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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 Sciences PO Box 1346 Gloucester Point, VA 23062	Mary C. Fabrizio, (804) 684-7308, mfabrizio@vims.edu
PRIORITY AREA OF CONCERN:	**PROJECT LOCATION:**
Research	Virginia Institute of Marine Science; Lower Chesapeake Bay

DESCRIPTIVE TITLE OF PROJECT:

Migrations of adult summer flounder from Chesapeake Bay: implications for stock structure

PROJECT SUMMARY:

Summer flounder are a highly targeted and valuable recreational and commercial fishery along the Atlantic coast of the United States. The stock structure of summer flounder has been debated in recent decades with some authors suggesting there is a single stock while others hypothesize there are multiple stocks within the population. This project will utilize data storage tags to record temperature and depth characteristics of habitats occupied by summer flounder throughout the year. Using these measurements, we will describe the thermal and bathymetric characteristics of habitats occupied by summer flounder within Chesapeake Bay and on the continental shelf, assess the proportion of summer flounder that remain within Chesapeake Bay throughout the winter, and identify the migration routes used by summer flounder to arrive at spawning grounds in the fall and winter. Results from this project will provide a more comprehensive understanding of summer flounder stock structure in the Mid-Atlantic bight.

EXPECTED BENEFITS:

This project is expected to benefit recreational anglers by:

(1) providing anglers with an increased understanding of summer flounder behavior, especially as it relates to preferred habitat characteristics and migration behavior; and
(2) improving knowledge of the potential stock structure of adult summer flounder that use Chesapeake Bay for feeding and growth.

COSTS:

We are requesting funds to support 0.5 months of Principal investigator salary. We are also requesting funds for supplies including data storage tags, surgery equipment, expendable laboratory supplies, and vessel fuel. Other costs include recapture rewards, local travel, printing costs, vessel rental, and indirect costs.

VMRC Funding:	$ 83,605
Recipient Funding:	$ 32,528
Total Costs:	**$ 116,133**

Detailed budget must be included with proposal.

Updated 6/1/05

***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 : Due dates are June 15 (Jul. – Nov. Cycle) and December 15 (Jan. – May Cycle)**

		RFAB	VIMS	Total
Personnel				
	salary	5,900	9,800	15,700
	fringe	1,664	0	1,664
	subtotal	**7,564**	**9,800**	**17,364**
Tuition		**0**	**5,400**	**5,400**
Supplies				
	tags	37,500	0	37,500
	mperature logger and mooring equipment	500	0	500
	vessel fuel	2,000	0	2,000
	surgery and lab supplies	4,000	0	4,000
	subtotal	**44,000**	**0**	**44,000**
Recapture rewards		**4,400**	**0**	**4,400**
Printing		**500**	**0**	**500**
Vessels		**6,420**	**0**	**6,420**
Travel		**4,000**	**0**	**4,000**
	subtotal	**66,884**	**15,200**	**82,084**
Indirect Costs		**16,721**	**17,328**	**34,049**
	Total	**83,605**	**32,528**	**116,133**

Proposal Submission to

VMRC RECREATIONAL FISHING ADVISORY BOARD

By

THE VIRGINIA INSTITUTE OF MARINE SCIENCE
COLLEGE OF WILLIAM AND MARY

Migrations patterns of adult summer flounder from Chesapeake Bay: implications for stock structure

Mary C Fabrizio

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Principal Investigator

Mark J. Henderson
Co-Principal Investigator

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JUNE 2008

Migration patterns of adult summer flounder from Chesapeake Bay: implications for stock structure

Mary C. Fabrizio and Mark J. Henderson
Department of Fisheries Science
Virginia Institute of Marine Science
P.O. Box 1346, Gloucester Point, VA 23062

Need:

Summer flounder *Paralichthys dentatus* are one of the most targeted and valuable commercial and recreational fish species of the US Atlantic coast (Terceiro 2001). Summer flounder from Maine to North Carolina are managed as a single stock (the 'northern stock'), which is currently under a rebuilding plan due to large declines in abundance observed during the early 1990s. Management actions used to rebuild the stock along the Atlantic coast include size limits, quotas, and seasonal closures. Recently, the rebuilding plan was extended by three years in response to a lower population growth rate than predicted. Effective management relies on understanding the stock structure of this species (Hilborn and Walters 1992) because individual stocks can have unique rates of recruitment, growth, and mortality (Cushing 1981). If multiple stocks are present, then management of the summer flounder population as a single stock could hinder rebuilding efforts (Hilborn and Walters 1992; Kraus and Musick 2001). We propose to use data storage tags to determine the migration patterns of summer flounder from Chesapeake Bay to distinct offshore regions for spawning. The observance of multiple migration patterns will provide evidence that more than one stock of summer flounder occupies Chesapeake Bay.

