# NOAA Chesapeake Bay Office
# 2009 Fisheries Science Symposium

**Patuxent National Wildlife Refuge Visitor Center**
**Laurel, Maryland, April 21-22, 2009**

*Research funded by the NOAA Chesapeake Bay Office provides science and information to enable natural resource managers to make informed decisions across multiple jurisdictions.*

NOAA Chesapeake Bay Office
410 Severn Ave., Suite 107A
Annapolis, MD 21403
410-267-5660
http://chesapeakebay.noaa.gov

# 2009 NOAA Chesapeake Bay Office Fisheries Science Symposium • Agenda

## Tuesday, April 21, 2009

| | |
|---|---|
| 9:00-9:30 a.m. | Registration/Coffee and Pastries |
| 9:30-9:35 a.m. | Welcome/Logistics; D. Orner and K. Sellner |
| 9:35-9:50 a.m. | Welcome/Introduction; Peyton Robertson, Director, NOAA Chesapeake Bay Office |
| 9:50-10:10 a.m. | Assessment of Local Abundance, Demographics, Health, and Exploitation of American Eel in the Chesapeake Bay; K. Fenske, D. Secor*, and M. Wilberg |
| 10:10-10:30 a.m. | Life History, Trophic Ecology, and Prey Handling of Cownose Rays from the Chesapeake Bay; R. Fisher*, G. Call |
| 10:30-10:50 a.m. | Chesapeake Bay Clam Fishery Collapse: Probable Disease Impacts; C. Dungan*, M. Homer, M. Tarnowski, E. Peters, K. Reece, E. Burreson |
| 10:50-11:10 a.m. | Population Genetics of Horseshoe Crabs in the Chesapeake Bay and Range-Wide; M. Eackles, E. Hallerman, and T. King* |
| 11:10-11:30 a.m. | Unprecedented Restoration of a Native Oyster Metapopulation in the Chesapeake Bay; R. Burke, R. Lipicius, and D. Schulte* |
| 11:30 a.m.-12:50 p.m. | LUNCH and posters |
| 12:50-1:10 p.m. | *Life in the Chesapeake Bay*; V. Christensen, S. Lai, and H. Townsend* |
| 1:10-1:30 p.m. | Evaluation of the Thermal Niche-Oxygen Squeeze Hypothesis for Patuxent Estuary Striped Bass Based upon Acoustic Telemetry; D. Secor, R. Kraus, and R. Wingate* |
| 1:30-1:50 p.m. | The Role of Mycobacteriosis in Elevated Natural Mortality of Chesapeake Bay Striped Bass: Developing Better Models for Stock Assessment and Management; D. Gauthier, J. Hoening, W. Vogelbein*, M. Smith, R. Latour, P. Sadler, M. Matsche |
| 1:50-2:10 p.m. | Restoring Atlantic Sturgeon, *Acipenser Oxyrhynchus*, to the Chesapeake Bay; G. Garman and C. Hager* |
| 2:10-2:40 p.m. | BREAK and posters |
| 2:40-3:00 p.m. | Quantifying the Effects of Derelict Blue Crab Traps in the Chesapeake Bay; D. Bruce, J. Dew, S. Giordano*, J. Lazar, D. Levin, C. Little, W. Slacum, and J. Volstad |
| 3:00-3:20 p.m. | Derelict Blue Crab Traps in the Virginia Portion of the Chesapeake Bay; K. Angstadt, D. Bilkovic*, K. Havens, and D. Stanhope |
| 3:20-3:40 p.m. | Evidence for Recruitment Limitation of Blue Crabs in the Upper Chesapeake Bay; E. Johnson*, R. Aguilar, M. Goodison, A. Hines, M. Kramer, P. Roberts, H. Soulen, O. Zmora, and Y. Zohar |
| 3:40-4:00 p.m. | Enhancement of Blue Crab Nursery Habitats in the Lower Chesapeake Bay; J. Falls, E. Hamman, C. Johnston, K. Knick, R. Lipcius, K. Mahalak, D. McCulloch, J. van Montfrans, A. Place, G. Ralph, M. Seebo, R. Seitz, A. Smith*, and O. Zmora |
| 4:00-4:15 p.m. | Closing/Daily Wrapup |

* indicates which author will be presenting

All sessions in Auditorium; all coffee/pastries and lunches in Multipurpose Room. No food or beverages are allowed into the Auditorium.

Cover inset photos by David Harp, Chesapeakephotos.com

# 2009 NOAA Chesapeake Bay Office Fisheries Science Symposium • Agenda

## Wednesday, April 22, 2009

| | |
|---|---|
| 9:00-9:30 a.m. | Registration/Coffee and Pastries |
| 9:30-9:35 a.m. | Welcome/Logistics; D. Orner and K. Sellner |
| 9:30-9:50 a.m. | Welcome/Introduction; B. Beal |
| 9:50-10:00 a.m. | Atlantic Menhaden Coastwide Assessment; R. Latour* |
| 10:00-10:20 a.m. | LIDAR and Video Aerial Surveys of Menhaden in the Chesapeake Bay; J. Churnside* and A. Sharov |
| 10:20-10:40 a.m. | ~~Regional Assessment Approach~~ cancelled |
| 10:40-10:50 a.m. | Discussion on Abundance |
| 10:50-11:10 a.m. | BREAK and posters |
| 11:10-11:30 a.m. | Probing the Population Structure of Atlantic Menhaden (*Brevoortia Tyrannus*) in the Mid-Atlantic; C. Jones, T. Miller, and J. Schaffler* |
| 11:30-11:50 a.m. | Ingress of Larval Atlantic Menhaden: Supply-Side Dynamics; A. Hashinaga, E. Houde*, and C. Lozano |
| 11:50 a.m.-12:10 p.m. | Do Environmental Conditions in Nursery Habitat Contribute to a Mismatch in Growth and Production of Young Atlantic Menhaden and Striped Bass?; B. Ciotti, J. Edwards*, T. Miller, and T. Targett |
| 12:10-12:20 | Discussion on Exchange Rates |
| 12:20-1:30 p.m. | LUNCH and posters |
| 1:30-1:50 p.m. | Ecological Depletion of Atlantic Menhaden/Effects on Atlantic Coast Striped Bass: A Year-Round Food Habit Study of Large Chesapeake Bay Striped Bass; J. Boone, A. Overton, and J. Price* |
| 1:50-2:10 p.m. | Estimating Removals of Key Forage Species by Predators in the Chesapeake Bay; C. Bonzek, J. Gartland, and R. Latour* |
| 2:10-2:30 p.m. | Predatory-Prey Interactions among Fish-Eating Birds and Selected Fishery Resources in the Chesapeake Bay; A. Duerr, G. Garman*, S. Macko, S. McInish, and C. Viverette |
| 2:30-2:40 p.m. | Discussion on Predator Removals |
| 2:40-3:00 p.m. | BREAK |
| 3:00-3:20 p.m. | Menhaden Abundance and Productivity: Linking Recruitment Variability to Environment and Primary Productivity in the Chesapeake Bay; E. Annis, L. Harding, E. Houde*, and M. Wilberg |
| 3:20-3:40 p.m. | Age, Growth, Hatch-Date Distributions and Otoloth Chemistry of Young-of-Year Atlantic Menhaden in the Chesapeake Bay; E. Houde, D. Secor*, and M. Wilberg |
| 3:40-4:00 p.m. | Factors Influencing Grown of Young-of-Year Atlantic Menhaden in the Chesapeake Bay; E. Houde, D. Secor, and M. Wilberg* |
| 4:00-4:15 p.m. | Discussion on Recruitment |
| 4:15 p.m. | ADJOURN |

