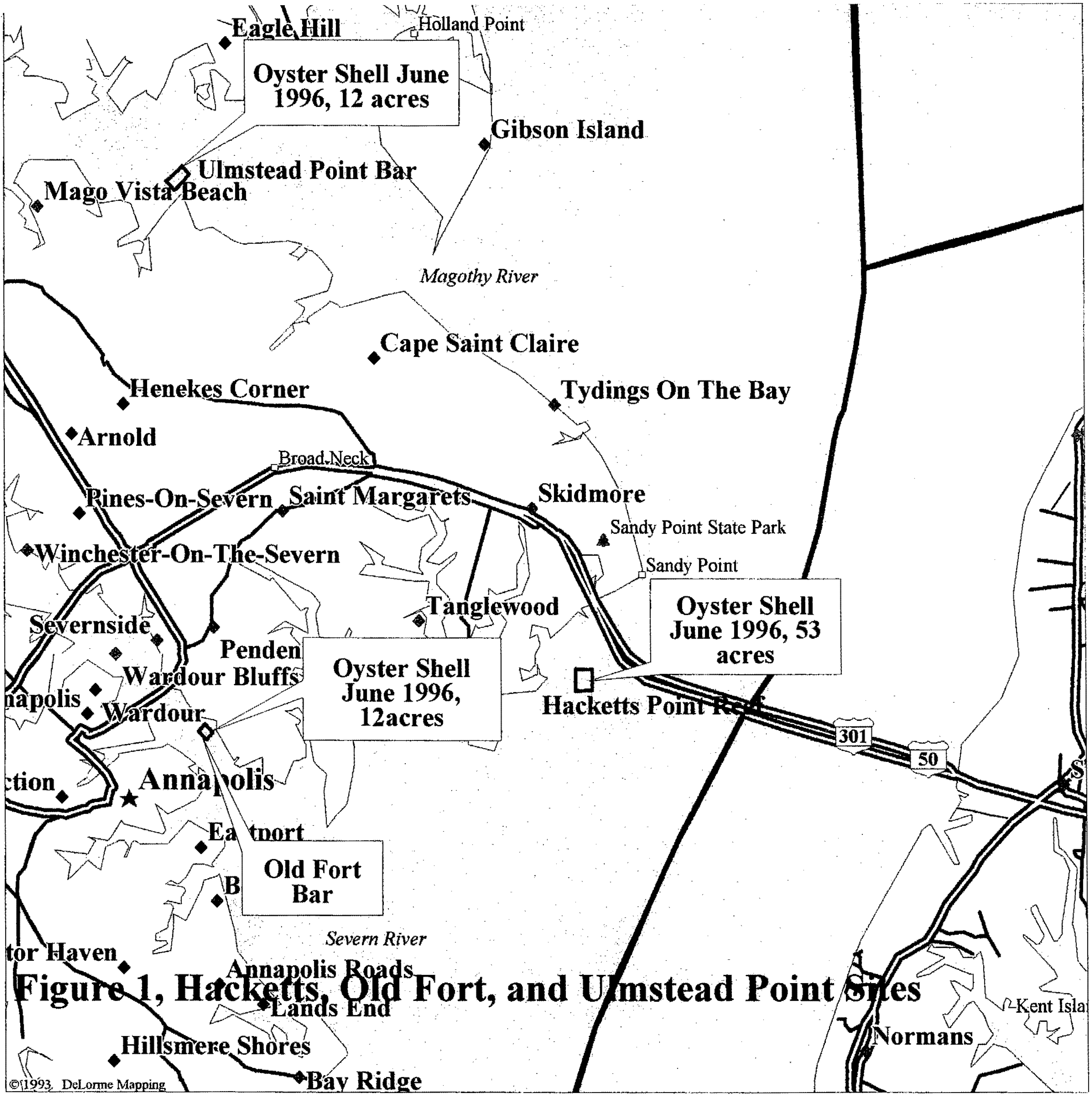


Figure 1, Hacketts, Old Fort, and Ulmstead Point Sites

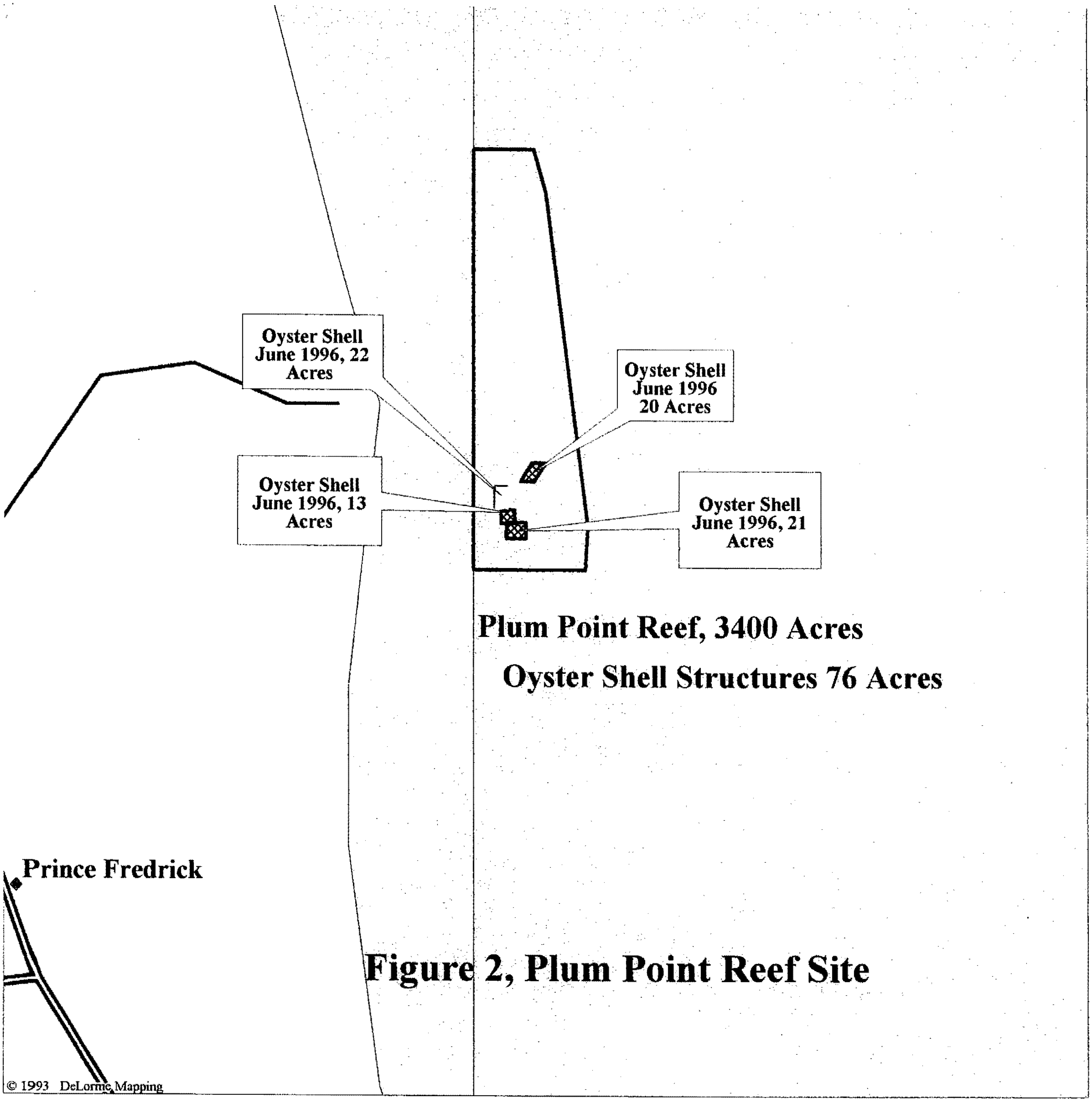


Figure 2, Plum Point Reef Site

Appendix A

1995 NMFS Grant

OYSTER SPAT SETTLEMENT ON SUBSTRATES SUITABLE FOR ARTIFICIAL REEFS

Sam Alspach
Western Maryland College
Westminster, MD

Introduction:

When it comes to the question of recruitment of oyster spat in the natural environment several methodologies currently exist to measure the recruitment of a juvenile cohort of oysters for a particular year class. The traditional oyster bar survey, typically performed in the fall, counts and sizes juveniles which have successfully been recruited into the population from the onset of spawning and survivability throughout the summer months. Usually this fall survey is performed by biologists at the DNR to gain more details about natural fluctuations in cohorts of oysters, weekly, bimonthly, or monthly surveys can be performed. Scientific collection of spat is traditionally observed on artificial materials such as slate or PVC plates rather than on natural materials. An advantage of this latter method is that it fine tunes the spawning, setting periodicities of the natural population.

Since artificial materials such as slate and PVC are known to be favorable surfaces for the settlement of oyster larvae, construction of larger sized structures of materials known to favor settlement would increase the surface area for natural recruitment on an already depleted bottom in the Chesapeake Bay. Changes in the bottom sediment composition have been noted for large areas of the Bay, especially as a result of the loss of natural oyster bars. This loss of cultch is attributed to a combination of over-harvesting of adult oysters, disease and pollution.