In recent decades, the stock structure of summer flounder has been debated with some fisheries scientists suggesting the existence of a single stock (Wilk et al. 1980; Jones and Quattro 1999), and others indicating the potential for multiple stocks (Desfosse 1995; Burke et al. 2000; Kraus and Musick 2001). The single-stock hypothesis was supported by a study indicating a lack of genetic diversity in mitochondrial DNA haplotypes for summer flounder along the Atlantic coast (Jones and Quattro 1999). However, migration patterns inferred from mark-recapture studies have led others to conclude that multiple stocks of summer flounder may exist along the US Atlantic coast from North Carolina to Maine (Desfosse 1999; Burke et al. 2000; Kraus and Musick 2001). The apparent conflict between conclusions drawn from genetic studies and inferences made from mark-recapture studies is not unusual, and can be reconciled. For example, Waples (1998) demonstrated that genetic differences between putative stocks can be diluted when even a small number of individuals stray between stocks. This was demonstrated in a study by Thorrold et al. (2001) that used geochemical otolith signatures to demonstrate the existence of stock structure in a population of weakfish (*Cynoscion regalis*). This result contrasted with conclusions based on previous genetic analyses for this species (Crawford et al. 1989; Graves et al. 1992). These contrasting results were attributed to a small amount of straying between adjacent stocks (Thorrold et al. 2001). The weakfish example illustrates that genetic analyses are not always sufficiently sensitive to identify stock structure and suggests that the use of novel techniques may be necessary to reveal structure within some fish populations.

One approach that can be used to investigate stock structure is to examine the spawning migration patterns of individuals within a population. Mature summer flounder migrate from coastal bays and estuaries during the fall to spawn along the edge of the continental shelf (Morse 1981; Kraus and Musick 2001). Spawning occurs for a protracted time period from September through March, with peak spawning occurring in October in the mid-Atlantic region (Morse 1981). After spawning is complete, individuals migrate back into coastal bays and estuaries, where they reside during the spring and summer (Kraus and Musick 2001). Although this general migration pattern is well known, effects of environmental factors on migration timing are unknown. In addition, uncertainties remain about the existence of distinct migration routes and the potential for mature summer flounder to use separate spawning areas. Understanding how environmental characteristics, such as temperature, influence fish migrations patterns is especially important given the predicted environmental changes associated with global climate change. Possible changes in summer flounder migration patterns have already been noted by a number of recreational anglers in Chesapeake Bay (J. Lucy, pers. comm.). In recent years, anglers have reported catching large summer flounder within the Bay throughout the winter months. Our own study with acoustically-tagged summer flounder also detected adult fish during December and January in Chesapeake Bay (Fabrizio et al. 2007). This presumed change in behavior may be correlated with warmer than average temperatures in recent years, but this hypothesis has not yet been investigated. Beyond understanding how temperature may influence migration patterns of summer flounder, we also wish to examine the diversity of distinct migration routes, as well as the potential for fish to use separate winter habitats. Such observations may lend further support to the hypothesis that more than one summer flounder stock inhabits Chesapeake Bay.

We propose to use data storage tags to describe the thermal and bathymetric characteristics of habitats occupied by summer flounder within Chesapeake Bay and on the continental shelf, assess the proportion of summer flounder that remain within Chesapeake Bay throughout the winter, and identify the migration routes used by summer flounder to arrive at spawning grounds in the fall and winter. Studying these aspects of summer flounder behavior will improve our understanding of the population's stock structure, as well as the potential impacts of rising water temperatures on migration patterns.

