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VIRGINIA SALTWATER RECREATIONAL FISHING DEVELOPMENT FUND SUMMARY PROJECT APPLICATION*

NAME AND ADDRESS OF APPLICANT:	PROJECT LEADER (name, phone, e-mail):
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PRIORITY AREA OF CONCERN:	**PROJECT LOCATION:**
Research	Lower Chesapeake Bay, Virginia Institute of Marine Science

DESCRIPTIVE TITLE OF PROJECT:

Connecting Productivity in Eelgrass Beds to Recreationally Important Finfishes in Chesapeake Bay: Forage Fishes as Trophic Conduits

PROJECT SUMMARY:

In Virginia, seagrass beds provide food and shelter for several important sportfishes, including spotted seatrout, Atlantic croaker, summer flounder, and striped bass. Seagrass beds also support a number of prey species (smaller mobile fishes) that are critically important to maintaining sportfish abundances. However, the degree to which complex trophic interactions between invertebrate grazers, low trophic level mobile fishes, and larger predatory fish species are connected is not well described. This project will employ intensive field sampling, diet analysis, and statistical modeling to quantify food-chain links from benthic invertebrates through small fishes, to recreationally and commercially important predatory fishes. Clarifying the critical but poorly understood role of small invertebrate communities in channeling primary production to predatory fishes via intermediate fish predators is central to understanding how and why SAV habitats are essential to fish production.

EXPECTED BENEFITS:

This research will benefit recreational fisheries for several species in Virginia estuarine and coastal waters by providing a more complete mechanistic understanding of the widely recognized, but poorly understood, link between production in submerged aquatic vegetation and fish production via low trophic level mobile fish (baitfish). A novel aspect of this work is its focus on identifying the mechanisms behind previously documented strong variation in fish production among superficially similar seagrass beds in Chesapeake Bay.

COSTS:

VMRC Funding:	$58,329
Recipient Funding:	$8,399
Total Costs:	$66,728

Detailed budget must be included with proposal.

Updated 11/12/08

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

2009 RFAB Proposal (Eelgrass and Forage Fish)

	RFAB	VIMS	TOTAL
SENIOR PERSONNEL			
PI: Sobocinski (12.0 mo)			
PI: Latour (1.0 mo/yr)	6,200		6,200
PI: van Montfrans (1.0 mo/yr)	6,635		6,635
PI: Duffy (0.5 mo/yr)	4,967		4,967
OTHER PERSONNEL			
Marine Scientist II (2 mo)	6,600		6,600
Student workship (hrly)	4,000		4,000
FRINGE BENEFITS	9,761		9,761
TOTAL SALARY & FRINGE BENEFITS	**38,163**		**38,163**
TRAVEL	2,000		2,000
VIMS truck (mileage, tolls)			
OTHER DIRECT COSTS			
1. Materials and supplies	1,500		1,500
2. Stable isotope analysis (250 @$8)	2,000		2,000
4. Vessels (30 days @ $100/d)	3,000		3,000
TOTAL DIRECT COSTS	**46,663**		**46,663**
INDIRECT COSTS	**11,666**	**8,399**	**20,065**
TOTAL DIRECT & INDIRECT	**58,329**	**8,399**	**66,728**

Proposal Submission to

The Virginia Marine Resources Commission
Virginia Recreational Fishing Development Fund

By

THE VIRGINIA INSTITUTE OF MARINE SCIENCE
COLLEGE OF WILLIAM AND MARY

Connecting Productivity in Eelgrass Beds to Recreationally Important Finfishes in Chesapeake Bay: Forage Fishes as Trophic Conduits

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15 April 2009

Connecting Productivity in Eelgrass Beds to Recreationally Important Finfishes in Chesapeake Bay: Forage Fishes as Trophic Conduits

Need

Recreationally important fish species in Chesapeake Bay, such as striped bass (*Morone saxatilis*), spotted seatrout (*Cynoscion nebulosus*), summer flounder (*Paralichthys dentatus*), and others forage heavily on small baitfishes such as Atlantic silverside (*Menidia menidia*) and bay anchovy (*Anchoa mitchilli*), especially during juvenile stages. Some of these baitfishes in turn forage extensively in eelgrass (*Zostera marina*) beds and are thought to provide a critical link between productive benthic habitats and pelagic fisheries. However, despite ongoing research efforts to characterize both the pelagic fish and eelgrass ecosystems in Chesapeake Bay, the importance of seagrass beds in supporting larger transient predatory fishes via export of lower-level production to the adjacent pelagic systems remains unresolved.

