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VIRGINIA RECREATIONAL FISHING DEVELOPMENT FUND
SUMMARY PROJECT APPLICATION*

NAME AND ADDRESS OF APPLICANT:	PROJECT LEADER (name, phone, e-mail):
Virginia Institute of Marine Science P.O. Box 1346 Gloucester Point, VA 23062	Rochelle D. Seitz (804) 684-7698, seitz@vims.edu
PRIORITY AREA OF CONCERN:	**PROJECT LOCATION:**
Habitat Improvement	VMRC Artificial Reef sites--Northern Neck reef and Poquoson reef

DESCRIPTIVE TITLE OF PROJECT:

Habitat Suitability for Artificial Recreational Fish Reefs

PROJECT SUMMARY:

This proposal requests funds to complete the currently funded RFAB project to monitor environmental factors surrounding recently deployed subtidal artificial reefs that were designed to attract large, structure-dependent fish such as sheepshead and tautog. We will investigate the effectiveness of placement of various combined artificial fish/oyster reefs in enhancing fish production of structure-associated recreational fish (e.g., sheepshead) by examining the prey food base and predator-prey interactions along with environmental conditions. Based on knowledge of habitat quality, we hypothesize that where environmental factors are optimal, the prey will develop, and production of large fish will be enhanced.

EXPECTED BENEFITS:

Field sampling of the environmental parameters on recently deployed artificial reefs will give direct evidence of optimal conditions for recreational fishery species that develop on artificial reefs. A comparison of environmental factors will allow a quantitative understanding of ecological conditions beneficial to local recreational fishery species and their food-web interactions. We will document increased production of the ecosystem that stems from optimal deployment of these reefs and a comparison among reefs will identify key habitat characteristics that are beneficial for increased production.
enhancement of fish production.

COSTS:

VMRC Funding:	$ 44,244
Recipient Funding:	$5,617
Other Funding Sources (please list) **:**	State/NOAA/ACoE
Total Costs:	$ 49,861

Detailed budget must be included with proposal.

Updated 4/27/06

*This form alone does not constitute a complete application, contact Sonya Davis at 757-247-8155 or sonya.davis@mrc.virginia.gov

Habitat Suitability for Artificial Recreational Fish Reefs

P.I.: R.D. Seitz

1.) **Need**

A. Introduction

Habitats vary in physical and biological attributes that can influence their ability to support various species. Habitat Suitability Indexes (HSIs) are numerical indexes that demonstrate the capacity of a given habitat to support selected species. They are influential management tools and have been used for many years by natural resource managers (Cole and LeFebvre 1989). Species-habitat relationships are important in determining the HSIs, and positive correlations of environmental factors with elevated species abundances can indicate increased habitat suitability; however, these models do not prove cause and effect relationships (Brooks 1997). HSI model results represent the interactions of the habitat characteristics with abundance of species. A value of the habitat suitability (between 0 [not suitable] to 1 [optimal]) can aid in understanding species-habitat relationships and can lead to educated decision making (Verner et al. 1986) with regard to locating artificial reefs in optimal habitats. Various ecological factors affect the abundance and density of species within a habitat and these factors can be predictive of habitat suitability. For example, recent analyses of benthic data from the Chesapeake Bay show that dissolved oxygen is a strong predictor of benthic community density (Fig. 1), suggesting that optimal habitats can be predicted by oxygen conditions. We propose to examine environmental factors that affect reef success with the goal of predicting where to place future reefs to optimize fish production.

Artificial reefs can enhance the production of recreationally important fish by providing habitat for structure-dependent fish (Seaman 2000) and by increasing prey availability for resident and transient fish that forage on the reefs (Peterson et al. 2003a). The empirical means of estimating fish production on artificial reefs has been developed and used successfully to demonstrate enhanced production of fish with artificial reefs (Peterson et al. 2003a). There are various ways by which fish production is increased by artificial reefs. For example, if there is a bottleneck for survival of early life history stages of fish, then providing additional habitat (e.g., artificial fish reefs) is projected to cause increased recruitment of the species. Moreover, artificial reefs may provide additional food resources, via the reef-associated invertebrate prey, that may enhance growth of fish species associated with the reef (i.e., bottom-up control), or reefs can enhance fish survival by providing refuges from predation (Hixon 1998; Peterson et al. 2003a, b). If recruitment is limited by habitat area, additional reef habitat can result in increased fish production by improving habitat area, or by augmenting growth currently limited by reef refuges and associated prey (Peterson et al. 2003a). Given these strong arguments in support of enhanced fish production with artificial reefs, it is typically recognized that such reefs can benefit recreational anglers who fish on artificial reefs.