Migration patterns of summer flounder will be reconstructed based on the temperature and depth characteristics of coastal waters used during migration. We will tag adult fish with data storage tags that record and store temperature and depth data at regular time intervals. These continuous measurements provide more information than can be obtained with conventional tagging studies, where data are limited to the date and location of tagging and recapture (Bolle et al. 2005). Data storage tags have been used to monitor migration behavior of bluefin tuna *Thunnus* spp. (Block et al. 2001; 2005), yellowtail flounder *Limanda ferruginea* (Walsh and Morgan 2004), Pacific salmon *Onchorhyncus* spp. (Friedland et al. 2001), and North Sea plaice *Pleuronectes platessa*

(Hunter et al. 2003a; 2004), often with novel and unexpected results. For example, Atlantic bluefin tuna *Thunnus thynnus* were found to undertake cross-oceanic migrations, presumably to spawn in the Mediterranean Sea (Block et al. 2001). Currently, the allocation of commercial catches for this species is made assuming no mixing between the eastern Atlantic stock and the western Atlantic stock (Block et al. 2005), but the management of Atlantic bluefin tuna may be more effective if such findings are taken into consideration.

Objectives:

The objectives of this study are to:

(1) describe the thermal and bathymetric characteristics of habitats occupied by summer flounder within Chesapeake Bay and on the continental shelf;
(2) assess the proportion of summer flounder that remain within Chesapeake Bay throughout the winter; and
(3) identify the migration routes used by summer flounder to arrive at spawning grounds in the fall and winter.

Combined, the results from this study will provide a more comprehensive understanding of summer flounder stock structure in the Mid-Atlantic bight.

Expected Results or Benefits:

This project is expected to benefit recreational anglers by:

(1) providing anglers with an increased understanding of summer flounder behavior, especially as it relates to preferred habitat characteristics and migration behavior;
(2) improving knowledge of the potential stock structure of adult summer flounder that use Chesapeake Bay for feeding and growth.

Although recreational anglers already have an intimate understanding of sport fish behavior, our previous research study using acoustic telemetry to monitor movements of summer flounder provided some unexpected insights. For example, smaller fish tagged at Gloucester Point Pier were far more mobile than had been previously hypothesized based on results from the Virginia Game Fish Tagging Program (Fabrizio et al. 2007; Lucy and Bain 2007). Similarly, we believe that information from data storage tags will reveal new movement and habitat use patterns that could be useful in determining preferred habitats by summer flounder throughout the year.

In addition, understanding of the stock structure of adult summer flounder may contribute to the effective management and sustainability of this species. Individual fish stocks can have unique rates of recruitment, growth, and mortality (Cushing 1981) and thus, require different management strategies to ensure sustainability (Hilborn and Walters 1992).

We will use information from data storage tags to infer stock structure of summer flounder based on observed spawning migration routes. Although some summer flounder are expected to remain in the bay throughout the year, most fish are expected to emigrate from the bay during the fall spawning migration. Based on results from trawl surveys (Terceiro 2006) and mark-recapture experiments (Desfosse 1995; Kraus and Musick 2001) we expect that individuals will utilize three different migration routes from Chesapeake Bay (Figure 1):

1) migration south along the inner coast to the shelf off North Carolina;
2) migration directly across the continental shelf; and
3) migration north along the coast to offshore northern shelf habitats.

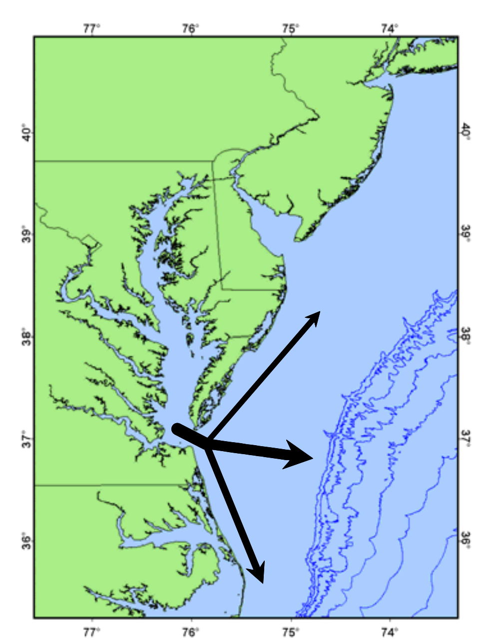

Figure 1. Potential fall migration routes of summer flounder from of Chesapeake Bay. Modified from Figure 1b in Kraus and Musick (2001).

