VIRGINIA RECREATIONAL FISHING DEVELOPMENT FUND
SUMMARY PROJECT APPLICATION*

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PRIORITY AREA OF CONCERN:	**PROJECT LOCATION:**
Research	Virginia Institute of Marine Science

DESCRIPTIVE TITLE OF PROJECT:

Towards validation of juvenile indices of abundance for several fish species in Chesapeake Bay

PROJECT SUMMARY:

Fisheries-independent monitoring programs are designed to provide scientists and managers with information regarding the population dynamics of natural resources. Well-designed monitoring programs are assumed to provide unbiased estimates of population parameters. However, for scientists and managers to have confidence in the data being collected, validation of the survey is required. In the Chesapeake Bay region, several fisheries-independent surveys are routinely conducted to measure the relative abundance of juvenile and, more recently, adult fishes in the bay. Collectively, these indices of abundance are used to assist in the development of management regulations, however, no attempts have been made to formally validate the indices derived from these sampling programs. In this proposal, we outline a series of data analysis and statistical modeling approaches that will facilitate validation of survey –based indices of abundance.

EXPECTED BENEFITS:

Virginia is one of 15 member states of the (ASMFC), which serves a deliberative body, coordinating the conservation and management of the states shared nearshore fisheries resources. Several of the fisheries management plans that are under the auspices of the ASMFC require (among other things) the development of YOY indices of abundance. While Virginia has systematically complied with this mandate, no attempt has been made to evaluate the quality and accuracy of the YOY indices. That is, we do not know if the temporal trends of the YOY indices properly reflect the variations in recruitment to the harvestable stock. This proposal represents the first attempt to address this question and it has the potential to yield valuable information about the recruitment dynamics of several important fish species in Chesapeake Bay as well as to provide guidance regarding the design and implementation of fisheries-independent sampling programs.

COSTS:

VMRC Funding:	$ 60,916
Recipient Funding:	$ 23,624
Total Costs:	$ 84,540

Detailed budget is included with proposal

Proposal Submission to

THE RECREATIONAL FISHING ADVISORY BOARD
VIRGINIA MARINE RESOURCES COMMISSION

By

THE VIRGINIA INSTITUTE OF MARINE SCIENCE
COLLEGE OF WILLIAM AND MARY

Towards validation of juvenile indices of abundance for several fish species in Chesapeake Bay

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December 15, 2005

Background/Need

Chesapeake Bay is the largest estuary in the continental United States, occupying approximately 10,000 km^2 of surface area. Physically, more than 20 major tributaries drain into the bay from a watershed that stretches across six states – New York, Pennsylvania, Maryland, Delaware, Virginia and West Virginia – and the District of Columbia. The largest of these tributaries, the Susquehanna River, provides more than half of the fresh water that flows into the bay. The mixture of freshwater from the tributaries and seawater from the coastal ocean has served to create and maintain a variety of brackish habitats within the bay. Most notably are the marshes on intertidal lowlands, aquatic grass beds in the shallow flooded flatlands, and oyster reefs, which are a subtidal hard-bottom substrate. Due to such a diversity of habitats, the bay is extremely rich in natural resources, supporting nearly 3,000 species of plants and animals within its waters and tidal margins. Most of the marine fishes that inhabit Chesapeake Bay spawn in the coastal ocean, however, some spawn in the lower portion of the bay where salinity is very high. The net flow of seawater into the bay and its tributaries serves to transport the resulting larval fishes to their nursery habitats. This transport mechanism is very important to the population dynamics of many species, since these nursery areas are highly productive and facilitate rapid growth under relatively protected conditions.

Since the early 1900s, the production and seasonal dynamics of resources indigenous to Chesapeake Bay have supported a variety of fisheries both within the bay and along the Atlantic coast. During the past 50 years, large-scale fisheries have targeted (among others) striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), summer flounder (*Paralichyths dentatus*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). These fisheries have resulted in significant levels of harvesting for several of the aforementioned species, and although trends in the commercial and recreational landings have been quite variable during the last several decades, many species have experienced overexploitation.