## Assessment of Local Abundance, Demographics, Health, and Exploitation of American Eel in the Chesapeake Bay

*Kari Fenske, David Secor, Michael Wilberg (Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science)*

Eel fisheries have a long history in the Chesapeake; over most of their exploitation history, eels have supported over 300 mt of harvest yearly and represented one of the top 15 Chesapeake species in commercial value. During the most recent 15 years, however, harvests have declined threefold, coincident with declining population trends throughout the species' range. During 2007-08, we undertook directed demographic surveys of American eel in the Potomac and other tributaries of the Chesapeake Bay. Specific objectives included: 1) measure local abundances of yellow eels in three regions of Potomac River; 2) obtain estimates of exploitation rate in the Potomac River fishery; 3) conduct demographic studies of eels in the Potomac and other major Chesapeake Bay tributaries to estimate mortality and growth rates and evaluate the effects of the parasite, *Anguillicola crassus* on eel condition; and 4) develop a stock assessment model for the Potomac River to evaluate affect of exploitation on stock production.

**Key Findings**

- Estimates of local abundance (hundreds/hectare) were substantially higher than similar estimates from the Hudson River estuary (dozens/hectare). Mark-recapture experiments using pot-captured eels (>5000 individuals marked) in a mesohaline portion of the Potomac River supported 2007 abundance estimates.
- Across the study tributaries, yellow eel ages ranged from 3 to 11 years; annual instantaneous total mortality rates ranged from 0.41 to 0.88. These estimates were based upon otolith interpretations from 800 eels collected from fishery samples throughout the Chesapeake Bay. Females dominated the catch, but sex ratios varied across tributaries.
- Incidence of parasitism by A. crassus ranged 18 to 72% across tributaries; maximum infection rates exceeded 40 parasites per eel and we observed a high incidence of damaged swimbladders associated with high rates of infection. There was a trend for decreased incidence and swimbladder damage and decreased infection rate with increased eel size.
- Data from the Potomac River Fisheries Commission indicates that coincident to declines in landings, commercial pot effort also declined substantially in the past 20 years. The remaining participants in the fishery are experiencing increased catch per unit effort.

**Implications**

- An assessment model is under development that will evaluate the effect of exploitation on Chesapeake eels. Atlantic States Marine Fisheries Commission American Eel Technical Committee members have been apprised of our plans and activities.

## Life History, Trophic Ecology, and Prey Handling of Cownose Rays from the Chesapeake Bay

*Robert Fisher, Garrett Call (Virginia Institute of Marine Science, College of William and Mary)*

This study attempts to assess many aspects of cownose ray (*Rhinoptera bonasus*) biological and behavioral characteristics. Ray natural diet complex is being evaluated, but bias as to sampling methods has prioritized effort for this summer sampling program using fishery-independent methods. Ray age-at-sexual maturity is also being prioritized for summer 2009 sampling to fill crucial voids in the data set. Ray shellfish handling and predation studies were conducted to determine rays ability to manipulate oysters and hard clams and to discover predation patterns related to species or size of prey if present. This study determined several patterns of predation by rays on three species of bivalves, *Crassostrea virginica* Gmelin, *Crassostrea ariakensis* Fujita, and *Mercenaria mercenaria* Linnaeus.

**Key Findings**

- In trials where various size oysters were introduced together (comingled trials), a logistic regression model indicated native oysters with shell heights of 30-70 mm and shell depths of 8-22 mm have the highest likelihood of predation.
- Rates of predation in comingled tests were lower than in trials where same size oysters were used (no-choice trials).
- Comparative oyster-oyster tests show no differences in predation ($p > 0.05$) between *C. virginica* and *C. ariakensis*.
- Comparative oyster-clam tests show significant ray preference for clams ($p < 0.05$).
- Rays were highly successful preying upon cultchless oysters, but were also successful preying upon cultched (spat-on-shell) oysters.
- Throughout this study, observations of cownose ray foraging and feeding suggest oysters were viewed as a general food source and prey selection was not based on a particular oyster size, rather on morphometric limitations of the rays mouth/jaw structure.

**Implications**

- Data generated from this study will provide the oyster and clam aquaculture industry and restoration programs with insight into the susceptibility of various life stages of bivalves to predation by cownose rays. Efforts can then be directed toward protection of these life stages.
- Results will also provide state and regional management agencies the tools to help estimate sustainable levels of cownose ray exploitation for use in developing management plans.

## Chesapeake Bay Clam Fishery Collapse: Probable Disease Impacts

*Christopher F. Dungan, Mark L. Homer, Mitchell Tarnowski (Maryland Department of Natural Resources)*
*Esther C. Peters (Pathobiology Consultants)*
*Kimberly S. Reece, Eugene M. Burreson (Virginia Institute of Marine Science)*

Landings from a virgin subtidal fishery for softshell clam (*Mya arenaria*) in the Chesapeake Bay escalated rapidly during 1955-1965, as a growing fleet acquired then-novel hydraulic escalator dredges. Landings from that fishery had already begun to decline when dramatic freshwater and sediment inflows from Tropical Storm Agnes damaged regional clam populations during 1972. During 1974-1990, moderate and variable softshell clam landings occurred, but documented landings since 1992 have been persistently negligible or absent. During recent years, harvesters have targeted less-valuable razor clam (*Tagelus plebeius*) with benthic escalator dredges, but razor clam populations now appear to be similarly depleted.

**Key Findings**

Since 2000, we have assessed and described several diseases that are currently prevalent, and sometimes coincident, among members of one or both species of commercial Chesapeake Bay clams and which may contribute to current depressed clam population numbers.