Approach:

Tagging

A total of 200 adult summer flounder will be captured by hook-and-line and bottom trawling in Chesapeake Bay in the late summer. To maximize survival of fish after surgical implantation with data storage tags, we will collect fish larger than 286 mm total length (11.3 inches; Fabrizio and Pessutti 2007). Our tagging effort will be distributed between four established fishing locations and sites randomly distributed throughout the lower Chesapeake Bay (Figure 2). Forty fish will be tagged in August at each of four fishing locations: Back River reef, Cape Charles (near buoy 36A), the Hampton Roads bridge-tunnel, and the Chesapeake Bay bridge-tunnel. The remaining 40 fish will be tagged in September at random stations sampled in the lower bay by the Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP; Latour et al. 2003).

Following capture, Lotek LAT 1400 data storage tags will be surgically implanted into the peritoneal cavity of fish using procedures described in Fabrizio and Pessutti (2007). Briefly, summer flounder will be anesthetized, a small incision will be made on the non-ocular side (non-pigmented side), a beeswax coated tag will be inserted into the peritoneal cavity, and the incision will be stitched closed using non-absorbable sutures in an interrupted pattern. While anesthetized, the size and weight of the fish will be measured, and a T-bar anchor tag will be inserted into the dorsal musculature. Fish will then be resuscitated using ram ventilation and released at the capture location.

The T-bar anchor tags will allow for identification and reporting of recaptured fish; these tags will contain an individual identification number, a phone number to report the recapture, and a statement that a $200 reward is offered in exchange for return of the fish to the Virginia Institute of Marine Science (VIMS). This large reward will increase return rates of the data storage tags (we require the return of these tags to be able to download the stored data).

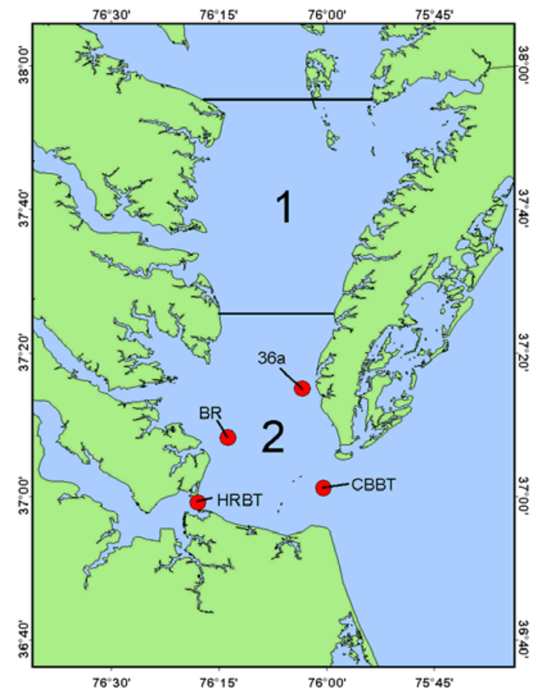

Figure 2. The four recreational fishing areas selected to tag and release summer flounder (red dots). Also shown are the two regions sampled by ChesMMAP in the Virginia portion of the Chesapeake Bay.

Recapture rates from the Virginia Game Fish Tagging Program (Lucy and Bain 2007) and those observed during our recent acoustic telemetry project with summer flounder (Fabrizio et al. 2007), indicate that we can expect about 5 to 15% of our tagged fish to be recaptured and reported to us. However, non-reward tags typically have low reporting rates (Pollock et al. 2001); we expect that reward-tag reporting rates will be higher, and that 15 to 20% of fish will be recaptured and reported. Thus, we will likely realize 30 to 40 returned data storage tags by the end of the first year. Data from these tags will form the basis of our sample for analysis. To further encourage tag reporting, we will distribute posters and meet with local angler associations to describe the project and the reward-tag program.