Aside from slate and PVC, many artificial materials and natural products are known to be adequate substrates for the recruitment of oyster spat. Such materials include glass, frosted glass, tires, clam shell (several species), asbestos, concrete, and natural rock such as fossilized coquina marl. In addition, materials of opportunity such as sunken vessels and concrete structures also have had success in recruitment. However, to construct a large sized structure that meets the demands of deployment into the estuarine environment requires materials which lend themselves to the rigors of an ever-changing estuary. Consequently concrete cubes and coquina marl were chosen to study their success in recruitment and survivability of oyster spat.

Since 1991, the Artificial Reef program under DNR deployed a variety of artificial substrates in the mesohaline Chesapeake Bay with the intention that these substrates would serve as favorable settlement surfaces for benthic fouling community species, especially the American oyster. Crassostrea virginica. To date, detailed analysis of 100 cm^2 of each substrate has shown that normal assemblages of fouling organisms are attracted to and settle on slate, PVC, concrete and tires. Members of this assemblage include: barnacles, bryozoans (2 species), hydroid, tunicates, amphipods, and several species of neraid polycheates. At no time, were oyster spat observed on the test plates. However, spat were observed on the interior of tire reef structures. Consequently, this raises some interesting questions which require further investigation. One immediate question is: Are our substrates competent to attract settlement of oyster larvae? If not, why, and are there better choices of artificial material?

Therefore, we undertook a controlled laboratory and field study whereby we exposed each of our substrate types to a population of hatchery-reared oyster larvae of known density. The oyster larvae staged at the point in the life cycle just prior to settlement but at a time where settlement is imminent. Three replicate experiments with the same cohort of oyster larvae were performed. Microscopic analysis for settlement density and spacing were made.

Each substrate type with known numbers of oyster spat was deployed to a field site where known artificial reef structures are present. Spat on each substate were counted and measured to monitor in situ survival and growth. Control substrates remained in the laboratory to be monitored. Areas for deployment will be the Choptank River system (Oxford Laboratory Pier) and Hollicut's Noose.

Those materials we used for substrates include:

1. Concrete cubes 12 x 12 inches square
2. Coquina marl boulders piled on a 24 x 24 inch plastic tray
3. Cleaned, natural oyster shell laid flat in a 24 x 24 inch plastic tray

Spat settlement on these substrates can indicate the suitability of each for larger, long-term construction of artificial reef habitats. Similarly, the use of natural materials can indicate their role in attracting oysters to reef structures, as well as their possible incorporation into a reef unit.

Methods and Materials:

Three tanks were used in the summer of 1995 at the Oxford Laboratory for the larval settlement studies on selected reef materials: concrete cubes, trays of oyster shell, and coquina marl. Each tank received continuous flow through ambient Tred Avon river water and aeration. Basic salinity and temperature were monitored.

Prior to the introduction of oyster larvae these structures were presoaked for approximately one month in the tanks, then cleaned of major fouling just before the addition of larvae. Eyed oyster larvae (D shell stage of approximately 150-200um) were obtained from the DNR oyster hatchery at Deale Island, Maryland, on nytex screen at a concentration of about 1 million. Upon arrival at the Oxford facility, the larvae were put into suspension in a five gallon bucket with ambient Tred Avon river water, gently swirled for an even distribution, and allowed to equilibrate until microscopic examination clearly indicated they were actively swimming. At this time equal doses were placed into each tank. The continuous flow water was shut off, but aeration was maintained.

Larvae were artificially fed a diet of algal monocultures of either Isochrysis or Tetraselmis or both. This regime continued until microscopic or visual inspection indicated that settlement had occurred on the substrates. At that time the ambient water supply was turned on. The recently set spat were then allowed to grow for about one month before counting and sizing individual oysters.

Each substrate type was removed from the tank, the number of spat on the entire surface counted, and sized with a micrometer. Concrete cubes and coquina marl were tagged while each individual oyster shell was individually tagged for further identification after field deployment.

Replicate sets of substrates were field deployed at three locations: Crisified, MD, Oxford Laboratory Pier, and Eastern Bay (Hollicutt's Noose). Each set consists of two trays of oyster shell, two trays of coquina marl, and two concrete cubes. These sets remained in the field for one month prior to sampling.

At each sampling period, one of each substrate type was brought to the surface by divers for counting and sizing. Survivability and growth are based on the number of live juveniles found from the initial number set while growth is the increase in size from the initial set measurement. Since we were unable to consistently measure the oysters deployed in Crisfield, we have not included them in the data analysis.