Bottom-up control of production has been demonstrated in several fisheries species. A combination of predation (i.e., top-down factors) and food limitation (i.e., bottom-up factors) likely influences species distributions in marine, freshwater, and terrestrial habitats, depending on aspects of the local food web (Posey et al., 1995; Menge et al., 1996). At broad spatial scales, bottom-up or physical factors may be more important than top-down factors (Power, 1992; Menge et al., 1997; Seitz and Lipcius, 2001). For instance, a recent study provided evidence for bottom-up control of an upper level omnivore (i.e., the blue crab) by its primary prey (i.e., the Baltic clam) (Fig. 2). Similarly, we expect that abundance of fish on artificial reefs will be directly related to the abundance of their prey.

We request funds to assess environmental factors that influence the production of subtidal artificial fish reefs. The reefs attract large, structure-dependent fish, such as sheepshead and tautog. Specifically, we will investigate the effectiveness of artificial fish reefs in enhancing local production of structure-associated recreational fish in two different locations that vary in environmental characteristics. We will accomplish this by examining environmental factors, the prey food base that develops on recently deployed reefs, and predator-prey interactions through direct sampling of fish gut-content analyses. We expect that at reefs where environmental factors are suitable, fish have adequate prey, and fish feed upon intermediate predators such as mud crabs, then the production of fish will be enhanced. Sampling of artificial reefs and fish diets, combined with mathematical HSI modeling, will allow quantification of habitat suitability and will elucidate how this relates to reef production. Ultimately, we will be able to determine which environmental factors promote production of recreationally important fish. We will then integrate our findings with those of the complementary project by Lipcius on fish production and provide recommendations on the optimal reef types to increase recreational fish production on new reefs.

Based on knowledge of food-web interactions (Chesapeake Bay Fisheries Ecosystem Plan), we hypothesize that on artificial reefs in quality habitats where fish have abundant prey and the benthic community provides high production value, the fish will have increased productivity. Reefs were deployed using previous VMRC funding and we request renewed funding to follow development of the reefs over time. We also aim for a quantitative understanding of ecological conditions that are beneficial to local recreational fishery species, such as dissolved oxygen levels. Our studies will help evaluate the performance of existing reefs (e.g., VMRC tetrahedron and pipe reefs in the Northern Neck) in relation to habitat characteristics. Ultimately, our evaluation of environmental conditions necessary for successful reef production could lead to a rapid assessment of habitats suitable for future reef deployment.

We intend to address the following major elements: (1) assessment of environmental factors at four replicate locations at two different sites (Northern Neck, Poquoson); (2) quantification of the production value of the prey community for recreational fish species; (3) monitoring of fish predators' diet choice on artificial reefs;

(4) Utilization of Habitat Suitability Indexes (HSIs) to relate fish production to habitat characteristics.

B. Artificial reef substrates

Various artificial reefs may enhance fish production by (1) providing shelter or (2) providing food (prey) for associated fish, however, some reefs may be able to provide both of those aspects. Environmental factors may influence habitat quality and thus will affect reef performance. This study aims to determining which environmental factors contribute most to the production of recreational fish and invertebrates on artificial reef structures.

In Chesapeake Bay, a subtidal modular reef structure deployed in 2000 was successful in supporting various prey for fish, such as mud crabs, polychaete worms, and small mollusks. Moreover, this reef supported sheepshead, tautog, striped bass, croaker and other recreational fish (diver observations). This 3-D modular reef structure apparently was in a suitable habitat and provided an architecture that is conducive for survival of prey for finfish. Therefore, such modular structures should be considered as viable alternative reef structures when they are placed in suitable habitats. Given the documented success of modular reef structures, we aim to test the performance of this type of artificial reef for recreational fish.