Analysis

The temperature and depth history from individual tags will be summarized using descriptive statistics (e.g., mean temperature occupied by each fish per month), and the time of emigration from Chesapeake Bay will be determined based on consistent changes in both temperature and depth. The data storage tags we propose to use have an accuracy of $\pm$ 0.2 degrees C and $\pm$ 5 m. Temperature, depth, and tide information will be used to determine the relative locations of individual fish. Depth and temperature measurements recorded by the data storage tags will be compared with shelf-water bottom temperatures recorded during seasonal cruises conducted by the National Oceanic and Atmospheric Administration's Northeast Fisheries Science Center (M. Taylor, NEFSC, pers. comm.). Bottom-water temperature for the lower Chesapeake Bay will be obtained from monthly cruises conducted by the VIMS trawl survey (Fabrizio and Montane 2007) and from a temperature logger we plan to deploy in the lower bay. Although it is not possible to determine the exact location of an individual fish based on temperature and depth, location can be assigned to a region due to distinct temperature differences observed among regions of the shelf (Figure 3). For a given region in the fall, bottom temperatures in inshore waters are consistently 5 to 10 ˚C warmer than temperatures offshore (September-November; Figure 3B). During the same time period, offshore temperatures in the Delaware region and north are 3 to 5 ˚C cooler than temperatures offshore of Virginia and North Carolina (Figure 3B). More accurate estimation of an individual's location (within 40 km) may be possible for fish that remain immobile on the seafloor for a complete tidal cycle (Hunter et al. 2003b).

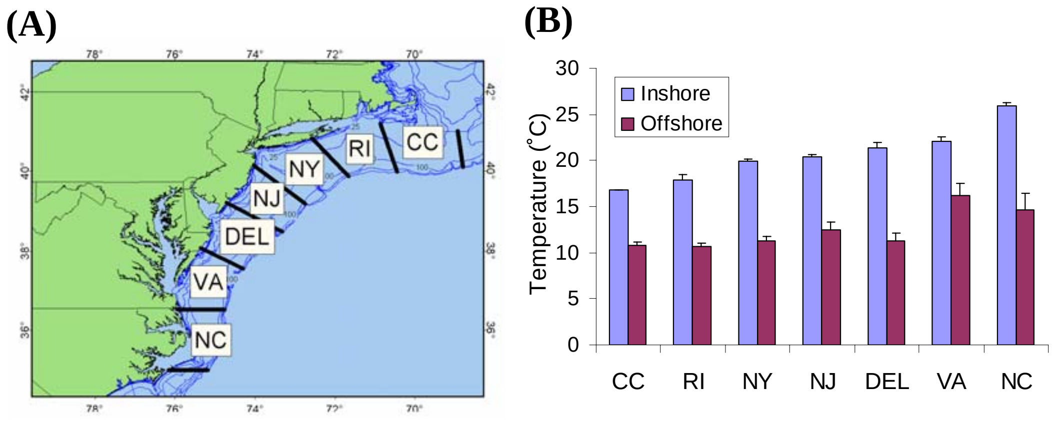

Figure 3. (A) The North Carolina (NC), Virginia (VA), Delaware (DEL), New Jersey (NJ), New York (NY), Rhode Island (RI), and Cape Cod (CC) region boundaries. **(B)** Mean inshore (<25 m) and offshore (>25m) temperatures in each region during the fall (September, October, November) from NOAA cruises (M. Taylor, pers. comm.).

We expect some summer flounder will remain in Chesapeake Bay throughout the winter; the temperature and depth history of these fish should be different from those that emigrate from the bay to the continental shelf as the Chesapeake Bay encompasses more shallow areas. Fish may inhabit deep (>15 m) channels within Chesapeake Bay, but these fish will be differentiated from fish inhabiting the continental shelf based on depth history (i.e., rapid changes in depth associated with swimming into a channel), and differences in temperature between the two locations. The proportion of fish remaining in the bay throughout the winter will be calculated using a simple ratio estimator.

Rates of dispersal of fish from Chesapeake Bay will be compared with those estimated previously to ensure that tag returns from this study are not biased by recapture location. Summer flounder that emigrate away from Chesapeake Bay will provide information on dispersal dates, which will be used to model dispersal rates using the Kaplan-Meier (KM) approach (Bennetts et al. 2001). The KM method is a nonparametric approach, requiring no assumptions about the underlying hazard function. KM estimators are robust, have well described variances (Pollock et al. 1989a), and can be modified to permit staggered entry of individuals (Pollock et al. 1989b). Fabrizio et al. (2005; 2007) applied this approach to estimate dispersal of summer flounder from coastal habitats in New Jersey and Chesapeake Bay. The exact day of dispersal from Chesapeake Bay need not be known to apply the KM model; the model uses data that are binned by time intervals (e.g., one-week periods). Thus, we expect to be able to determine the number of flounder emigrating during each weekly period of the study.