- Disseminated neoplasia (DN) is a lethal disease in which functional clam blood cells (hemocytes) are replaced by proliferating and dysfunctional neoplastic cells. Both *M. arenaria* and *T. plebeius* clams are affected, at prevalences to 33% among some softshell clam samples (Dungan et al. 2002).
- *Perkinsus chesapeaki* is a potentially lethal protozoan pathogen related to the agent of oyster dermo disease; but which infects at least six species of Chesapeake Bay clams, including the two commercial species, at infection prevalences that frequently approach or reach 100% (Reece et al. 2008, Burreson et al. 2005).
- A previously unrecognized virus commonly infects the nuclei of *Mya arenaria* softshell clam gill epithelial cells at prevalences to 97% of clams in some samples. We are currently working to describe the viral agent, to evaluate its pathological effects, and to determine its transmission mechanisms.

**Implications**

- Although filter-feeding, infaunal clams provide many of the same ecological services ascribed to oysters in the Chesapeake Bay, conservation measures for clam resources, habitats, and services have received relatively little public or management attention to date. Unlike oysters, whose growth and survival require increasingly scarce solid benthic substrates, clams perform and deliver their ecological services from common sand and mud habitats.

Reece, K.S., C.F. Dungan and E.M. Burreson. 2008. Molecular epizootiology of *Perkinsus marinus* and *P. chesapeaki* infections among wild oysters and clams in Chesapeake Bay, USA. Dis. Aquat. Org. 82: 237-248.
Burreson, E.M., K.S. Reece and C.F. Dungan 2005. Molecular, morphological, and experimenetal evidence support the synonymy of *Perkinsus chesapeaki* and *Perkinsus andrewsi*. J. Eukaryot. Microbiol. 52: 258-270
Dungan, C.F., R.M. Hamilton, K.L. Hudson, C.B. McCollough and K.S. Reece 2002. Two epizootic diseases in Chesapeake Bay commercial clams *Mya arenaria* and *Tagelus plebeius*. Dis. Aquat. Org. 50:67-78

## Population Genetics of Horseshoe Crabs (*Limulus Polyphemus*) in the Chesapeake Bay and Range-Wide

*M. Eackles, T. King (U.S. Geological Survey, Leetown Science Center, Kearneysville, WV)*
*E. Hallerman (Horseshoe Crab Research Center, Virginia Polytechnic Institute and State University, Blacksburg, VA)*

A total of 1465 Limulus polyphemus have been surveyed at 13 microsatellite DNA loci from 28 spawning and 5 near- or off-shore dredge or trawl collections ranging from Franklin, ME to the Yucatan Peninsula, Republic of Mexico). This survey revealed a high degree of genetic diversity (up to 50 alleles per locus) and heterozygosity (up to 97.2%). Correlation between genetic distance and geographic distance among all collections supports isolation-by-distance as a mechanism underlying population structure. Within the continuum of isolation-by-distance clustering of specific collections on a tree of genetic distances and hierarchical gene diversity analyses demonstrated discrete regional units. These results suggested the definition of five management units within the United States: 1) Gulf of Maine (Maine and New Hampshire collections), 2) mid-Atlantic (Massachusetts to Virginia), 3) southeast (including North Carolina, South Carolina, and Georgia collections), 4) Florida-Atlantic, and 5) Florida-Gulf. Hierarchical gene diversity analyses found 10% of observed variance due to differentiation among these proposed management units. Multilocus assignment tests indicated a high probability of correctly assigning individuals back to the proposed management unit from which they were collected. The results of assignment testing to identify the source of animals that are caught at sea will be discussed along with a series of analyses assessing the demographic status of each population. Estimates of effective population sizes (Ne) varied greatly along the Atlantic coast. While Ne estimates for some populations are relative large, analyses suggest that a dramatic decline in the abundance of *L. polyphemus* in all five proposed management units has occurred.

**Key Findings**

- Three collections from the Chesapeake Bay (Turkey Point, MD; Flag Pond State Park, MD; Kiptopeke State Park, VA) indicated relatively little genetic differentiation among these sites and among other sites within the mid-Atlantic management unit.
- Nuclear DNA results show some degree of isolation of upper-Bay populations, and mixing of lower-Bay and ocean populations, mostly mediated by sex-biased (male) dispersal.

**Implications**

- Given the restriction in female-mediated gene flow observed in our study and that of others surveyling mitochondrial DNA, and the absence of larval migration reported by others, the large amount of gene flow we have documented within the Chesapeake Bay and along North America's Atlantic coast is most likely to be the result of effective migration by sub-adult or adult males.
- Management efforts may best be targeted at local populations in some instances rather than at a management unit level as an absence of an effective number of females may result in local functional extinctions. It may become necessary to institute harvest limitations on female L. polyphemus for populations known to have low census sizes.
- The patterns of genetic differentiation observed in this study also suggest that relocations from adjacent embayments could serve as a source for future restoration efforts.

## Unprecedented Restoration of a Native Oyster Metapopulation in the Great Wicomico River, Chesapeake Bay

*David M. Schulte (Army Corps of Engineers)*
*Russell P. Burke, Romuald N. Lipcius (Virginia Institute of Marine Science)*

Native oyster species were once vital ecosystem engineers whose populations have collapsed worldwide due to overfishing and habitat destruction. In 2004, we initiated a vast (35 ha) field experiment with native oyster reefs in sanctuaries protected from exploitation in the Great Wicomico River, Chesapeake Bay, using three reef types (high-relief, low-relief, unrestored) sampled in 2007 and in 2009. We report an unparalleled restoration of this metapopulation, comprising 185 million oysters of three dominant year classes. A key mechanism underlying recovery was vertical relief—oyster density was fivefold greater on high-relief than low-relief reef—which explains the success of this restoration effort and the failures of past attempts. Juvenile recruitment and reef accretion correlated with oyster density, feedback processes that facilitate reef development and population persistence, suggesting the existence of alternative states. This reestablished metapopulation is the largest of any native oyster worldwide, and validates ecological restoration of native oyster species.

**Key Findings**

- Achieved a 57-fold increase in native oysters from the 1994 baseline, exceeding the Chesapeake Bay 2000 Agreement goal by nearly 6-fold.
- Achieved over 1,000 oysters/square meter via natural recruitment on the High-Relief Reefs (HRR) (over 700 of which are adults), a density not recorded on subtidal reefs in the Bay before, compared to 250 oysters/square meter on the Low-Relief Reefs (LRR).
- The HRR are growing, not degrading, adding over 20 liters of new material/square meter of reef since they were constructed.
- HRR are cohering into a solid reef structure, akin to preexploitation reefs.