In the past year, using VMRC funding, we deployed replicate concrete modular reefs (Fig. 3) in the Northern Neck and Poquoson. In addition, we conducted a detailed examination of environmental factors at the existing Northern Neck reef site (Fig. 4), as well as an assessment of infaunal benthos in the general area of reef deployment, and we have similar information for other sites. Previously at the Northern Neck site, VMRC had established two different reef types, tetrahedrons and pipes, located at slightly different locations (Fig. 5), and the two reefs differ in their effectiveness as fish reefs. Our analyses show that tetrahedron reefs had a ratio of live to dead prey of approximately 1:1, whereas the pipe reefs had a ratio of 3:1 live to dead, suggesting that the pipe reefs are performing better. Anglers and M. Meier (personal communication) have confirmed that the pipe reefs are more productive for fish in the area. Comparing our environmental data with biological data, we can see that oxygen conditions are adequate (above 2 mg/L) at both reef sites (Fig. 4 bottom left panel, including VMRC reef polygon in green dots), but excessive organic carbon (TOC) (Fig. 4 bottom right panel) at the tetrahedron site may be indicative of poor water quality or poor hydrodynamic flushing of the habitat. Incidentally, the abundance of infaunal benthos nearby the tetrahedrons (mean of 19.4 $\pm$ 2.2 SE individuals/sample) was much higher than that away from tetrahedrons (mean of 10.5 $\pm$ 1.8 SE individuals/sample). This abundance nearby the tetrahedrons was possibly in response to favorable oxygen conditions, or increased TOC, which is beneficial to deposit-feeding polychaetes and bivalves. Additional studies examining production on our recently deployed modular reefs throughout the artificial-reef polygon will allow a direct comparison of environmental factors and reef production; because the prey community is just developing, we will need additional funding to follow the reef establishment.

This project falls under the categories of both habitat improvement and research. The artificial reefs are designed to improve habitat for recreational fish species, and the accompanying research will identify the environmental conditions necessary for increased benthic and fish production and thus determine the factors necessary for successful reef deployment in the future.

2.) **Objectives**

A) Quantify environmental factors at two different reef-deployment locations.

B) Identify prey species and production on artificial reefs in two locations.

C) Determine predator-prey interactions through gut-content analysis of structure-dependent reef fish.

D) Use habitat suitability indexes to relate fish and invertebrate production to habitat characteristics.

3.) **Expected Results or Benefits**

Virginia's recreational fishermen can benefit from deployment of our experimental reefs (deployed during previous funding period) but the success of these reefs will be determined in subsequent months. In this phase of the project, we can demonstrate development of the reef-dependent community and relate success at different locations to variations in environmental factors. Traditionally, artificial reefs have been deployed but quantitative evaluation of conditions leading to success or failure has not occurred. Fishermen will benefit in subsequent years because this study will determine the optimal reef type for prey settlement and resultant high carrying capacity based on evaluation of environmental conditions and prey resources on various reefs. For example, in previous studies on the benefits of artificial reefs, three years after deployment, the increase in average catch weight for certain fish species was 10–42 times the initial values. The use of an experimental approach with replicates throughout the habitat in two different locations will allow determination of the optimal habitat for future artificial reefs.

4.) **Approach**

A) Experimental Design

In conjunction with a companion study from our previous VMRC funding, 4 replicates of modular concrete reefs were deployed at each of two locations (Northern Neck, Poquoson)(Fig. 3).

B. Field sampling – environmental conditions

Prior to reef deployment, environmental variables such as temperature, salinity, dissolved oxygen, sedimentary carbon and nitrogen, and sediment grain size (often indicative of water-column turbulence), were quantified. A detailed mapping of these factors (in Arcmap GIS) can lead to a better understanding of habitat quality (for example, Fig. 4). HSI models examining the response of the biological reef community will suggest optimal conditions for future placement of reefs.

C. Field sampling – invertebrates

Before deployment of reefs, we sampled the infaunal invertebrates in the bare sediment in the reef footprint and surrounding area to establish a baseline productivity value for each site and relate initial benthic production to environmental factors. To obtain ash free dry weight (AFDW), invertebrates will be dried to a constant weight (~48 h) at 60°C, and ashed at 550°C for 4 h to obtain ash weight. Through collection of invertebrates at multiple sampling times (summer, fall) we can estimate annual production (g AFDW m^{-2} yr^{-1}) by use of the increment summation method (Downing and Rigler 1984) on the basis of AFDWs quantified. In the companion Lipcius proposal, fish production will be quantified with a combination of an underwater video system, direct diver observations, and selective capture of fish. Subsequently, we will statistically compare the abundance of fish prey at the two reef locations, and determine which environmental variables lead to optimal prey for recreationally important fish species and highest fish production.