The observance of unique migratory patterns in summer flounder prior to the fall spawning period may indicate the existence of more than one stock; further support for the multi-stock hypothesis may be provided if the groups exhibiting these patterns also differ in size or behavior (timing of emigration). Using exploratory data techniques, we will examine the temperature and depth histories of individual fish prior to the spawning season to determine membership in one of four possible migration groups:

1) fish that reside in the bay throughout the winter (no migration),
2) fish that move south along the coast before moving to the shelf break,
3) fish that move directly east across the shelf, and
4) fish that move north along the coast before moving to the shelf break.

Thus, fish will be assigned to one of four groups by comparing the mean temperature and mean depth occupied by the fish during winter (December to February) to the mean bottom water temperatures along the shelf from NOAA cruises (e.g., Figure 3), and mean depth obtained from detailed bathymetric charts. We selected the December to February period because we expect all fish emigrating from Chesapeake Bay to move offshore by December (Fabrizio et al. 2007). Fish that reside in the bay throughout this period will have occupied shallower habitats than fish that have moved offshore. We expect that fish exhibiting migration pattern 4 will be smaller in size than those that move south or directly across the shelf. Furthermore, unlike fish from groups 2 and 3, we do not expect group 4 fish to return to Chesapeake Bay the following spring. We will use multivariate analysis of variance (MANOVA) to test for significant differences among the four groups; variables included in the MANOVA are fish size, release location (coded 1, 2, 3, 4, 5, 6), and time of emigration The hypothesis tested is that of group effect on fish size and behavior. Results of these analyses will allow us to infer potential stock differences among adult summer flounder that use Chesapeake Bay for growth and in preparation for spawning in continental shelf waters.

Analysis of the data and preparation of the final report will require approximately six months; we anticipate completion of the final report by December 2010.

Location:

All fish will be tagged and released in the Virginia portion of Chesapeake Bay. Fish will be captured at four recreational fishing locations as well as at random stations sampled by the ChesMMAP survey conducted by our colleagues at VIMS. The four recreational fishing locations are: Back River artificial reef, Hampton Roads bridge-tunnel, Cape Charles (near buoy 36A), and the Chesapeake Bay bridge-tunnel. These sites were selected because they are heavily targeted by recreational anglers, and thus, maximize the chance of recapturing and reporting of fish.

References:

Bennetts R.E., Nichols, J.D., Lebreton, J.D., Pradel, R., Hines, J.E., and Kitchens, W.M. 2001. Methods for estimating dispersal probabilities and related parameters using marked animals. *In* J. Clobert, J.D. Nichols, E. Danchin, and A. Dhondt, (Eds.), Dispersal. Oxford University Press, Oxford, UK, pp. 3-17.

Block, B.A., Dewar, H., Blackwell, S.B., Williams, T.D., Prince, E.D., Farwell, C.J., Boustany, A., Teo, S.L.H., Seitz, A., Walli, A., and Fudge, D. 2001. Migratory movements, depth preferences, and thermal biology of Atlantic bluefin tuna. Science 293: 1310-1314.

Block, B.A., Teo, S.L.H., Walli, A., Boustany, A., Stokesbury, J.W., Farwell, C.J., Weng, K.C., Dewar, H., and Williams, T.D. 2005. Electronic tagging and population structure of Atlantic bluefin tuna. Nature 434: 1121-1127.

Bolle, L.J., Hunter, E., Rijnsdorp, A.D., Pastoors, M.A., Metcalfe, J.D., and Reynolds, J.D. 2005. Do tagging experiments tell the truth? Using electronic tags to evaluate conventional tagging data. ICES Journal of Marine Science 62: 236-246.

Burke, J.S., Monaghan Jr., J.P., and Yokoyama, S. 2000. Efforts to understand stock structure of summer flounder (*Paralichthys dentatus*) in North Carolina, USA. Journal of Sea Research 44: 111-122.

Crawford, M.K., Grimes, C.B., and Buroker, N.W. 1989. Stock identification of weakfish, *Cynoscion regalis*, in the middle Atlantic region. Fisheries Bulletin, U.S. 87: 205-211.

Cushing, D.H. 1981. Fisheries biology. A study in population dynamics. 2nd ed. University of Wisconsin Press, Madison, WI. 295 pp.