**Implications**

- Native oyster restoration has and can produce persistent, growing reefs if new methods are employed.
- Large increases in native oyster biomass are possible in Zone 3 waters and large-scale, wisely placed sanctuaries will be needed to do it.

## *Life in the Chesapeake Bay*—An Animated Documentary

*Villy Christensen, Sherman Lai (Fisheries Centre, University of British Columbia)*
*Howard Townsend (NOAA Chesapeake Bay Office)*

We present a six-minute, not-yet-released documentary of life in waters of the Chesapeake Bay. The documentary is developed using a 3D gaming engine, and tells the story of how the oyster populations have plummeted, of the current state, and it finishes with a 'dream-scene' expressing how the Bay may look in the future if we were able to restore it. The power of the animation is that we are able to communicate scientific information to a much wider range of people than what our normal scientific products allow. We believe that this form for communication has a very strong potential in an education setting, and anticipate that the underlying methodology—which includes linking a scientific ecosystem model of the Chesapeake Bay to a gaming engine—will be a very powerful tool for communicating scientific simulations in a management context.

**Key Findings**

- Potential for educational activities
- Can communicate scientific information in an intuitive manner

**Implications**

- A new and powerful tool for communicating environmental concern and trade-offs
- Potential for reaching and engaging the public

## Evaluation of the Thermal Niche-Oxygen Squeeze Hypothesis for Patuxent River Striped Bass Based upon Acoustic Telemetry

*Rebecca L. Wingate, David H. Secor (Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science)*
*Richard T. Kraus (George Mason University)*

Increased densities of Chesapeake Bay striped bass together with decreased water quality may have altered behavior, condition, disease prevalence, and mortality rates during summer and fall months. Past literature supports the hypothesis that summer-time conditions of high temperature and low oxygen constrain striped bass distributions with consequences to growth and survival. We used acoustic telemetry to better understand these constraints on striped bass habitat selection. In fall 2007, striped bass were implanted with depth telemetry transmitters and released into oligohaline and mesohaline regions of the Patuxent River (N=42). Remote receivers continuously monitored for tagged fish at intercept sites near the mouth of the Patuxent, at the down-estuary boundary of the oligohaline zone, and at the down-estuary boundary of the freshwater zone. Nine mobile telemetry surveys of the Patuxent River were conducted from June to December 2008 to monitor fine-scale patterns of habitat use. Four additional surveys will be conducted during summer 2009.

**Key Findings**

- Tagged striped bass exhibited seasonal, albeit variable migration patterns. Seventeen fish were detected leaving the Patuxent River soon after tagging (0-2 months). The remaining 25 fish continued to be detected by both remote receivers and mobile telemetry surveys for 5-13 months within the Patuxent River study area. Most fish migrated to the lower Patuxent River and into the Chesapeake Bay during winter months. Striped bass exhibited an upstream migration into the freshwater zone of the Patuxent River during March-May, presumably for spawning. Nineteen fish were actively detected at the remote receiver intercept sites and during the manual surveys during the summer and/or fall months, and mean residence time in the Patuxent River was 191 days.
- Tagged striped bass avoided summertime hypoxia. During summer months, low dissolved oxygen levels (<4 mg/L) and warm temperatures (>24 ºC) dominated. Tagged striped bass were concentrated in the oligohaline zone during these months. While some fish were detected at sub-pychnocline depths with low dissolved oxygen levels, a majority were detected just above this zone, supporting the inference that striped bass avoid summertime hypoxia. Tagged fish moved to deeper waters in fall months when temperatures dropped and dissolved oxygen levels were not restrictive.

**Implications**

- We will develop a habitat preference model and contrast this with bioenergetic predictions. Data will be provided to the NOAA Sarbanes Oxford Laboratory to calibrate their Chesapeake Bay striped bass habitat suitability model.

# The Role of Mycobacteriosis in Elevated Natural Mortality of Chesapeake Bay Striped Bass: Developing Better Models for Stock Assessment and Management

*W. K. Vogelbein, M. Smith, J. Hoenig, R. Latour, P. Sadler (Virginia Institute of Marine Science, College of William and Mary)*
*D. T. Gauthier (Old Dominion University)*
*M. Matsche (Cooperative Oxford Laboratory, Maryland Department of Natural Resources)*

Recent stock assessments have identified a significant increase in natural mortality of Chesapeake Bay striped bass (*Morone saxatilis*). This has alarmed fisheries managers and researchers and has led to speculation that mycobacteriosis, a bacterial disease endemic to striped bass since at least the late 1990's, may be the cause. We therefore initiated two independent field investigations to monitor this emerging disease and to better understand its potential adverse impacts on Chesapeake Bay striped bass. We hypothesized that mycobacteriosis causes significant adverse effects including mortality of infected bass. The first study, using a fisheries-independent year-round trawl survey called ChesMMAP, is providing extensive spatial and temporal data coverage across the Bay mainstem. New epidemiological models were applied to apparent disease prevalence data obtained by ChesMMAP and this approach has recently provided first evidence of disease-associated mortality in the striped bass. A second field study funded by NCBO is a tag-recapture program aimed at clarifying disease progression and disease-associated population impacts (e.g., mortality) within the Rappahannock River. Maryland collaborators have implemented a similar program in the northern portions of the Bay. Our approach compares tag-recapture rates between healthy and diseased striped bass, making the assumption that if disease-associated mortality occurs, then returns of affected bass should be significantly lower than returns of healthy ones. Because non-lethal (serologic/immunologic) diagnostics for mycobacteriosis are not available, we are using skin lesion severity as a nonlethal indicator of disease status. We have assessed health status, archivally photographed, tagged and released striped bass during spring and fall since 2005. To foster high tag return rates, we have set up a reward system that provides fishers in possession of tagged bass with VMRC, PRFC, and MD DNR-sanctioned size, season and kreel limit exemptions and pays a reward of $5 (tag data) or $20 (whole fish on ice) for returns. So far, we have tagged and released 11,290 striped bass and have recaptured 1229 (~11%) of them. We have additionally collected random seasonal necropsy samples at our river mouth and up-river stations in order to track spatial and temporal trends in disease status. Analyses of the tag-recapture data to elucidate disease impacts and progression are underway using modeling, logistic regression, and conventional hypothesis testing.