Many fish species occupy particular habitats during various phases of their life cycle because these habitats enhance survival, growth and/or reproduction. In estuarine and coastal marine systems, seagrass beds and other submerged aquatic vegetation (SAV) are habitats that provide this enhancement for a variety of small predatory fish species, such as Atlantic silversides and several goby species. Interactions of recreationally targeted species with fishes at lower trophic levels and invertebrate assemblages within eelgrass beds comprise elements of the complex estuarine food web. Yet these interactions are understood only in broad, qualitative outline. Identifying and quantifying the variability in food-chain links by which seagrass habitats support recreationally important predators is critical to explaining fish production and the response of fisheries to habitat loss mediated through the food web. Such understanding will enable resource managers to make informed decisions about management of eelgrass habitats and intermediate trophic-level finfish which they support; these fishes are the prey for larger predatory fishes important in recreational fisheries.

Background

Seagrass beds are important systems with very high levels of primary production, both from the plants themselves and the associated epiphytic algae growing on the plants (Orth et al. 2006). This primary production supports a rich community of small invertebrates, which are hypothesized to in turn support diverse coastal marine fishes via energy efflux from seagrass beds to the greater coastal marine ecosystem. Valentine and Heck (1993) showed that the abundance and production of small seagrass-associated invertebrates and fishes in the Gulf of Mexico are some of the highest values reported among all types of marine communities. However, quantitative data showing the value of seagrasses in terms of export from the seagrass beds themselves to the adjacent marine system are lacking (Heck et al. 2008). For Chesapeake Bay, lower to mid-trophic-level interactions, from invertebrate consumers to small mobile predators (especially fishes) have remained largely unresolved but may structure trophic dynamics both above and below this level (Rooney et al. 2008). Describing and quantifying the effect of the connectivity between seagrass beds and fisheries production is critical to understanding both systems.

While the potential for export of energy away from eelgrass beds to the pelagic food web via mobile animals (small fishes) is likely, this export depends first on the production of prey items in eelgrass habitats. Douglass (2008) and others in the Marine Biodiversity Lab (Biological Sciences Department) at VIMS have described low-level trophic dynamics within the eelgrass beds in the lower Chesapeake Bay. This community is characterized by high levels of amphipod and isopods production. These marine crustaceans are thought to play a central role in community dynamics and flow of energy and materials in aquatic ecosystems. First, energetic analyses of seagrass beds (Kikuchi 1974, Edgar and Shaw 1995) and rocky reef communities (Taylor 1998) indicate that production by small crustaceans is the most important predictor of fish production in vegetated aquatic systems. Second, epifaunal and infaunal invertebrates are the most highly connected trophic group in food webs of the Chesapeake Bay (Lipcius et al. 2005), and in many other aquatic food webs. Third, epifaunal crustaceans have been found packing the stomachs of normally piscivorous apex predators, such as 2-5 year old striped bass, in Chesapeake Bay (van Montfrans and Latour, unpublished). All of these considerations indicate that small crustaceans form the primary intermediate link between submerged aquatic vegetation and fish production.

While the role of grazers in cycling nutrients and thus, energy, within eelgrass systems is well documented, the transfer of this energy to areas beyond eelgrass beds is poorly understood and is likely mediated by mobile fishes and invertebrates. Numerous studies in recent decades have shown that the primary food sources of fishes associated with submerged vegetation are small crustaceans, including amphipods, isopods, shrimp, and small crabs (e.g., Adams 1976, Klumpp et al. 1989). Unpublished data from lower Chesapeake Bay show eelgrass residents such as pipefish (*Syngnathus* spp.) as well as more transient fishes such as silver perch (*Bairdiella chrysoura*), Atlantic silverside and naked goby (*Gobiosoma bosc*) to be especially successful invertebrate predators (J. van Montfrans, unpublished data). Indirect evidence for the importance of particular forage species comes from stable isotope studies by van Montfrans et al. (unpublished) in coastal bays of the Eastern Shore, where it was shown that the seagrass-associated isopod *Erichsonella* sp., along with amphipods and mud crabs, was an important dietary source for many fishes, including silver perch (*Bairdiella chrysoura*), pig fish (*Orthopristes chrysoptera*), tautog (*Tautoga onitus*), and Northern pipe fish (*Syngnathus fuscus*), which in turn are important links to recreationally important predators such as spotted seatrout, summer flounder, and striped bass. These examples show direct predation on invertebrate consumers in eelgrass beds.