Desfosse, J.C. 1995. Movements and ecology of summer flounder, *Paralichthys dentatus*, tagged in the southern Mid-Atlantic Bight. Ph.D. dissertation, College of William and Mary, Williamsburg, VA. 187 pp.

Fabrizio, M.C. and M.M. Montane. 2007. Estimating relative juvenile abundance of ecologically important finfish and invertebrates in the Virginia portion of Chesapeake Bay. Final report to NOAA Chesapeake Bay Office, August 2007. [http://www.fisheries.vims.edu/trawlseine/Reports/VIMS%20Trawl%20Final%20Report%20For%20NOAA_June2003_May2007.pdf]

Fabrizio, M. C., and J. P. Pessutti. 2007. Long-term effects and recovery from surgical implantation of dummy transmitters in two marine fishes. Journal of Experimental Marine Biology & Ecology 351: 243-254.

Fabrizio, M.C., Pessutti, J.P., Manderson, J.P., Drohan, A.F., and Phelan, B.A. 2005. Use of the historic area remediation site by black sea bass and summer flounder. NOAA, NEFSC Center Reference Document 05-06 [http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0506/]

Fabrizio, M.C., Henderson, M.J., and Lucy, J.A. 2007. Understanding localized movements and habitat associations of summer flounder in Chesapeake Bay using passive acoustic arrays. Final report to VMRC, December 2007. [http://www.mrc.state.va.us/vsrfdf/pdf/RF06-11_Dec07.pdf]

Friedland, K.D., Walker, R.V., Davis, N.D., Myers, K.W., Boehlert, G.W., Urawa, S., Ueno, Y. 2001. Open-ocean orientation and return migration routes of chum salmon based on temperature data from data storage tags. Marine Ecology Progress Series 216: 235-252.

Graves, J.E., McDowell, J.R., and Jones, M.L. 1992. A genetic analysis of weakfish *Cynoscion regalis* stock structure along the mid-Atlantic coast. Fisheries Bulletin, U.S. 90: 469-472

Hilborn, R. and Walters, C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, NY. 570 pp.

Hunter, E., Metcalfe, J.D., and Reynolds, J.D. 2003a. Migration route and spawning area fidelity by North Sea plaice. Proceedings of the Royal Society of London 270: 2097-2103.

Hunter, E., Aldridge, J.N., Metcalfe, J.D., and Arnold, G.P. 2003b. Geolocation of free-ranging fish on the European continental shelf as determined from environmental variables. Marine Biology 142: 601-609.

Hunter, E., Metcalfe, J.D., Arnold, G.P., and Reynolds, J.D. 2004. Impacts of migratory behavior on population structure in North Sea plaice. Journal of Animal Ecology 73: 377-385.

Jones, W.J. and Quattro, J.M. 1999. Genetic structure of summer flounder (*Paralichthys dentatus*) populations north and south of Cape Hatteras. Marine Biology 133: 129-135.

Kraus, R.T., and Musick, J.A. 2001. A brief interpretation of summer flounder, *Paralichthys dentatus*, movements and stock structure with new tagging data on juveniles. Marine Fisheries Review 63: 1-6.

Latour, R.J., M.J. Brush, and C.F. Bonzek. 2003. Toward ecosystem-based fisheries management: strategies for multispecies modeling and associated data requirements. Fisheries 28:10-22.

Lucy, J.A. and Bain III, C.M. 2007. Virginia game fish tagging program annual report. Virginia Marine Resource Report Number 2007-1. VA Sea Grant, Gloucester Point, VA. [http://www.vims.edu/adv/recreation/2006%20Annual%20Report/MRR2007_1.pdf]

Morse, W.W. 1981. Reproduction of the summer flounder, *Paralichthys dentatus* (L.). Journal of Fish Biology 19: 189-203.

Pollock, K.H., Winterstein, S.R., and Conroy, M.J. 1989a. Estimation and analysis of survival distributions for radio tagged animals. Biometrics 45: 99-109.

Pollock, K.H., Winterstein, S.R., Bunck, C.M., and Davis, P.D. 1989b. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53: 7-15.

Pollock, K.H., Hoenig, J.M., Hearn, W.S., and Calingaert, B. 2001. Tag reporting rate estimation: 1. An evaluation of the high-reward tagging method. North American Journal of Fisheries Management 21: 521-532.