**Key Findings**

- In the absence of specific and rapid non-lethal diagnostics for this disease, gross skin pathology has become a viable non-lethal indicator of mycobacterial disease status in striped bass (the skin lesions are pathognomonic).
- Overall disease prevalence in Rappahannock River bass is very high (dermal: 50-70%; visceral: 75-98%) but temporally and spatially stable. Disease severity is greater at the river mouth.
- Tag-recaptures are revealing that striped bass with moderate to severe dermal disease (~25% of the stock) are experiencing a mortality rate nearly double that of fish exhibiting no dermal disease.
- Dermal mycobacteriosis is chronic, taking 2 – 3 years to progress from incipient to severe disease.
- Growth rates in bass with moderate to severe dermal disease are about two-thirds the rate of striped bass with no dermal disease.

**Implications**

- We provide strong new evidence that mycobacteriosis has significant negative impacts on Chesapeake Bay striped bass. However, the underlying environmental factors modulating disease expression within the Bay are currently not known. Such information is crucial to a full understanding of the causes of this emerging infectious disease and to development of effective management interventions in the future.

## Restoring *Acipenser Oxyrhynchus* to the Chesapeake Bay

*Christian Hager (Virginia Sea Grant, VIMS)*
*Greg Garman (Virginia Commonwealth University)*

Once abundant and discarded as useless, then prized and heavily targeted; in 2009 the Atlantic sturgeon is likely to be listed under the ESA. In 1998, when the species was reviewed for listing, full protection from harvest was established. However, no recognizable population recovery has occurred. When another listing review was conducted in 2007, Distinct Population Segments [DPS], to include the Chesapeake's stock, were suggested for listing. The Virginia Sturgeon Restoration Partnership has investigated Atlantic sturgeon in the Chesapeake Bay since 2005, primarily in the James River. The partnership's over arching goal is to qualify and quantify the factors hindering recovery and contribute to conservation actions to achieve restoration. Research has been diverse, including bycatch, gear engineering, vessel and dredge interactions, genetic characterization and acoustic fingerprinting. Active and passive tracking research is being conducted congruently with habitat assessment and mapping to define temporal and spatial aspects of habitat quality, and simultaneously establish patterns of use. Research will provide information necessary to understand anthropogenic influences and formulate appropriate responses so that negative outcomes affecting the species at all life stages can be mitigated. Though water quality has improved since imposition of the Clean Water Act, many of the most beneficial benthic habitats have been destroyed and/or degraded to the extent that sturgeon restoration efforts will be required to recover historic diversity and productivity levels. Availability of complex hard substrate with sufficient flow necessary for successful sturgeon spawning has been severely limited. Once hatched, such substrate normally also provided predator refuge. Inappropriate temperature regimes can severely effect juvenile sturgeon production. Bioenergetic models suggest that warm water inputs into traditional upriver nursery grounds maybe limiting the availability of access to productive habitats during summer months, even in years of average flow. Channels, habitats used by sturgeon of all life stages, are routinely dredged and dredge material disposed of on shallow forage areas used by juveniles. The affects of such ongoing disturbance is unknown. At later life stages, juveniles and adults suffer mortality due to bycatch, intentional harvest (poaching) and vessel strikes. In short, the species has and continues to suffer from many of the limiting factors that affect the recovery of diadromous fishes. Due to this similarity in restoration challenges and the species sensitivity to water quality issues, the species well being provides a good indicator of estuarine restoration in general. In turn, efforts targeting the species restoration provide an appropriate broad based conservation model for Bay species in general.

**Implications**

- ESA listing will bring additional scrutiny of fisheries, dredging activities, vessel interactions and habitat standards.
- Gear, temporal and spatial aspects of fisheries can be altered to reduce the retention rates of sturgeon.
- Tidal fresh water habitats have been severely degraded and will require restoration efforts to restore historic biodiversity and production levels.

## Quantifying the Effects of Derelict Blue Crab Traps in the Chesapeake Bay

*Steven D. Giordano, Colin Little, Doug Levin (NOAA Chesapeake Bay Office)*
*David Bruce, H. Ward Slacum Jr., Jay Lazar, Jody Dew, Jon Volstad (Versar)*

During acoustic survey operations, the NOAA Chesapeake Bay Office (NCBO) Habitat Characterization and Mapping Program identified large numbers of derelict crab traps in high value blue crab habitat in the upper Chesapeake Bay. NCBO coordinated and led it partners in creating its Derelict Fishing Gear Program (DFGP) with partial funding from the NOAA Office of Response and Restoration's Marine Debris Program to evaluate the scope and character of potential fisheries impacts from potential habitat degradation and 'ghost fishing' traps in the Chesapeake Bay. The primary objectives of this program are to 1) quantify the occurrence, distribution, and abundance of derelict crab traps, 2) characterize the effects of derelict traps through field experiments and trap retrievals, and 3) Develop and facilitate appropriate remedial actions. Following thorough testing and experimentation, DFGP developed reliable acoustic survey methods to accurately identify, locate, and quantify derelict crab traps in the Bay. Using a stratified random sampling survey design, DFGP estimated that approximately 42,000 derelict blue crab traps were on the bottom in the Maryland portion of the Bay as of winter 2007. DFGP initiated a parallel stratified random survey in Virginia waters using identical methods in partnership with the Virginia Institute of Marine Science Center for Coastal Resource Management. The Virginia transect survey is ongoing. To quantify the effects of derelict traps, DFGP conducted field experiments during 2006 and 2007 simulating ghost fishing to estimate the impacts of derelict traps on blue crabs, and non-target bycatch species. Field experiments supplied information on overall catch, CPUE for blue crabs, bycatch, crab mortality, escapement, trap degradation, and fouling.

**Key Findings**

- A total of 1,388 individuals belonging to 10 different species were captured in experimental ghost fishing pots; 704 (51%) were blue crabs
- Male blue crabs were the most abundant gender (69%), followed by mature females (25%), and immature females (3%)
- The average size (carapace width) of blue crab captured was 140.41 ± 6.17 mm (mean ± standard error)
- The Catch per Unit Effort of blue crabs was 0.058 ± 0.004 (catch rate ± standard error), which is approximately 21 crabs caught per trap per year (not necessarily killed)
- Blue crab catch varied significantly among seasons, with summer having the highest daily catch rate. Catch was also significantly associated with bottom water temperature and salinity
- 592 of the 704 blue crabs captured died (84% of the catch)
- The mean daily mortality rate of blue crabs was 0.047 ± 0.003 (± 1 standard error), which is approximately 17 crabs dying in one ghost fishing pot per year
- Summer had the highest daily mortality rate
- Over the course of the study, 61 blue crabs (11% of crab catch) escaped from the experimental traps. Escapement was significantly different among seasons and highest in the summer
- White perch (*Morone Americana*) was the most abundant bycatch species collected (84%), followed by oyster toadfish (*Opsanus tau*) (8%), and spot (*Leiostomus xanthurus*) (4%)

**Implications**

- The effects of derelict crab traps on blue crab stocks was expressly identified as information needed for the Chesapeake Bay blue crab stock assessment. Once a Bay-wide estimate is available, resource management agencies will be able to make science-based decisions about potential mitigation actions and the management of blue crabs, bycatch species, and their habitats.