D. Predator-Prey interactions – gut contents

We will collect fish from the artificial reefs with hook and line and traps. Fish will be frozen immediately upon capture and stomachs will be removed either in the field or in the laboratory and immersed in preservative. The gut-processing protocol is as follows: (1) contents of each stomach are emptied and each prey item is identified to the lowest possible taxonomic level (usually species); (2) after identification, each prey item is counted, weighed and measured. We will then calculate diet indices such as %Weight, %Number, %Frequency, and %IRI (index of relative importance).

5.) **Location**:

The Northern Neck reef system has been used by VMRC and the location of existing artificial reefs are well-known. The Poquoson site also has VMRC reefs made from “materials of opportunity”.

As noted in the companion Lipcius proposal, this project will be a collaboration among several entities and personnel, and we are leverage various sources of funding to decrease the cost to VMRC and the state:

VIMS— R. Seitz will coordinate the project and interact with R. Lipcius on creating habitat maps for placement of Lipcius’s new artificial reefs. A.L. Hernandez, an M.S. student, will aid in coordination of the habitat suitability modeling effort and use a portion of the information for thesis research. A substantial portion of the graduate student costs is covered by other grants.

VMRC—Seitz and Lipcius are working closely with M. Meier and J. Travelstead in the Fisheries Division to determine how our data can aid in knowledge regarding success of existing and future fish reefs, and we have ensured that the reefs are in agreement with the goals and needs of the artificial reef program at VMRC. M. Meier has already used our environmental maps to aid in locating new “materials of opportunity” for artificial reefs.

CCA—We will work closely with representatives of CCA (communications have been established with T. Powers) to ensure that the recreational angler community is fully aware of the project and aids in the data collection. We have already gained support from some of the local anglers, but we want to communicate with the broader community through CCA.

NOAA—The Chesapeake Bay Office has funded some of the pilot studies conducted with the Rappahannock River artificial reefs.

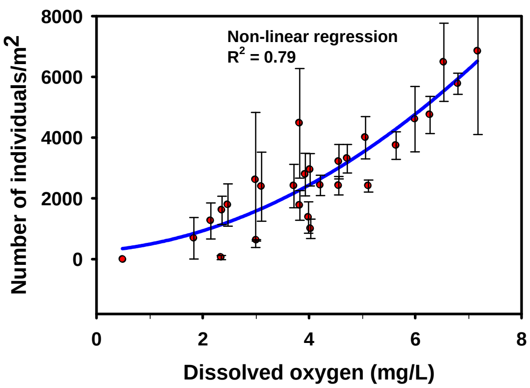

Figure 1. Relationship of benthic infaunal density to dissolved oxygen from Chespeake Bay Program benthic monitoring data from 1996-2004 (Seitz et al., ms in prep).

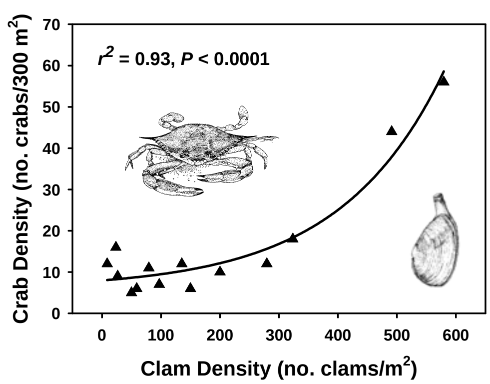

Figure 2. Crab density versus clam density for multiple sites in York River (Seitz et al. 2003).

Figure 3. Example of concrete modular reef recently deployed in Northern Neck, Poquoson, and Lynnhaven (6- foot tall person for scale).