Fisheries-independent monitoring programs are designed to provide scientists and managers with information regarding the population dynamics of natural resources. In addition, data collected from these programs are often used to parameterize the stock assessment models from which management regulations are derived. Well-designed monitoring programs are assumed to provide unbiased estimates of population parameters. However, for scientists and managers to have confidence in the data being collected and subsequent modeling results, validation of the survey is required.

In the Chesapeake Bay region, several fisheries-independent surveys are routinely conducted for the purpose of measuring the relative abundance of fishes in the bay. Specifically, the VIMS Juvenile Fish and Blue Crab Trawl Survey is a long-standing survey designed to derive indices of abundance of young-of-the-year (YOY) fishes in the Virginia portion of Chesapeake Bay. Complementing this program is the VIMS beach seine survey, which samples YOY fishes in habitats and regions of the bay where trawl gear cannot be deployed. Collectively, these indices of YOY abundance are used by the Atlantic States Marine Fisheries Commission (ASMFC) to infer recruitment success and assist in the development of management regulations. However, to date, no attempts have been made to formally validate the indices derived from these sampling programs. In this proposal, we outline a series of data analysis and statistical modeling approaches that will facilitate validation of survey –based indices of abundance.

Project Objectives

1) Compare YOY abundance indices to subsequent age-specific adult abundance indices for several recreationally and commercially important finfish species in Chesapeake Bay (i.e., striped bass, weakfish, summer flounder, spot, and Atlantic croaker).
2) Build a population dynamics model that can be used to derive estimates of recruitment abundance. Compare those model-based estimates with YOY abundance indices for those species mentioned in project objective 1.
3) During 2006, continue processing otoliths for age-determination of adult fishes.

Field methods

YOY fishes
The VIMS Juvenile Fish and Blue Crab Trawl Survey is a long-standing (initiated in 1955) fisheries-independent survey designed to sample YOY fishes in the Virginia portion of Chesapeake Bay. Sampling is based on depth strata (1 – 4 m, 4 – 9 m, 9 – 13m and >13 m) each defined within 15 latitudinal mile regions in the mainstem bay (to ensure proper spatial coverage, the mainstem was further divided into eastern and western areas within each latitudinal region) and 10 longitudinal mile regions in the tributaries (Figure 1A). Sampling is conducted monthly (with the exception of January and March when only the tributaries are sampled) and a 9 m semi-balloon otter trawl is deployed at 3 – 4 sites within each stratum of each region. The survey employs several fixed sampling locations, while others are randomly selected each month. Once onboard, the catch is sorted by species and individual lengths are recorded. Length frequency analysis is used to discern YOY from older fishes.

The Virginia Juvenile Striped Bass Seine Survey is also a long-standing fisheries-independent survey (conducted continuously since 1980) designed to measure the relative abundance of YOY striped bass in the tributaries of the Virginia portion of Chesapeake Bay. Sampling is conducted biweekly from July through September at 18 historic sites and 22 auxiliary sites along the shores of the James, York, and Rappahannock Rivers (Figure 1B). At each sampling location, a 30 m long, 1.2 m deep beach seine is hauled along the shoreline, generally not extending past the 1.2 m depth contour. All fishes collected are sorted by species and counted. All striped bass collected are measured.

Adult fishes
The Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) is a recently developed fisheries-independent trawl survey (initiated in 2002) designed to

sample the adult components of the finfish populations in the bay. Each year 5 ChesMMAP cruises are conducted (March, May, July, September, and November annually) and approximately 80 to 90 sites are sampled each cruise within the mainstem of Chesapeake Bay (Figure 1A). Sampling locations are chosen according to a stratified random design, with strata based on water depth (3 – 9 m, 9 – 15 m, and >15 m) within five 30 latitudinal minute regions of the bay. The number of locations sampled in each stratum of each region is randomly selected in proportion to the area of that stratum. At each sampling location, a 13.7 m 4-seam balloon otter trawl (15.2 cm stretch mesh in the wings and body and 7.6 cm stretch mesh in the cod end) is towed for 20 min at approximately 6.5 km h^{-1}. Each catch is sorted and individual lengths are recorded by species or size-class if distinct classes within a particular species are evident. A subsample of each species or size-class is further processed for age determination and diet composition analysis, respectively.