In all cases, the survivability of oyster spat on concrete cubes and coquina marl exceeds that of the oyster shell which showed the lowest survivability of all substrates. For both concrete cubes and coquina there was field recruitment onto these substrates as evidenced by the greater than 100% survivability at three months. This clearly indicated that these substrates are very suitable for field or hatchery-type setting of oyster larvae.

Discussion:

Spat settlement on concrete cubes, coquina marl and shell is highly successful under hatchery conditions in tanks with ambient water flow. The average number of 5-6mm spat per $100cm^2$ is 24 for all substrates. This size class represents a post-larval settlement and survival prior to field deployment.

The results, (Figures 1, 2, and 3), clearly indicate that oyster spat settle, have greater survival, and grow faster on both concrete cubes and coquina marl than on oyster shell in the mesohaline regions of Chesapeake Bay. Because successful recruitment and higher survivability does occur on these structures, it is suggested that these structures be used to enhance the oyster reefs in the Bay. These structures also serve as hard substrate for settlement of invertebrates typically associated with the oyster reef community. Thus, a more stable, diverse community system develops. Such a climax community is healthier and less likely to be disturbed.

Figure 1. Percent Survival After 3 Months

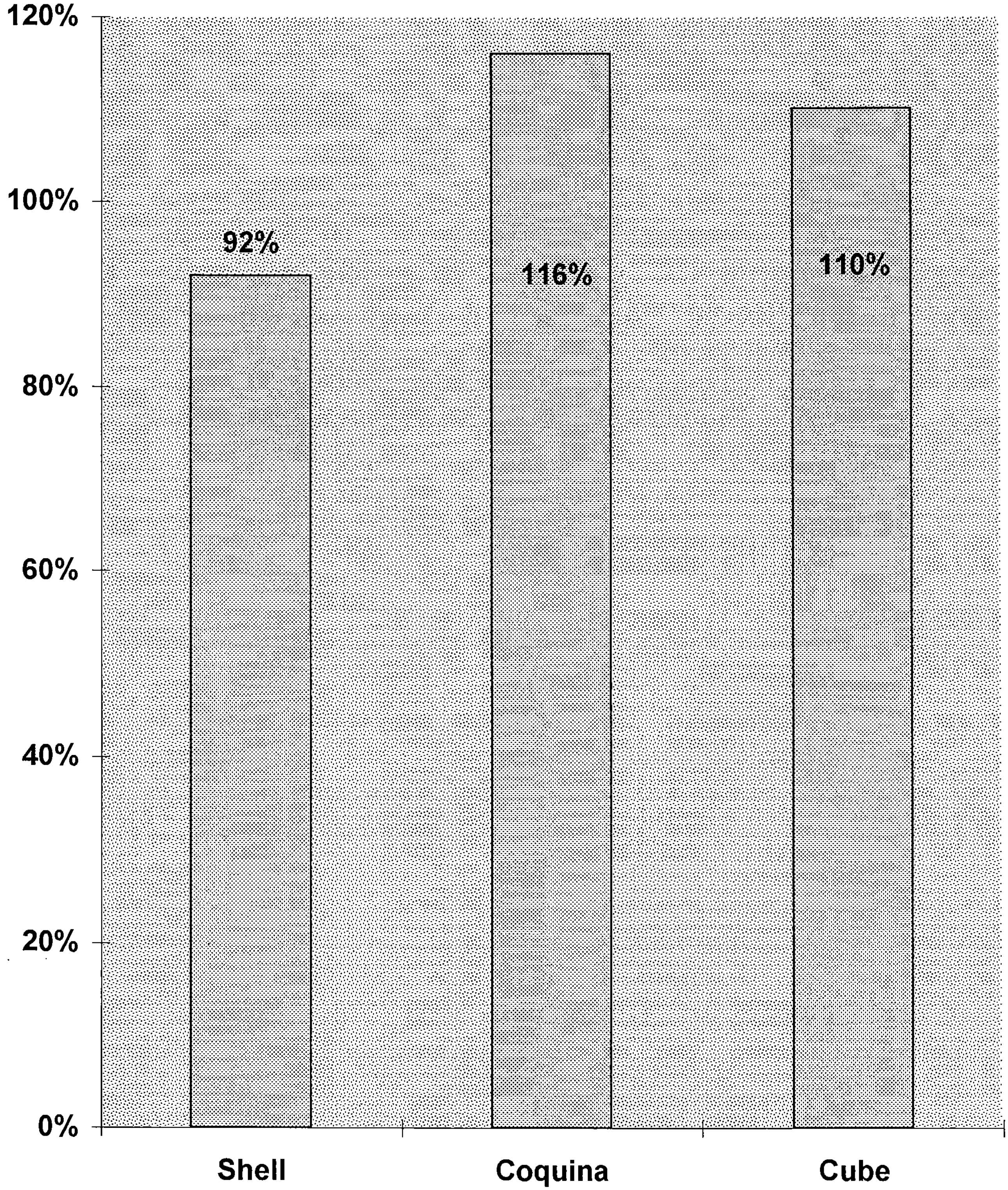


Figure 2. Percent Survival After 1 Year

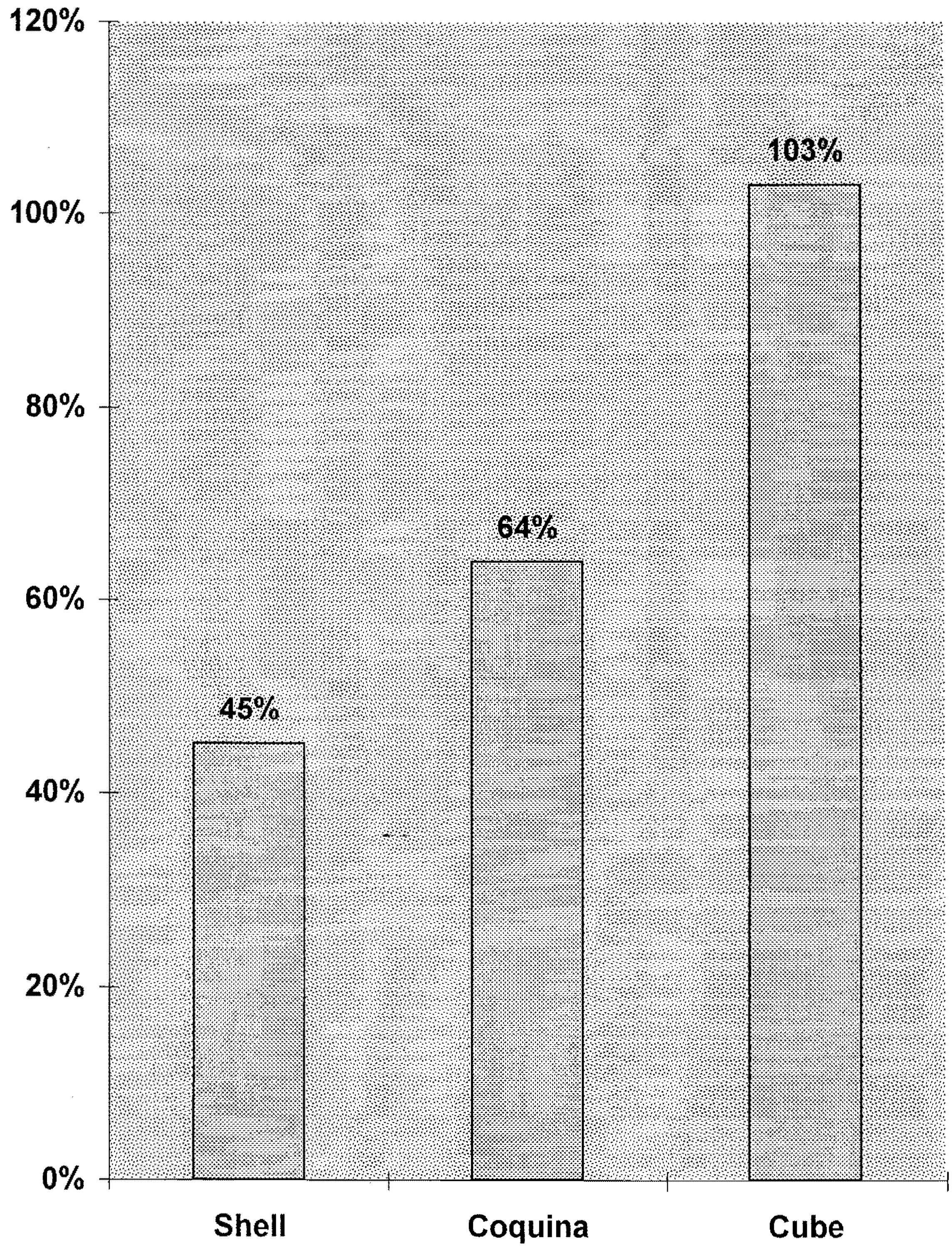
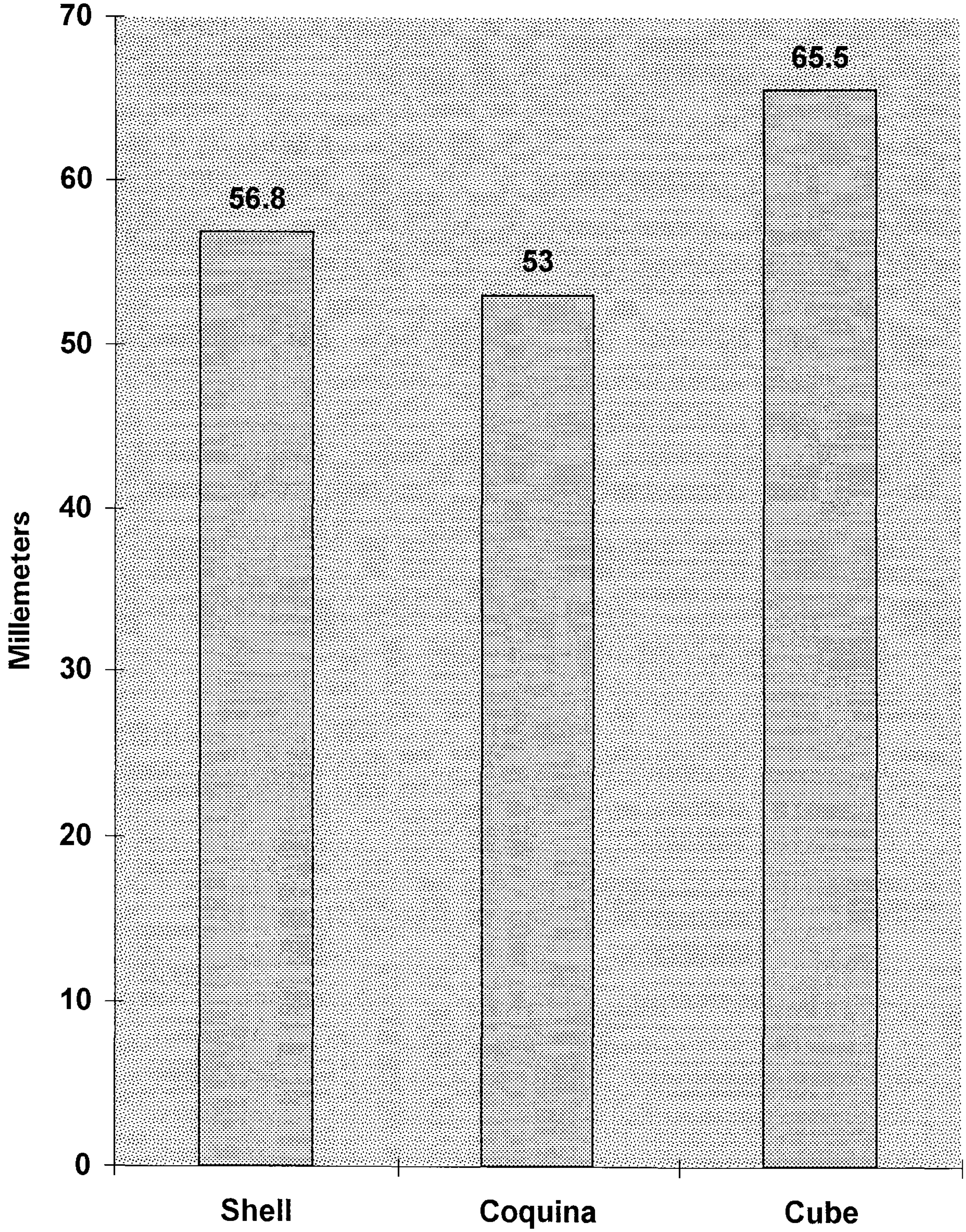