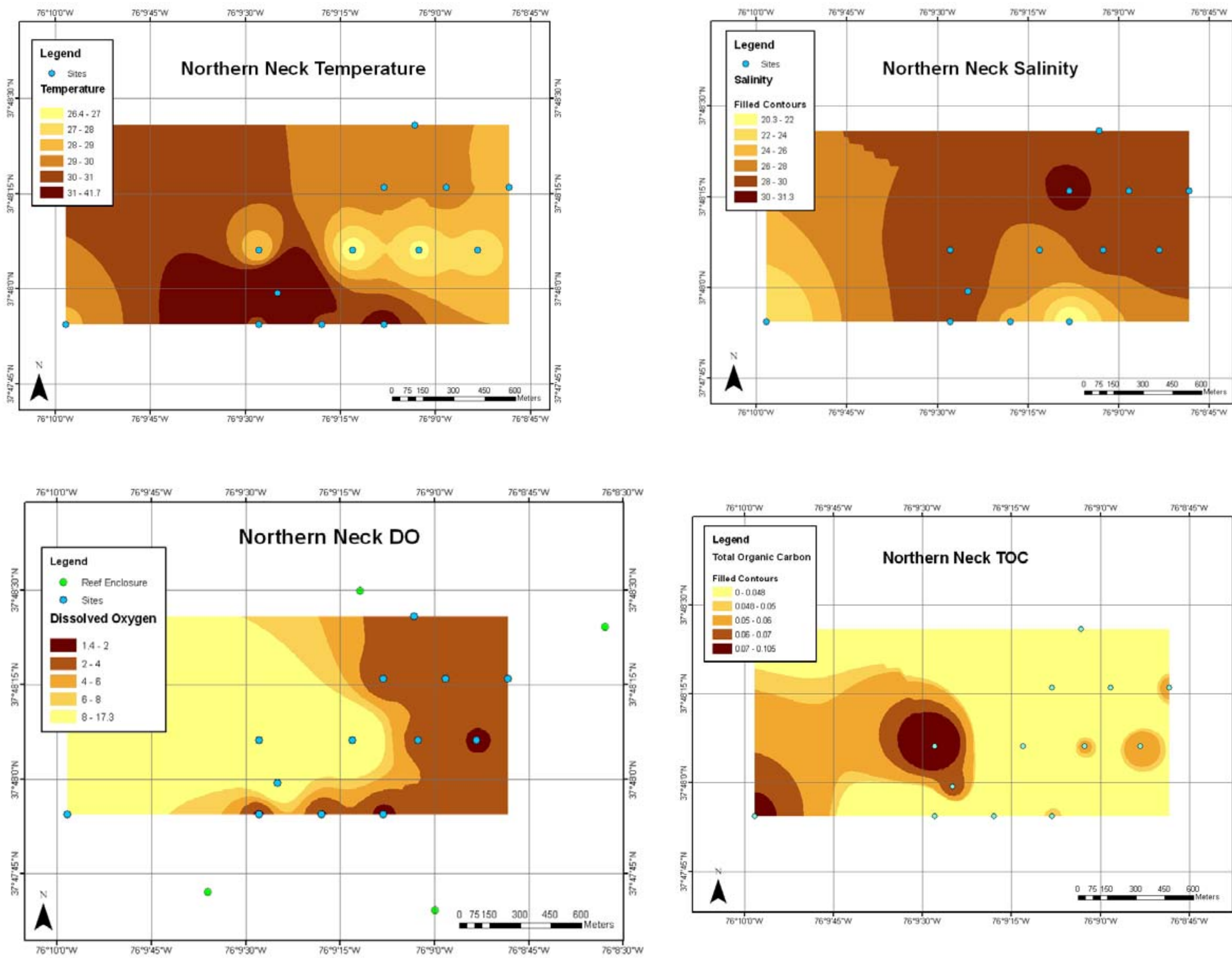

Figure 4. Environmental factors at Northern Neck reef site interpolated from point measurements at sites marked with blue circles including (a) temperature, (b) salinity, (c) dissolved oxygen (this map displays green markers at corners of the VMRC reef polygon, (d) total organic carbon (TOC).