Laboratory methods

Age determination
Sagittal otoliths are used for age determination of the species mentioned in the project objectives section (i.e., striped bass, weakfish, summer flounder, spot, and Atlantic croaker). For each otolith, a thin transverse section is cut through the nucleus and the resulting section is mounted on a glass slide. Annuli are counted by viewing the slide under a dissecting microscope using transmitted light (500X magnification). Three individuals generally read all specimens once and a randomly selected subsample of 200 specimens a second time. Two-dimensional tests of symmetry between and within readers can be used to test for consistency among assigned ages. ChesMMAP collected otolith samples from 2002 – 2004 have been aged; 2005 samples have yet to be processed.

Statistical methods

YOY abundance indices
Methods for calculating YOY abundance indices from the VIMS trawl and seine surveys are long-established and well documented (see Austin et al. 2005, Montane et al. 2004). In short, yearly catch-per-unit-effort (CPUE) calculations yield annual indices of relative abundance for YOY fishes (weighted geometric mean CPUE).

Adult abundance indices
Minimum trawlable fish abundance (N) is calculated as:

$$N = \frac{cA}{a} \tag{1}$$

where c is the mean catch per tow (estimated according to the methods of Cochran (1977) for estimating means from stratified random samples), A is the total survey area (mainstem of Chesapeake Bay), and a is the area swept by each tow (calculated using net monitoring gear and GPS). Equation (1) refers to minimum trawlable abundance because it does not account for net efficiency.

Age-specific abundance indices of bay fish stocks are estimated from the subsample of specimens from which otoliths were removed and analyzed; the number of fish in each age-class is expanded from the number of specimens in the subsample to the total number of specimens captured by ChesMMAP each survey year.

Validation approach 1: Survey vs. survey comparisons

As a first step, we propose a cross validation approach by comparing the indices of relative abundance of adults (derived from the ChesMMAP survey) to indices of YOY abundance (derived from the juvenile trawl and seine surveys). In the most basic form, a simple linear model can be used to relate the adult and YOY index values for each species:

$$I_{YOY,t} = \beta_0 + \beta_1 I_{a,t+a} + \beta_2 I_{a+1,t+a+1} + \cdots \qquad (2)$$

where the dependent variable $I_{YOY,t}$ is the YOY index of abundance in year t, β_i are the coefficients of the explanatory variables, and the independent variables $I_{j,k}$ are indices of adults abundance lagged forward in time.

Equation (2) is somewhat limiting since it can only accommodate a adult indices as explanatory variables. As a second step, we propose to build on equation (2) by relating the two survey indices along with other potential explanatory variables using generalized linear models (GLMs). This class of models is defined by the statistical distribution of the dependent variable (YOY index of abundance) and the nature by which a linear combination of a set of explanatory variables relate to the expected value of that dependent variable. The structure of a GLM is as follows:

$$g(\mu_i) = \sum_{1}^{p} \mathbf{x}_i \beta_i \qquad (3)$$

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.), $\mu_i = E(y_i)$, which is the expected value of the i^{th} dependent variable (i.e., YOY index of abundance), $\mathbf{x}_i$ are the p explanatory variables (e.g., water temperature, survey month, salinity, etc.), and β 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., survey year), 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. In the context of this proposal, this latter characteristic is important, since it is difficult to a priori know the exact structure of the data given the variable nature of indices of relative abundance.

Validation approach 2: Survey vs. landings comparisons

Approach 1 is designed to facilitate an exploration of the adult and YOY relative abundance datasets and to provide preliminary indications regarding the presence of any significant relationships. However, it is also possible to develop estimates of YOY abundance from a simple population dynamics model, and subsequently compare them to those measured by the juvenile trawl and seine surveys. Model predictions and survey indices would essentially validate each other if they both produce similar trends over time.