In addition to the provision of invertebrate prey, the physical structure of seagrasses provides shelter that allows fishes to escape their own predators during juvenile stages (Thayer et al. 1978, Heck and Orth 1980, Klumpp et al. 1989, Heck et al. 2003), making seagrass habitats important for survival during critical early life stages. Transient predatory species, such as bluefish may derive benefits from seagrass beds indirectly by foraging on primary finfish predators (e.g., Atlantic silversides). Gartland et al. (2006) showed the presence of amphipods and isopods in the diets young-of-the-year bluefish, but more important were small finfish, such as Atlantic silversides, bay anchovy, and striped anchovy (*Anchoa hepsetus*), especially during the early summer months (May-July), when Age-0 bluefish were themselves vulnerable to predators, and thus also when growth is essential.

Trophic interactions involving these intermediate—though little studied—trophic levels will strongly influence how environmental impacts propagate through the food web to influence fish production (Valentine and Duffy 2006). Additionally, it is likely that seagrass habitats provide differential benefits to the larger pelagic fisheries assemblage (i.e., particularly productive areas may provide more benefit to the assemblage than marginal or fragmented habitats). Aquatic food-web studies often lump lower and intermediate trophic levels into a few broad functional groups such as "benthos" and "plankton" (e.g., Chesapeake Bay Fisheries Ecosystem Plan, CFEPTAP 2006). Yet species composition of these animals varies considerably among sites and through the seasons, as well as with ontogenetic changes of intermediate consumers. Moreover, field research and experimental studies show that common epifaunal crustaceans of Chesapeake eelgrass beds differ strongly in grazing rate, population productivity, and vulnerability to predation (Fredette et al. 1990, Duffy et al. 2001, 2003, 2005). These data suggest that variation in species composition of epifauna among seagrass beds, and through the seasons, may strongly influence the abundance and productivity of fishes.

The importance of spatial variation in food web interactions and epifaunal community composition is illustrated by recent findings that spotted trout can be traced via otolith chemistry to specific seagrass beds separated by as little as 15 km (Dorval et al. 2005a, b). This tracer approach holds strong promise for determining which specific seagrass habitats contribute most to production of spotted seatrout and potentially to other recreationally important species, and in turn to illustrating what characteristics of those particular habitats are responsible for abnormally high growth and production. Understanding the characteristics which make one seagrass bed more productive than another for fish species is critical for understanding spatial variability at higher trophic levels.

In this proposal, we focus on critical, but minimally studied, intermediate links in the food chain as an important characteristic of seagrass habitats and address how variation in community composition and abundance of these lower trophic levels may influence variation among beds in fish production and population dynamics. The results of this study will contribute directly to ecosystem-based approaches to fisheries management by providing valuable information on the food web dynamics of fishes in Chesapeake Bay across temporal (i.e., seasonal) and spatial (i.e., habitat-specific) scales.

Objectives

The goal of the proposed study is to conduct field and modeling research to identify and rigorously quantify the links from seagrass habitat, through benthic invertebrate communities, to production of recreationally, commercially, and ecologically important fishes in the Chesapeake Bay. By focusing on the poorly studied primary predators on invertebrates (mobile baitfishes) that form a "black box" in the middle of the food chain, this research will begin to forge the missing mechanistic link between the comparatively well studied submerged aquatic vegetation and recreational fishes, both of which are subjects of important long-term monitoring programs in Chesapeake Bay.

Specific goals of the research are to:

1) Quantify spatial and seasonal variation in biomass, community composition, and productivity of lower trophic levels among four selected eelgrass beds.

2) Characterize the diets of seagrass-associated fishes to determine their dependence on small invertebrates using gut content and stable isotope analyses.

3) Use statistical modeling approaches to identify the role of individual invertebrate species in supporting growth and production of recreationally important predatory fishes and their forage species, and thereby, evaluate the contribution of eelgrass-supported species to the larger food web.

To maximize our power to quantify these linkages, we will focus on a variety of sites that differ strongly in predatory fish abundance. By measuring variation among beds in the abundance, species composition, and productivity of the intermediate links in the food chain, we can evaluate how they mediate variation in abundance and production of recreationally important predatory fishes.

The project will link two ongoing, complementary research programs: one focusing on species composition, abundance/biomass, age and size-structure, and trophic interactions of larger predatory fishes (Latour and van Montfrans) and the other focusing on these same variables at the lower end of the food web, among invertebrate grazers, small predators, and the algae that support them (Duffy, see Figure 1). This will enable a comprehensive and detailed understanding of the food web dynamics of seagrass-associated fishes, and will ultimately provide important models for developing ecosystem-based fisheries management plans.