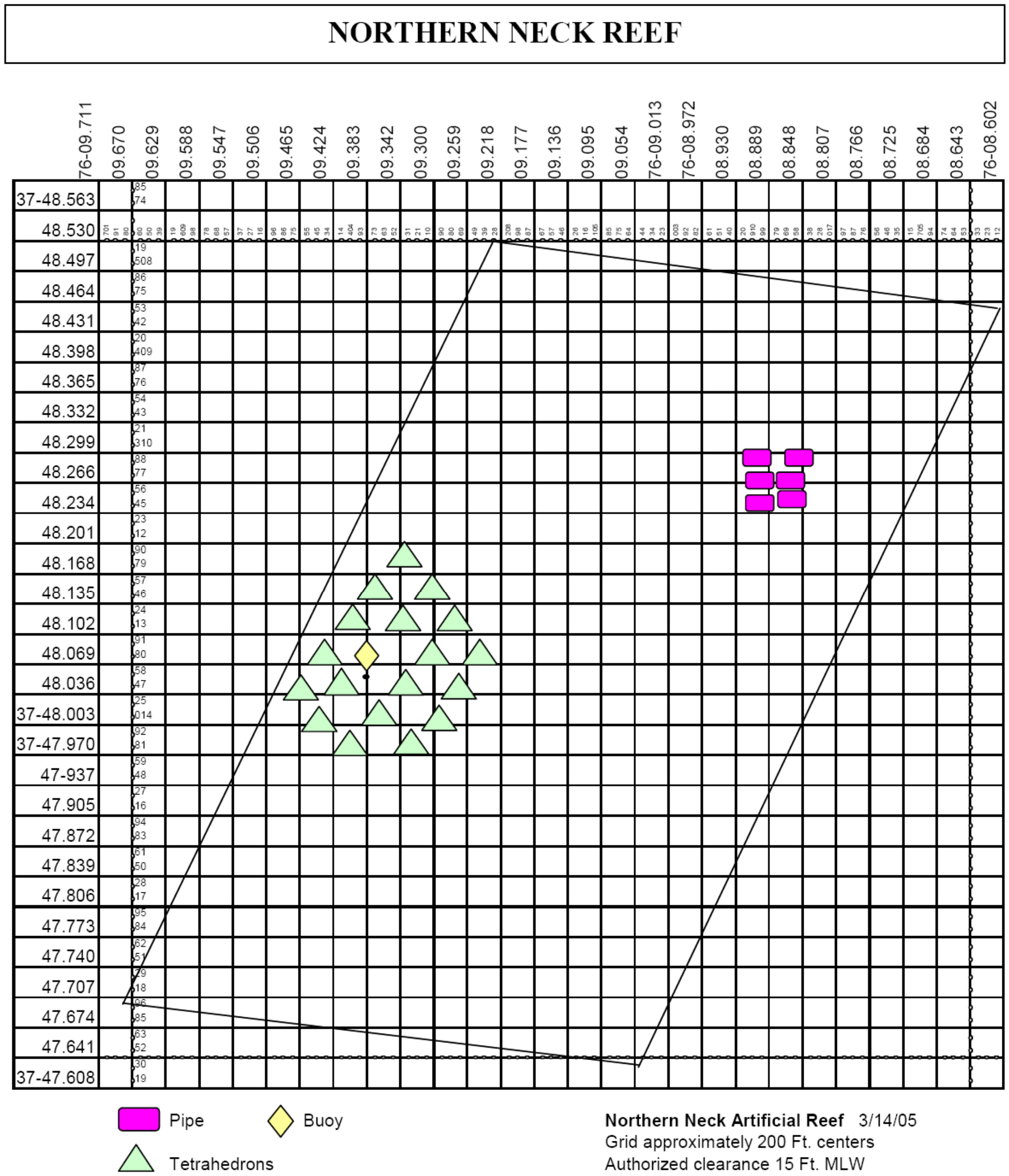

Figure 5. Northern Neck Artificial Reef grid with placement of tetrahedron (triangles) and pipe (rounded rectangles) reef structures.

References:

Bombace G, Fabi G, Fiorentini L (2000) Artificial reefs in the Adriatic Sea. *In* Artificial Reefs in European Seas, 31-64. Ed. by AC Jensen, KJ Collins, and APM Lockwood. Kluwer. 508 pp

Brooks, RP (1997) Improving habitat suitability index models. Wildlife Society Bulletin 25: 163-167.

Cole GA, LeFebvre EA (1989) Improving habitat suitability index models. Wildlife Soc Bull 25: 163-167.