## Derelict Blue Crab Traps in the Virginia Portion of the Chesapeake Bay

*Kirk J. Havens, Donna Marie Bilkovic, David Stanhope, Kory Angstadt (Virginia Institute of Marine Science)*

Derelict blue crab traps are lost either through accident (cutting of the buoy float line by boat propellers), storm events, or abandoned. To assess the magnitude of the problem derelict traps represent in Virginia, several key factors influencing derelict trap fishing mortality were examined, including number, accumulation rate, and capture rate of traps, as well as amount of time to deterioration. Side scan sonar was used to locate derelict traps and assess their extent and accumulation rate. In 2006, 635–676 derelict traps were identified in a 33.5 $km^2$ area of the lower York River. Annual trap loss rates were estimated at 20-30%. Experimental traps were monitored at four locations in the York River to calculate catch rates of marine organisms and trap degradation rates. Predominant species captured in the experimental traps were blue crab, Atlantic croaker, and oyster toadfish. Experimental traps captured 50.6 blue crab•$trap^{-1}$•$season^{-1}$ and 13.6 Atlantic croaker•$trap^{-1}$•$season^{-1}$ during April–October 2006. Baiting traps to simulate entrapped fish (self-baiting) doubled the catch rate. Data suggest a conservative estimate of blue crabs trapped by derelict traps in the Lower York River at an average of 1 market-sized crab every 4 days per trap (25,000-50,000 crabs/season). Derelict traps continued to capture organisms for 2 years in high saline/high energy systems, and at least 3 years in low salinity or low energy systems. In collaboration with NCBO and VERSAR, a survey is under way to estimate Bay-wide derelict trap abundance. To date in Virginia, transects were completed in the western tributaries producing estimates of 5,863-12,763 derelict traps. Prior to completion of transects on the Eastern shore, the watermen's marine debris removal program was initiated to distribute Federal disaster relief funds to crab dredgers after the fishery was closed. From Dec 2008-Mar 2009, 58 participants used Humminbird side imaging units for locating marine debris. GPS trap locations were marked and an image of the scanned object stored. Traps were removed with an approved retrieval device and bycatch recorded. In 2009, 1524 $km^2$ were scanned and 8643 derelict traps removed (38% abandoned, 62% grappled) from Virginia waters. Before the debris-removal program ends in two years, trap modifications and other measures should be implemented to reduce trap loss and fishing potential of lost traps.

### Key Findings

- Sonar is a highly effective tool for locating and retrieving derelict traps
- Derelict traps can effectively trap in high saline/high energy systems for ~2 years, while in lower saline or lower energy systems traps continue to capture for at least 3 years
- Derelict trap accumulation is ~20-30% of traps fished annually
- On average, 50.6 blue crab•$trap^{-1}$•$season^{-1}$ are captured with derelict traps, self-baiting doubled the capture rate
- 8,643 derelict crab traps were removed from Virginia waters in 2009, which have the potential to capture approximately 435,000-864,000 blue crabs per year

### Implications

- To reduce the fishing potential of derelict traps, actions should be implemented to 1) reduce trap loss, 2) require proper disposal of traps, and 3) modify trap designs to reduce capture efficiency of lost traps within a year

Additional Information: http://ccrm.vims.edu/marine_debris_removal/index.html

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## Evidence for Recruitment Limitation of Blue Crabs in the Upper Chesapeake Bay

*Eric G. Johnson, Anson H. Hines, Heather L. Soulen, Paige M. Roberts, Margaret A. Kramer, Michael R. Goodison, Robert Aguilar (Smithsonian Environmental Research Center)*
*Yonathan Zohar, Oded Zmora (Center of Marine Biotechnology, University of Maryland Biotechnology Institute)*

The major, persistent decline in the Chesapeake blue crab population appears to be largely driven by declines in the female spawning stock and subsequent reductions in juvenile recruitment. As a result, management agencies have focused recent regulations on reducing exploitation of adult female crabs in an effort to increase recruitment to rebuild stocks. In the Chesapeake Bay, spatial variation in blue crab abundance reflects both differences in initial densities established by recruitment of juveniles into nursery habitats, and in post-settlement processes affecting growth and survival. Herein, we summarize evidence from 1) existing fishery-independent data sets, 2) large-scale field surveys and experiments within shallow blue crab nurseries throughout Maryland, and 3) small-scale field releases of hatchery-reared juvenile blue crabs in the upper Chesapeake Bay, that provide strong indications that many areas of the upper Chesapeake Bay currently suffer from recruitment limitation. Population declines are evident in fishery-dependent landings data, fishery-independent winter dredge survey, and in independent measures of spawning stock abundance in the lower Bay spawning sanctuary which have declined by 84% since 1991. Our field surveys within shallow (< 1m), nearshore blue crab nursery habitats on both the eastern and western shores of the Chesapeake Bay clearly show that the density of juvenile blue crabs declines with increasing distance from the Bay mouth. Conversely, tethering experiments indicate that survival of blue crab juveniles is higher in up-estuary sites, and benthic samples revealed abundant prey at all sites. Collectively, these results suggest that low crab abundance in these locations is most likely a result of insufficient juvenile recruitment and not poor survival or lack of food resources. Field releases of hatchery juveniles directly augmented local wild stocks and demonstrated that localized enhancement of blue crab populations can be successful in the upper Chesapeake Bay. Hatchery crabs more than doubled production in release sites on average, and increased wild populations by as much as seven fold in some areas, clearly demonstrating our ability to increase productivity in these systems. Releases had no detectable impact on benthic prey communities indicating that release sites were not limited by prey availability and are below carrying capacity. Further, intensive sampling within release sites detected no declines in wild juvenile abundance following release of hatchery-reared crabs indicating that wild crabs were not displaced from release areas, and that local productivity was increased as a direct result of hatchery releases in these systems. Overall, our results are consistent with the hypothesis that important nursery habitats in Maryland are currently recruitment-limited and a contributing factor to the lack of population recovery.

**Key Findings**

- Population declines are evident in landings, fishery-independent surveys and in independent measures of spawning stock abundance.
- Field experiments indicate that low crab abundance in many upper Bay tributaries is most likely a result of insufficient recruitment, not poor survival or lack of food resources.
- Releases of hatchery-reared blue crabs doubled local populations, did not displace wild juveniles from release sites, and had no detectable impact on benthic prey communities indicating release areas were below carrying capacity.
- Overall, our results indicate that many of Maryland's tributaries are currently recruitment-limited and a contributing factor to the lack of population recovery.