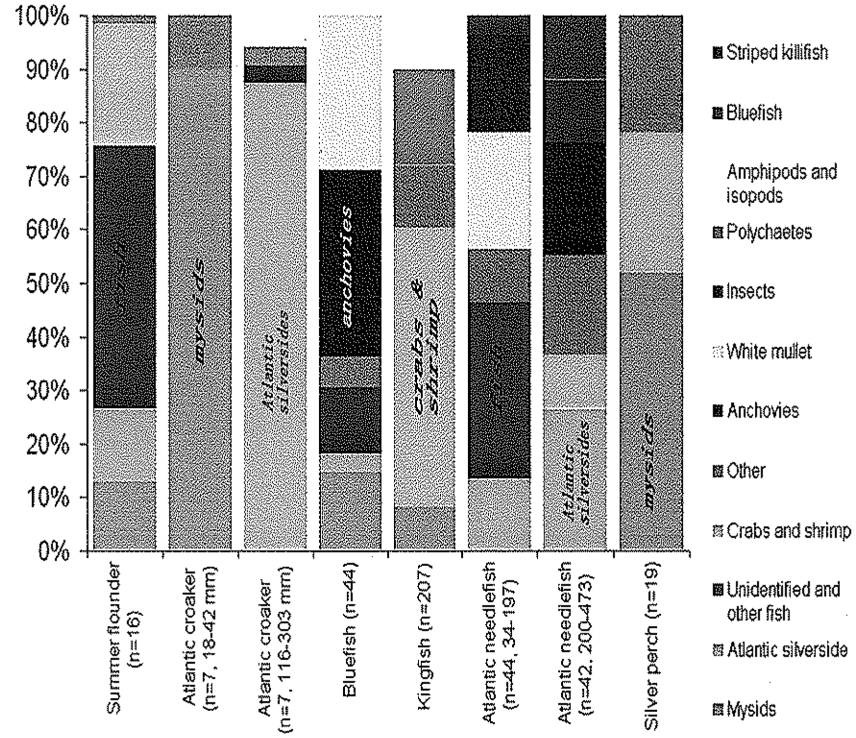

Figure 1. Diet by weight of fish species collected by the VIMS juvenile bluefish seine survey in the Eastern Shore and Southside Chesapeake Bay, VA, June through September 2004. Data from VIMS Juvenile Bluefish Seine Survey.

Intensive field sampling will be conducted from May-September 2010, with processing of samples and analysis of epifaunal community structure, gut contents, stable isotopes, and modeling completed by April 2011, at which time a final project report will be submitted.

Expected results or benefits

This research will benefit recreational fisheries for several species in Virginia estuarine and coastal waters by providing a more complete mechanistic understanding of the widely recognized, but poorly understood, link between epifaunal invertebrate communities supported by eelgrass beds, intermediate finfish predators, and recreational fish production. Little attention is paid to forage fishes, which may be sensitive to changes in foundational trophic interactions. A novel aspect of this work is its focus on identifying the mechanisms behind strong variation in fish production among superficially similar but functionally different seagrass beds in Chesapeake Bay.

Approach

1. *Variation in biomass, community composition, and productivity of lower trophic levels*

In each of two SAV beds we will sample SAV cover and biomass as measures of habitat quantity and quality, biomass of epiphytic algae as an estimate of primary production supporting the food web, and the abundance, species composition, and diets of animals ranging from small epifaunal invertebrates through adult fishes. Samples will be collected twice each month at each site between April, when juvenile and adult fishes begin to enter the estuary, through August.

Lower trophic levels

Eelgrass, epiphytic algae, epifaunal herbivores, carnivorous crustaceans and small fishes will be sampled using methods used in Duffy's group for several years (see Figure 1). Briefly, we sample each of two 50-m transects parallel to shore, one near the offshore margin and one near the inshore margin of a bed, and measure the following parameters: *seagrass cover* (N=25 +/- points per transect) and *seagrass biomass* (5 cores/transect) are measured on each date. *Epiphyte biomass* is sampled as chl *a* at N=5 points per transect. *Epifaunal invertebrates* are sampled at five randomly selected locations per bed on each of the inshore and offshore transects, using a mesh-paneled box that closes around the upright seagrass blades and traps associated epifauna inside (e.g. Duffy et al. 2001). Mobile epifauna are further sorted into size classes by passing through a series of nested sieves; empirically derived equations are then used to convert abundance by size class into biomass and, with inclusion of water temperature, to production of these small forage invertebrates (Edgar 1990). *Resident (sedentary) small predators* are sampled quantitatively using standardized dipnet sweeps (5 m long sweep x 0.53 m opening width = 2.65 m2 sampled), 3 sweeps per inshore and offshore transect, for a total of 6 predator samples on each date; small fishes, blue crabs (*Callinectes sapidus*), grass shrimp (*Palaemonetes* spp.), and sand shrimp (*Crangon septemspinosa*), are counted, measured, and all predators are then released.