Downing JA, Rigler FH (Eds). (1984) A manual on methods for the assessment of secondary productivity in fresh waters. Blackwell Publishers

Fabi G, Fiorentini L (1993) Catch and growth of *Umbrina cirrosa* (L.) around artificial reefs in the Adriatic Sea. Boll Oceanol Teor Applic 11:235-242

Fabi G, Fiorentini L (1997) Molluscan aquaculture on reefs. *In* European Artificial Reef Research, 123-140. Ed. by AC Jensen. Southampton Oceanography Centre. ISBN 0-904175-28-6. 449 pp

Grossman GD, Jones GP, Seaman WJ Jr (1997) Do artificial reefs increase regional fish production? A review of existing data. Fish Manag 22:17–23

Hixon MA (1998) Population dynamics of coral-reef fishes: controversial concepts and hypotheses. Aust J Ecol 23:192–201

Jensen, AC (2002) Artificial reefs of Europe: perspective and future. ICES J Mar Sci 59:S3-S13

Lipcius RN, Burke R (2006) Abundance, biomass and size structure of eastern oyster and hooked mussel on a modular artificial reef in the Rappahannock River, Chesapeake Bay. VIMS Special Report in Applied Marine Science and Ocean Engineering No. 390

Menge, BA, Daley B, Wheeler PA, and Strub PT (1997) Rocky intertidal oceanography: An association between community structure and nearshore phytoplankton concentration. Limnology and Oceanography 42:57-66

Nestlerode JA (2004) Evaluating restored oyster reefs in Chesapeake Bay: How habitat structure influences ecological function. PhD dissertation Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, Virginia

Peterson CH, Grabowski JH, Powers SP (2003a) Estimated enhancement of fish production resulting from restoring oyster reef habitat: quantitative valuation. Mar Ecol Prog Ser 264:249–264

Peterson CH, Kneib RT, Manen CA (2003b) Scaling restoration actions in the marine environment to meet quantitative targets of enhanced ecosystem services. Mar Ecol Prog Ser 264:173–175

Power, ME (1992) Top-down and bottom-up forces in food webs: do plants have Primacy? Ecology 73:733-746

Seaman WS Jr (2000) Artificial reef evaluation with application to natural marine habitats. CRC Press, Boca Raton, FL

Seitz, RD, Lipcius, RN, Hines, AH, Eggleston DB (2001) Density-dependent predation, habitat type, and the persistence of marine bivalve prey. Ecology 82 (9), 2435-2451

Seitz, RD, Lipcius RN, Stockhausen WT, Delano KA, Seebo MS, Gerdes PD (2003) Potential bottom-up control of blue crab distribution at various spatial scales. Bulletin of Marine Science 72 (2): 471-490

Verner J, Morrison ML, Ralph CJ (1986) Wildlife 2000: modeling habitat relationships of terrestrial vertebrates

6.) **Estimated Cost and Justification**

Brief Project Budget Justification

The Project Director Seitz, will oversee and manage the project, sample collection, and data analyses. We are requesting funds for one month of salary ($6,017/mo) for Seitz, with $6,017 match. We include 6 months of support for an hourly technician at VIMS ($2167/mo) to help with field work collecting environmental data, and conducting gut-content and production analyses. We apply the allowable 30% fringe for faculty, 7.65% for hourly staff.

We request 26 days of boat time on a VIMS vessel (large privateer) for sampling of all three reef locations and fish collection for diet analysis (3 work weeks for each of 3 months in summer). This vessel costs $125/day plus fuel and mobilization fee of $20 (listed in supplies).

Supply costs including sieves, formalin preservation chemicals, glassware, and forceps ($1,100), suction sampling bags and other field sampling supplies ($500) totaling $3,800. Supplies also include vessel fuel: 26 boat days ($2250) plus $900 in mobilization fees.

Travel includes trucks for trailering boats from the VIMS main campus to field sites. This totals $1,470 for travel. In addition, we request $500 for publication and dissemination costs including journal page charges and public relations printing/artwork support. Indirect costs limited to 25% for funds provided by Marine Recreational Fishing Advisory Board. Institutional approved rate is 45%. The remaining costs are contributed as part of the VIMS match for this project.

VMRC Recreational Fish/Oyster Reef
R.D. Seitz, PI

		monthly sal	VMRC	Match
Salaries				
Seitz, PI - 1 mon	1	6,017	6,017	
Marine Scientist1 (BS entry level)	6	2,333	13,002	
Fringe, 30% salaries; 7.65% waged			5,706	
Supplies				
Chemicals, Fuel, Jars, sampling bags, fuel			5,450	
Travel				
Travel to Field sites - ~41 miles one way @$.58/mile VIMS truck for 24 days			1,470	
Vessel Rental				
Rental - $125/day x 26 days, $90 x 20 days	24	96	3,250	
Publications/dissemination			500	
Facilities & Administrative Costs			8,849	5,617
Total			44,244	5,617