**Implications**

- The results indicate that management needs to take strong action both to reduce the fishery exploitation of the blue crab stock and to develop additional spatial management strategies for ensuring mature females survive to reproduce and for enhancing increased recruitment of juveniles into under-utilized nursery habitats of the upper Bay.

## LIDAR: Aerial Surveys of Menhaden in the Chesapeake Bay

*Jim Churnside (NOAA Research)*
*Alexei Sharov (Maryland Department of Natural Resources)*

We flew lidar surveys of menhaden in the Chesapeake Bay in September 2006, July and September 2007, and September 2008. At the same time we collected video data using a standard digital video (2006, 2008) or a high-definition video (2007) camera. In 2008, the high-definition camera was flown independently in July, August, September, and October. In 2006, we also made laboratory and open-ocean measurements of menhaden target strength. The target strength for a standard fish was estimated to be 1.5×10-5 m2 in the cross-polarized return based on the laboratory measurements. However, when we used this target strength to compare lidar estimated school size with actual size from catch data, we found the lidar to significantly underestimate the number of fish in the school. The reasons for this include a narrow lidar swath width compared with school width, shadowing of fish in the school by those above, uncertainties in target strength and lidar calibration, and fish below the penetration depth of lidar. While all of these effects can be mitigated to produce an absolute abundance estimates, aerial indices of abundance are probably a more practical near-term solution.

**Key Findings**

- Several indices of abundance are possible from aerial surveys – number of schools, surface area of schools, number of fish.
- Absolute biomass estimates are biased low.

**Implications**

- Combined lidar/video surveys are the most accurate; video alone is the least expensive

## Probing the Population Structure of Atlantic Menhaden (*Brevoortia Tyrannus*) in the Mid-Atlantic

*Jason Schaffler, Cynthia Jones (Old Dominion University)*
*Tom Miller (Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science)*

Recent stock assessments show a decline in Atlantic menhaden biomass even though there is no indication of overfishing. This indicates a decline in recruitment that is not well understood. One of the first steps in understanding recruitment declines is to clarify population structure and the spatial and temporal recruitment patterns contributing to the coastal migratory stock and adult fishery. Applied tags will not work for this purpose because of the high mortality experienced by both juvenile and adult menhaden. Natural tags would be an ideal candidate to answer these questions. Using natural tags, we are able to distinguish between juvenile menhaden in the Chesapeake Bay and other nearby estuaries using a combination of trace element and stable isotope chemistries in their otoliths. Furthermore, we are also able to detect differences in otolith chemistries within the Chesapeake Bay. This has many implications for our understanding of menhaden recruitment dynamics and population structure. Distinct within-Bay otolith chemistries imply limited dispersal once menhaden are recruited to nursery habitats. This also implies local factors such as food availability, DO, salinity, or other environmental parameters will control the recruitment process. For example, preliminary results indicate that recruits from the mid-Bay (Potomac River) are more important to the fishery than would have been predicted from habitat volumes.

**Key Findings**

- Chesapeake Bay and other estuaries (Delaware Bay) have unique chemistries
- Drainage basins within the Chesapeake Bay have unique chemistries
- Unique basin-scale chemistries implies restricted movements during first-year growth

**Implications**

- Managing on a watershed scale is paramount to understanding menhaden dynamics
- Knowledge of local processes is a key to ecosystem management

## Ingress of Larval Atlantic Menhaden (*Brevoortia Tyrannus*) to the Chesapeake Bay: Supply-Side Dynamics

*E. D. Houde, C. Lozano, A. Hashinaga (Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science)*

Recruitments of young-of-the year (YOY) juvenile Atlantic menhaden to the Chesapeake Bay are variable and have declined to low levels in the past two decades. Ecology of early-life stages and relationships to seasonal and inter-annual factors that affect larval ingress to the Chesapeake Bay were investigated. A pilot-scale sampling plan was developed to estimate patterns of ingress by larval menhaden from coastal-ocean spawning areas and to define relationships between ingress and oceanographic, seasonal, and climate variables. Inter-annual and monthly variability in abundances, ages, hatch dates and growth of larvae were estimated and compared, based on 18 research cruises conducted at the Bay mouth in 2005-2008. Ingressing larvae were more abundant in the 2007-08 season than in 2005-06 or 2006-07. Otolith microstructure analysis provided estimates of ages, hatch-date distributions, and larval-stage growth rates. Ingressing larvae, mostly 20-30 mm in length, were youngest in 2005-06 (mean=44 days), oldest in 2006-07 (mean=50 days) and intermediate in 2007-08 (mean=46 days). Ingressing larvae hatched from September to March. Growth rates differed inter-annually; they were fastest in 2007-08 and 2005-06 (means=0.36 and 0.33 mm/d, respectively) and significantly lower in 2006-07 (mean=0.22 mm/d). Length- and age-frequency distributions indicated presence of multiple cohorts of ingressing larvae. Despite this evidence of pulses, there was consistent ingress of larvae from September through March. Larvae at the Bay mouth fed primarily on copepods and marine cladocera. Feeding success was highest in 2006-07, lowest in 2007-08, and intermediate in 2005-06. An ongoing analysis of hydrographic conditions indicates that location and depth distributions of larvae differed among cruises, indicating complex relationships associated with ingress at the Chesapeake Bay mouth.

**Key Findings**

- Abundance of ingressing menhaden larvae from the coastal ocean varied four-fold interannually; larvae were most abundant in 2007-08 and least abundant in 2006-07.
- There is constant but variable ingress of menhaden larvae from September through March, with peak ingress from December-February.
- Ages at ingress were mostly 20 to 80 days posthatch. Mean ages varied inter-annually from 44 to 50 days.
- Mean growth rates of larvae varied significantly among years, ranging from 0.22 (2006-07) to 0.36 (2007-08) mm/d.
- Feeding success differed among years; it was highest in 2006-07 and lowest in 2007-08.

**Management Implications**

- The ingress research demonstrated that annual indices of ingress (larval supply) can be developed to relate to spawning biomass and recruitment success.
- Ingress surveys can provide information on trends in larval supply (abundance, hatch dates, growth), relationships to climate and ocean variability, and may have utility in predicting recruitment success.

## Do Environmental Conditions in Nursery Habitat Contribute to a Mismatch in Growth and Production of Young Atlantic Menhaden (*Brevoortia Tyrannus*) and Striped Bass (*Morone Saxatilis*)?