Terceiro, M. 2001. The summer flounder chronicles: science, politics, and litigation, 1975-2000. Reviews in Fish Biology and Fisheries 11: 125-168.

Terceiro, M. 2006. Status of fishery resources off the Northeaster US – summer flounder. [http://www.nefsc.noaa.gov/sos/spsyn/fldrs/summer/]

Thorrold, S.R., Latkoczy, C., Swart, P.K., and Jones, C.M. 2001. Natal homing in a marine fish metapopulation. Science 291: 297-299.

Walsh, S.J. and Morgan, M.J. 2004. Observations of natural behavior of yellowtail flounder derived from data storage tags. ICES Journal of Marine Science 61: 1151-1156.
Waples, R.S. 1998. Separating the wheat from the chaff: patterns of genetic differentiation in high gene flow species. The Journal of Heredity 89: 438-450.
Wilk, S.J., Smith, W.G., Ralph, D.E., and Sibunka, J. 1980. Population structure of summer flounder between New York and Florida based on linear discriminant analysis. Transactions of the American Fisheries Society 109: 265-271.

Estimated Cost: $ 116,133 [MRFAB = $ 83,605, VIMS matching = $ 32,528]

<u>Personnel</u> - $ 17,364 [MRFAB = $ 7,564, VIMS matching = $ 9,800]
We are requesting 0.5 month salary support and fringe benefits (30% rate) for M. Fabrizio. A VIMS fellowship providing six months of graduate student stipend for M. Henderson is provided as VIMS match.

<u>Tuition</u> - $ 5,400 [MRFAB = $ 0, VIMS matching = $ 5,400]
A VIMS fellowship providing six months of tuition for M. Henderson is provided as VIMS matching funds.

<u>Supplies</u> - $ 44,000
Supplies requested for this project include the data storage tags, surgery and laboratory supplies, a temperature logger, mooring equipment, and vessel fuel. The data storage tags we have selected to use are Lotek LAT 1400 tags because they are the smallest size available (important for internal implantation) with sufficient memory. The funds requested from MRFAB will purchase 50% of the requested tags. The remaining tags will be purchased using funds provided by M. Fabrizio. We requested funds for surgery and laboratory supplies (anesthetic, sutures, surgeon's gloves, veterinary epoxy, waterproof paper, external tags, fishing tackle, bait, and other expendable supplies). We are also requesting funds to purchase a HOBO temperature logger and mooring equipment to deploy the temperature logger near the Chesapeake Bay bridge-tunnel. Finally, we are requesting funds to supply vessel fuel to deploy and retrieve the temperature logger and for travel to the four fishing locations.

<u>Recapture rewards</u> - $ 4,400
Recapture rewards of $200 will be offered for recaptured fish that are returned to VIMS. We are requesting reward funds for 22 rewards, which assumes a 12% recapture rate. This assumed recapture rate is slightly higher than the 9-10% recapture rate estimated by the Virginia Game Fish Tagging Program (Lucy and Bain 2007) because the large monetary reward is expected to increase reporting rates. If more than 22 fish are recaptured, additional reward funds will be provided by M. Fabrizio.

<u>Printing</u> - $ 500
A small amount of funds are requested for the design and printing of a poster describing the research project, the recapture reward, and instructions for reporting recaptures.

Vessels - $ 6,420
Vessel rental rates were calculated based on the VIMS daily rates for 1 Garvey (26' vessel) for 1 day of temperature logger deployment, 1 day of temperature logger retrieval, and 20 days of tag implantation. Additionally, funds are requested for two large privateers (21' foot vessel) for a total of 40 vessel days (20 days per vessel) to assist with fish capture. Our participation on ChesMMAP cruises requires no additional funding.

Travel - $ 4,000
Funds are requested for truck rental for trailering vessels to fishing locations. We estimated costs based on current vehicle and vessel rates for 15 days of implantation activities. We also included funds for travel to local marinas and fishing clubs to discuss the project and distribute posters with instructions for reporting recaptures. In addition, a small amount of funds are requested to travel to a local conference to present research results.

Indirect costs - $ 34,049 [MRFAB = $ 16,721, VIMS matching = $ 17,328]
Facilities and administrative costs requested from MRFAB are calculated at 25% of total costs. The remaining indirect costs (at the VIMS rate of 45% for supplies, rewards, and travel) will be contributed as part of VIMS match for this project.