Figure 3. Average Size per Substrate



Appendix B

1995 NMFS Grant

DEPARTMENT OF THE NAVY
NAVAL RESEARCH LABORATORY
STENNIS SPACE CENTER, MISSISSIPPI 39529-5004

IN REPLY REFER TO

3910
Ser 7431/85
20 Sep 95

Mr. John Foster
Fisheries Division, Maryland Department
of Natural Resources
Tawes State Office Building, C-2
Annapolis, MD 21401

Dear Mr. Foster:

I had a programmer run the Plum Point raw data through our sediment classification computer to construct a navigation plot showing the tracks that were run last year onboard the R/V ELSER. Three copies of this plot are provided as well as a viewgraph (enclosure (1)). The lines are color coded according to the impedance scale which is included on the picture. Each line represents the upper 40 cm of the sediment column along the vessel track. Sediment cores were obtained at Plum Point and all of the other survey locations (enclosure (2)). However, I have not received the core analysis report, nor have I had time to look at the acoustic data. When I get the core report I can compare the core data to the predicted values that are shown on this plot. Enclosure (3) is a preliminary 2-D contour plot generated from the density data.

The track plot is what we 'normally' have available on the screen in real time when the data acquired by the first computer is sent over to the second computer which does the sediment property predictions. As you may recall, we did not have the second computer onboard the R/V ELSER last year because it was in transit from a survey that we had done in the Baltic. It also turns out we did not have enough room to put another full computer onboard the R/V ELSER.

The scales shown below the trackplot are a result of a regression plot of acoustic impedance vs. each sediment property (attenuation, bulk density, grain size, porosity, shear strength, sound speed). These regression curves have been empirically developed for the Navy over the last 20 years using core data. They basically provide a method for predicting sediment properties after the impedance is calculated from the raw acoustic return.

I'm sorry about the apparent mix-up regarding the vessel charges. I think everyone thought your organization would cover the R/V ELSER costs and Maryland Geological Survey (MGS) would cover the R/V DISCOVERY costs. In any case, we are very appreciative of your and your organization's support as well as that provided by Jeff Halka and the MGS in arranging for our use of the vessels to do the surveys last year. I'm truly sorry that I haven't had much time to take a good look at the data, but my work on other Navy projects during the year have pretty much precluded that.

Last week a colleague and I submitted an internal pre-proposal to continue research on sediments in the Chesapeake Bay. This would be a new start beginning sometime between October and January 1995. The proposal is for "basic research" to develop a better understanding of the interaction of biological, chemical and physical processes within fine-grained sediments in an estuarine environment. It is a smaller version of our submittal last year to the DOD/Special Environmental Research and Development Program. If funded, the first order of business would be to analyze last year's acoustic and other data from all of the eight sites which were covered during those surveys.

I've included a table that summarizes the survey sites and transects that were run (enclosure (4)), and another from Herb Herrmann of the in situ probe and core data that were obtained (enclosure (2)). This is an extensive data set that covers a wide geographic area and a variety of bottom types in the Maryland portion of the Bay.

I have been talking with Herb Herrmann (sponsor from Naval Facilities Engineering Service Center, D.C.), Peter Vogt (Naval Research Laboratory, D.C.), Jeff Halka and Randy Kerhin (MGS) regarding this data. Although we have not really worked the data up, we would like to conduct a small, informal workshop in the general Washington, D.C. area to review last year's data and also data that I will obtain during another survey which will probably take place in October aboard the R/V DISCOVERY.

I'll be coming back up to conduct another series of surveys over the same sites during the week of 16 October 1995. You are certainly welcome, at your convenience, to come along during the surveying aboard the R/V DISCOVERY. I'll just try to let Rick know so we don't overcrowd the boat on any day.

I'd like to plan on a meeting to discuss plans for a workshop during the week that I do the survey or the week after. Think about it, I'll be in touch after I get a consensus. Peter Vogt is on a trip right now, but I'll check with him on his return.