Larger transient fish predators

We will examine in detail the role of lower trophic levels in the food web dynamics of recreational fishes as the spring season progresses and fish enter these shallow habitats to feed. Fish predators will be sampled at high tide during the daytime and at night using a 600 foot long by 8 foot deep trammel net that will be deployed against the shoreline in the shape of an arc from a fast-moving, shallow-draft vessel. At least 2 - 3 net deployments will be made per seagrass bed, depending on bed size. GPS measurements will enable quantification of the area enclosed for deriving fish density estimates after adjusting for sampling efficiency. Sampling will occur around daytime and nocturnal high tide. Subsets of fish from each sample (approx. 10 – 15 randomly selected specimens per species or size-class within a species if necessary) will be processed for length, weight, sex and maturity-at-age determination, stomach contents and aging. Fish processing will occur as soon after capture as possible. Fish sex will be noted and age determined from otolith examination.

2. *Trophic relationships between invertebrates, forage fishes, and predators*
We will estimate trophic positions and diets by collecting and analyzing both gut contents from the most abundant species at all trophic levels, and stable C and N isotope data.

Gut content analysis
Immediately following collection (or gut evacuation), animals are frozen in liquid nitrogen. Gut contents of grazing invertebrates and shrimp are blotted on a microscope slide, and a point-count method is used to quantify remains of macroalgae, eelgrass, diatoms (periphyton), crustacean parts, mineral grains, and "detritus" (unidentifiable organic material). Blue crab guts will be analyzed according to Mansour (1992). For fishes, stomachs will be labeled, preserved in "normalin," and prey will be identified to the lowest possible taxon. Prey will be measured, and % number, wet weight and frequency of occurrence will be calculated by prey type.

Stable isotope analysis
Whereas gut contents provide a snapshot of an animal's most recent meal, stable isotopes of C, N, and S can provide a complementary time-integrated picture of certain aspects of diet, notably trophic level. Existing isotopic signatures (C and N) exist for benthic primary producers and will be used for reference with additional samples collected from forage fishes and mobile invertebrates. The δ 15N signature allows determination of consumer trophic level, because δ15N is enriched by a larger factor (3.4 ± 1‰) with each trophic step (Peterson and Fry 1987). We will calculate consumer trophic level as $\alpha + (\delta\ 15N_{organism} - \delta\ 15N_{base\ of\ food\ web})/3.4$, where d is the trophic position of the base of the food web, i.e. $d=1$ for primary producers (Post et al 2000). Formulae are available for determining trophic level of a consumer with multiple food sources that differ in δ 15N signatures (Post et al 2000). As basal food sources, we will use known values for seston, eelgrass, the most common macroalgal species, and epiphytic microalgae previous measured in lower Chesapeake Bay. δ 13C, and δ 15N values for several of these food sources have been shown to differ significantly in other estuaries (Currin et al. 1995, Riera et al 1999, Kharlamenko et al. 2001). We will sample ~25 taxa/food web components (N=5 each), near the beginning and end of the sampling period, for a total of ~250 samples. Samples will be analyzed by the Stable Isotope Facility, University of California, Davis, using a Europa Scientific Hydra 20/20 continuous flow isotope ratio mass spectrometer and Europa ANCA-SL elemental analyzer to convert organic C and N into CO_2 and N_2 gas.

3. *Statistical analyses of links between invertebrate species and fish production*
As a first step, we will analyze relationships among taxa in the food web using generalized linear models (GLMs). This class of models is defined by the statistical distribution of the dependent variable (e.g., predatory abundance) and the nature by which a linear combination of a set of

explanatory variables (e.g., prey type, water temperature, survey month, salinity, etc.) relate to the expected value of that dependent variable. The structure of a GLM is as follows:

$$g(\mu_i) = \sum_{1}^{p} x_i \beta_i \qquad (1)$$

where g is a differentiable and monotonic link function (e.g., identity function when the distribution of the response variable is normal, logit when the distribution is binomial, etc.), μi = E(yi), which is the expected value of the ith dependent variable, x_i are the p explanatory variables, and βi is the vector of parameters (McCullagh and Nelder 1989).