The basic approach for the population dynamics model is as follows. Given a time-series of relative abundance data for a particular species, the total population size in any given year t, denoted N_t, can be written as

$$N_t = S(N_{t-1} - C_{t-1}) + R_t \quad (3)$$

where $S = e^{-M}$ is the natural survival rate (assumed constant and known), C_{t-1} is the catch in the previous year and R_t is recruitment to the fishery (Walters and Hilborn 2005). It should be noted that R_t may represent a mixture of fish from different calendar ages if the age of recruitment to the fishery is greater than one (e.g. minimum size limit for striped bass is 18in, which correlates with fish that are older than age-1). Equation (3) can be solved for recruitment abundance as follows:

$$R_t = N_t - S(N_{t-1} - C_{t-1}) \quad (4a)$$

and assuming that a landings-based index of relative abundance I_t can be expressed as $I_t = qN_t$, where q is the catchability coefficient, then

$$R_t = \frac{I_t}{q} - S\frac{I_{t-1}}{q} + SC_{t-1}\,. \quad (4b)$$

If information on q is available, then equation (4b) can be used directly to generate a time-series of recruitment. However, q is often not known, so for an exploratory analysis of trends in recruitment, it is generally necessary to replace the index-based estimates of N_t with smoothed estimates of population size. We will explore several approaches for deriving smoothed estimates of N_t.

Expected Benefits

Virginia is one of 15 member states of the Atlantic States Marine Fisheries Commission (ASMFC), which serves a deliberative body, coordinating the conservation and management of the states shared nearshore fisheries resources. Several of the fisheries management plans that are under the auspices of the ASMFC require (among other things) the development of YOY indices of abundance. While Virginia has systematically complied with this mandate, no attempt has been made to evaluate the quality and accuracy of the YOY indices. That is, we do not know if the temporal trends of the YOY indices properly reflect the variations in recruitment to the harvestable stock. This proposal represents the first attempt to address this question and it has the potential to yield valuable information about the recruitment dynamics of several important fish species in Chesapeake Bay as well as to provide guidance regarding the design and implementation of fisheries-independent sampling programs.

Location

All analyses of YOY and adult relative abundance data will take place in the Fisheries Science Laboratory (FSL) at the Virginia Institute of Marine Science. Otolith samples for age determination of adult fishes will be processed in FSL aging laboratory.

Estimated cost

We expect the cost of this study to be $X for one year. The PI and co-PIs will be responsible for the statistical modeling activities while the laboratory technician will be responsible for data extraction/management/organization and processing otoliths for age determination (i.e., samples collected in 2005 and those that will be collected in 2006).

Requested funds would cover:

(1) the salary and fringe costs of the PI and co-PIs,

(2) the salary and fringe costs for a laboratory technician,

(3) a partial supplies budget to offset costs associated with otolith processing,

(4) VIMS Facilities & Administrative Costs at the VMRC reduced rate of 25% (the standard institutional rate is 47.45%). VIMS will provide the difference of the reduced rate versus the institutional rate as match funds.

Literature Cited

Austin, H.M, A.H. Hewitt, and J.K. Ellis. 2005. Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay. U.S. Fish and Wildlife Service Sportfish Restoration Project F87R16, January 2004 – December 2004. Annual progress report to the Virginia Marine Resources Commission.

Cochran, W.G. 1977. Sampling Techniques. John Wiley and Sons, New York. 3rd edition.

McCullagh, P. and J. A. Nelder. 1989. Generalized Linear Models. Chapman and Hall, 2nd edition.

Montane, M.M., W.A. Lowery and H.M. Austin. 2004. Estimating relative juvenile abundance of ecologically important finfish and invertebrates in the Virginia portion of Chesapeake Bay, Project # NA03NMF4570378, June 2003 - May 2004. Annual report to NOAA Chesapeake Bay Office.

Walters, C.J. and R. Hilborn. 2005. Exploratory assessment of historical recruitment patterns using relative abundance and catch data. Canadian Journal of Fisheries and Aquatic Sciences 62:1985-1990.

Figure 1A. Sampling locations for the ChesMMAP (open circles) and the VIMS Juvenile Fish and Blue Crab Trawl Survey (solid triangles) during 2004.