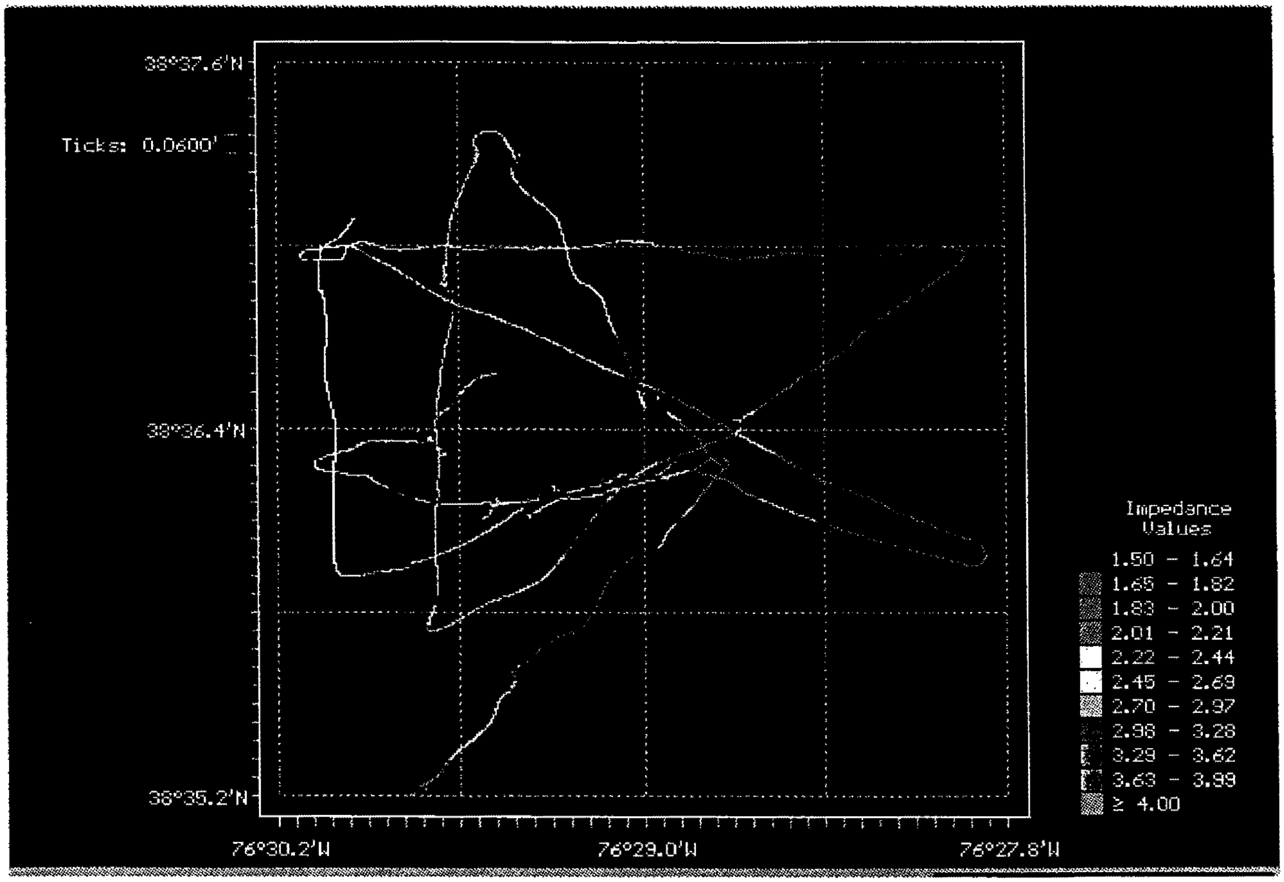
Sincerely,

Donald J. Walter

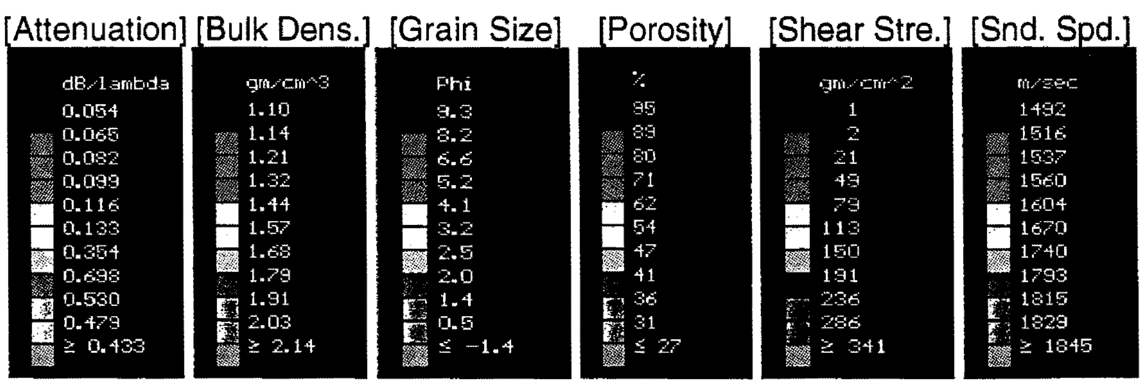
DONALD J. WALTER
Oceanographer

Encl:
(1) Track Plot with color coded surficial sediment layer (40cm) properties.
(2) Table summarizing in-situ sampling that was at each survey site.
(3) 2-D contour plot of estimated bulk density at Point site, Chesapeake Bay.
(4) Table of acoustic data collected at each site and along transects between sites.

Copies to:
NFESC (H. Herrmann)
Maryland Geological Survey (J. Halka)



(a) Color plot of surficial sediment acoustic impedance along tracklines run off Plum Point, Md during August 1994 aboard the R/V Elser.



(b) Sediment property reference scales shown below the trackplot indicate color scale that represents a corresponding predicted value for the specific property.

(enclosure 1)

Appendix C

1995 NMFS Grant