GLMs can be used to analyze data under a variety of designs, including those containing only categorical explanatory variables (e.g., prey type), those containing only continuous explanatory variables (e.g., water temperature), and those containing both categorical and continuous explanatory variables. Further, mixed-model designs where levels of categorical explanatory variables vary randomly can also be accommodated. We are opting for the GLM approach because this class of models is very powerful and general.

As a second step, we will analyze relationships among taxa in the food web using path analysis. Path analysis is based on multiple regression (Sokal and Rohlf 1981) and begins with a path diagram indicating (1) the potential, directional influences of each predictor variable (e.g., abundance or production of an invertebrate prey species) on the response variable (e.g., spotted seatrout abundance or growth), as well as (2) potential correlations among predictor variables. Path analysis uses a multiple regression approach to estimate a standardized path coefficient (i.e., correlation) for each arrow, allowing all path coefficients to be expressed in comparable, standardized units. The correlation between two variables can be visualized as the sum of the path coefficients between them. Thus, both the relative importance of different predictor variables and their direct vs. indirect influence can be distinguished.

By combining data on consumer field abundance, diet fraction in gut contents, and prey abundance, and making energetic assumptions based on body size and taxonomy, we will estimate interaction strengths (IS) from the field data (e.g., Bascompte et al. 2005). Interaction strength estimated from field data will be compared with our experimental measurements of IS in the corresponding season.

Location
We will sample in four seagrass beds, two each on the western and eastern shore of the bay. These beds will be selected on the basis of published research by Dorval et al. (2005 a,b) and Douglass (2008) and on discussions with VIMS researchers and C. Jones (ODU) who has documented habitat-specific growth rates for spotted seatrout in Chesapeake Bay (unpublished data). Sample processing and statistical modeling will occur at the Virginia Institute of Marine Science.

Estimated cost
Requested funds will go primarily to support salaries of two skilled technicians, who along with a VIMS graduate student, will conduct most of the labor-intensive work of collecting, sorting,

and processing samples of seagrass invertebrates and fishes, analyzing stomach contents, and preparing tissue samples for stable isotope analysis.

Salary funds are requested for one month of PI Latour's time and one month of van Montfrans' salary, and 0.5 months PI Duffy who will collectively oversee all aspects of this project. The remainder of Latour and Duffy's salaries and the differential indirect costs will be provided by VIMS as match. This project will be conducted in support of dissertation research for the listed graduate student (K. Sobocinski) whose stipend and tuition is supported through a VIMS fellowship. Additional costs will be incurred for use of vessels and equipment and for stable isotope analysis and miscellaneous supplies needed to support the research.

We request VIMS Facilities and Administrative Costs at the reduced rate of 25% of direct costs. VIMS will provide the difference between this figure and the standard institutional rate of 43%.

Broader impacts

1. *Dissemination of results*: The results of our work are routinely disseminated in peer-reviewed publications and scientific presentations at national meetings. Outside the scientific community, we will engage the recreational fishing community by giving public seminars at local fishing clubs. Additionally, the PIs hold advisory positions on numerous national and regional committees devoted to fisheries management (e.g., Atlantic States Marine Fisheries Commission, Mid-Atlantic Fishery Management Council, etc.) which provides an immediate avenue for information exchange among the research community and resource managers.

2. *Promoting teaching, training, and learning*: Since 2001, Latour has focused on studying the trophic ecology of fishes across habitats within Chesapeake Bay and the nearshore regions of the mid-Atlantic bight. This is large-scale, multidimensional program involves collection of detailed ecological data for over 10 finfish species. In short order, this program has provided the basis for thesis/dissertation research to five graduate students, first exposure to field work for over 10 undergraduate interns, and field and laboratory experience to nine technicians.

Duffy's research at VIMS has provided field and research experience, peer mentoring, and teamworking experience to a large and diverse group over the last twelve years, and this proposal will continue the tradition. His seagrass epifaunal monitoring program began in 1998 as an informal side-project with two graduate students. The program evolved by adding sampling of additional ecosystem components, and by modifying the gear and sampling regime slightly. Most modifications were initiated, and essentially all of the sample processing and sorting were conducted, by graduate and undergraduate students. The program has involved at least 30 graduate students, undergraduate interns and honors students, undergraduate volunteers, high-school students, postdocs, technicians, and colleagues.

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