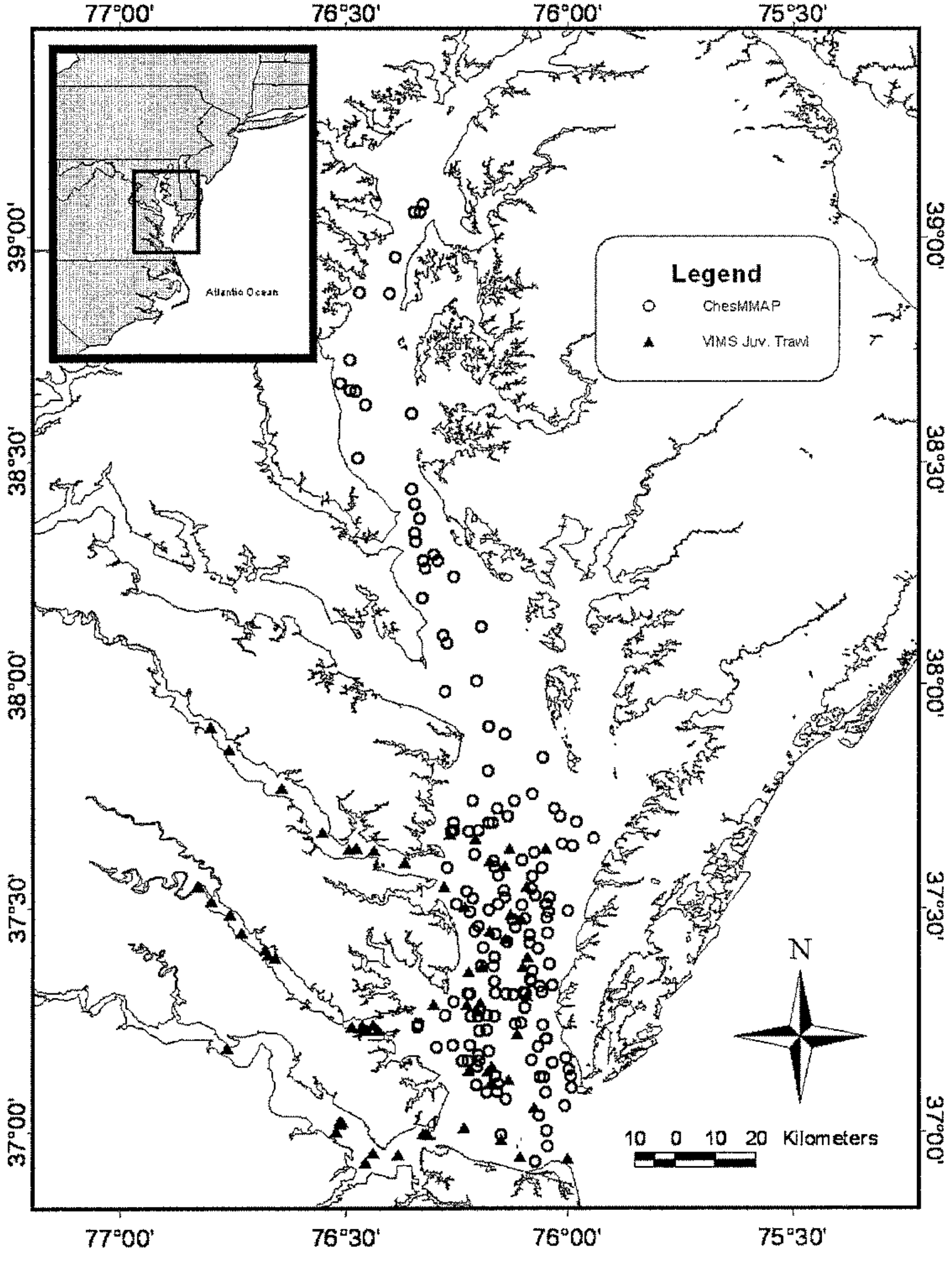
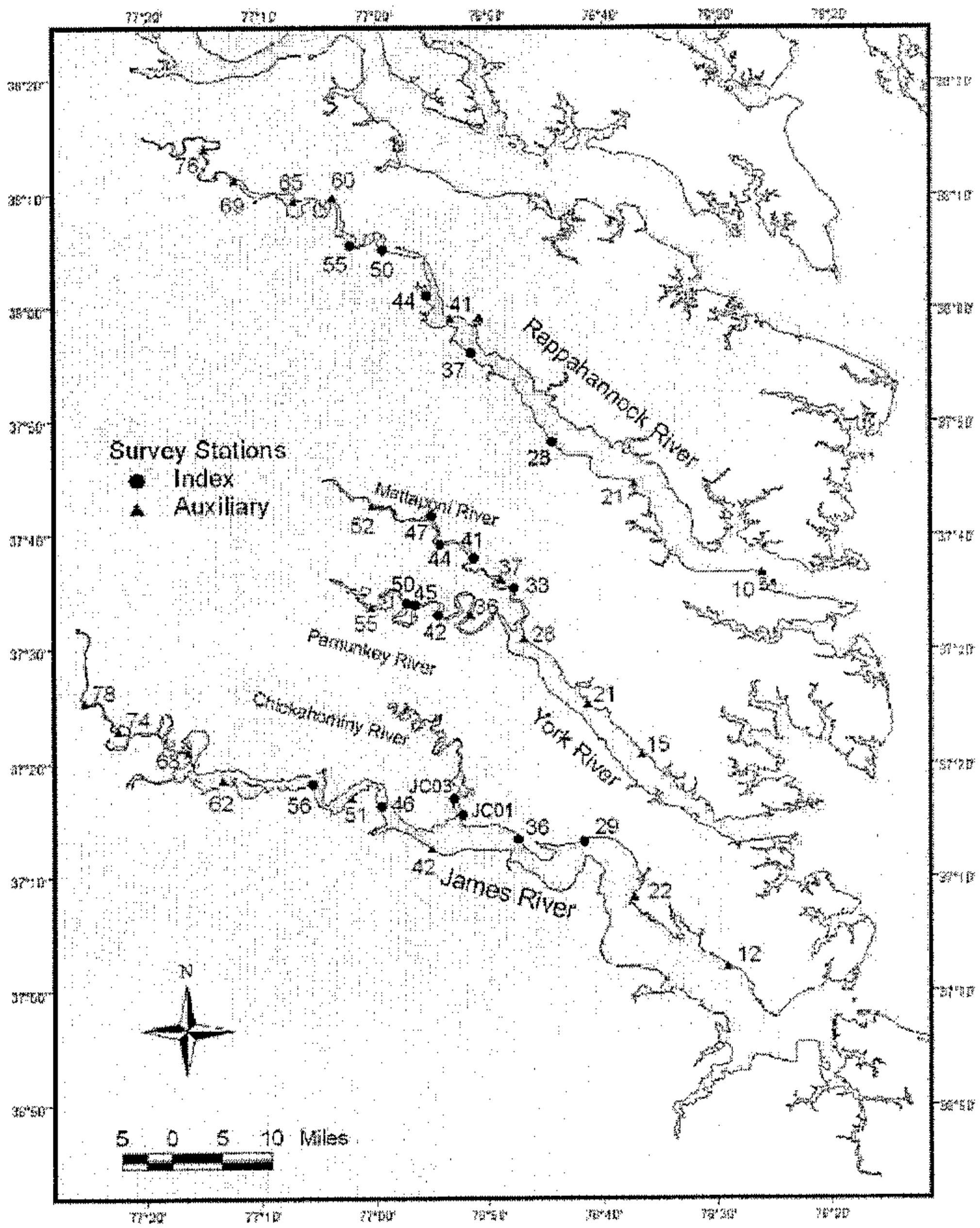


Figure 1B. Sampling locations for the Virginia Juvenile Striped Bass Seine Survey during 2004.



BUDGET

Personnel	RFAB	VIMS	Total
Latour, PI; 1.0 mos.	2,791	2,791	5,582
Bonzek, co-PI; 1.0 mos.	3,077	3,077	6,154
Fabrizio, co-PI; 0.5 mos.	2,734	2,734	5,468
Lab Technician, 12 mos.	28,500		28,500
Fringe, 30% salaries	11,131		11,131
Supplies			
Otolith processing supplies including isomet saw blades, glass slides, Crytalbond, etc.	500		500
Facilities & Administrative Costs - 25%	12,183	15,022	27,205
Total	60,916	23,624	84,540