*Jason L. Edwards, Thomas J. Miller (Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science)*
*Timothy E. Targett (College of Marine and Earth Studies, University of Delaware)*
*Benjamin J. Ciotti (College of Marine and Earth Studies, University of Delaware and Centre de Recherches Insulaires et Observatoire de l'Environnement, Moorea, French Polynesia)*

Atlantic menhaden and striped bass both rely on estuarine habitats as juveniles. Changes to the quality of these habitats likely influence the population dynamics of these two fishes. Differences between the two species in spatial and prey resource utilization generate the potential for mismatches in patterns in their juvenile growth and production. This has major implications for the relative abundance of adult striped bass and their menhaden forage base.

In carefully controlled laboratory experiments, we have developed and validated RNA:DNA-based growth indices for both species. Subsequently, we quantified the temporal sensitivity of the RNA:DNA index to changes in ration. With our most recent NCBO support, we have used this approach to quantify growth and relative production of juvenile menhaden and striped bass in the Chesapeake and Delaware Bay ecosystems. Our sampling design included both broad spatial scale, low temporal resolution coverage in both systems and small spatial scale, high temporal resolution coverage in targeted subestuaries. Here, we focus on results for menhaden, but note that parallel results are available for striped bass. We are currently working on integrated results from both species to assess spatial and temporal patterns of covariance in production of both species.

Menhaden were sampled in the Delaware and Chesapeake Bays in 2007-2008 by project staff and in collaboration with biologists with the New Jersey Bureau of Marine Fisheries and the Virginia Institute of Marine Sciences. The growth of 1,050 individual juvenile menhaden has been quantified using RNA:DNA levels and site temperature. Menhaden collected in the field over the course of our sampling ranged from 39 mm total length (TL ~ 0.5 g wet weight) – 79 mm TL (~200g). Specific growth rates of menhaden collected ranged from -0.035-0.078 g.g-1.day-1. In general growth rates declined over the course of each year sampled. Relative production was calculated as the average abundance at a site multiplied by the average growth rate of menhaden at that site. There was clear evidence of interannual variation in production. There was no clear pattern of differences among subestuaries, although some sub-estuaries exhibited more variability in production than others.

**Implications**

- The approach developed herein permits managers to estimate juvenile production of these two species at relevant spatial and temporal scales. This may lead to better approaches to identifying essential fish habitat and to ranking habitats for protection and conservation.
- The approach may also help explain patterns of covariation in the abundances of these two species at later life stages.

## Ecological Depletion of Atlantic Menhaden/Effects on Atlantic Coast Striped Bass: A Year-Round Food Habit Study of Large Chesapeake Bay Striped Bass

*James Price, Joseph Boone (Chesapeake Bay Ecological Foundation, Inc.)*
*Anthony Overton (East Carolina University)*

The Chesapeake Bay Ecological Foundation, with initial assistance from East Carolina University, has been examining striped bass since 2004 through the Predator/Prey Monitoring Program (PPMP) to investigate biological characteristics, characterize diet composition by season and determine age structure and size spectrum of Atlantic menhaden consumed by striped bass. A decline in body fat levels and weight-at-length (malnutrition) observed in striped bass >12" from Maryland's Chesapeake Bay (upper Bay) has been a consequence of ecological depletion (insufficient numbers to provide adequate prey for dependent predators) of Atlantic menhaden. Most striped bass >12" aggregate in the main stem of the upper Bay during summer through early fall; a period when menhaden <10" (ages-0&1) are less available than menhaden >10" (ages-2+): age-0 menhaden still inhabit tributary nursery areas and few age-1 menhaden have re-entered Maryland's mid-Bay region following their southern coastal migration. Consequently, during summer through early fall, striped bass 16" to 24", which prey primarily on menhaden <9" (ages-0&1), are more nutritionally limited than striped bass >24" that prey on menhaden of all sizes. These findings are substantiated by relative body fat levels recorded in 2007–2008 which averaged approximately three times higher in striped bass >24". Body fat levels of resident striped bass >16" and migratory striped bass >28" have been declining since 2006. During years of low menhaden recruitment in the upper Bay, the average weight of striped bass approximately 18" in length caught during the fall can be less than 70% of their historical weight. PPMP data shows that approximately 90% of upper Bay resident striped bass 16" to 24" are males and approximately 80% of migratory striped bass >28" are females. Since the winter of 2006-2007 many adult migratory striped bass >28" have changed their historical ocean migration patterns and now enter the Chesapeake Bay during late fall and remain through the spring spawning season – a previously undocumented event. Changes in established feeding patterns and low levels of body fat in pre-spawned migratory striped bass since the winter of 2006-2007 indicate that menhaden are ecologically depleted on their historical inshore winter feeding grounds within mid-Atlantic coastal waters. Adult migratory striped bass >28" over-wintering in the upper Bay consume more menhaden, including ages-0&1 than those remaining on historical coastal winter feeding grounds. This additional competition for ages-0&1 menhaden could exacerbate growth and health problems currently affecting upper Bay resident striped bass >12". PPMP studies of striped bass >16" in Chesapeake Bay and >28" in mid-Atlantic coastal waters found that menhaden constitute more than 75% of their annual diet (by weight), and are essential to maintenance of healthy striped bass populations.

**Key Findings**

- Factors that have contributed to the ecological depletion of Atlantic menhaden include: Poor recruitment since the mid-1990s, increased predation by high populations of striped bass and a failure to implement ecologically sound management.
- Effects on striped bass caused by the ecological depletion of Atlantic menhaden include: Malnutrition in upper Chesapeake Bay resident striped bass >12". Changes in established feeding patterns and declining body fat levels that are lower for pre-spawned migratory striped bass >28" in mid-Atlantic coastal waters than in the upper Bay. Lower carrying capacity for upper Bay resident striped bass >12" and in mid-Atlantic coastal waters for migratory striped bass >28".

**Implications**

- Establish prey fish management plans to reestablish ecological balance between Atlantic menhaden populations and dependant predators.

## Estimating Removals of Key Forage Species by Predators in the Chesapeake Bay

*Robert J. Latour, PhD., Christopher F. Bonzek, James Gartland (Virginia Institute of Marine Science)*

While historically fisheries management has been based on the results of single-species stock assessment models that focus on the interplay between exploitation level and sustainability, the inclusion of ecological processes into fisheries management plans is now strongly recommended and in some cases even mandated. As a result, multispecies models have been developed to in an effort to move towards an ecosystem-based approach to fisheries management. These models typically involve sub-models designed to estimate predator consumption, which (along with the supporting fish stomach contents data) has therefore become a focal area in applied fisheries science.

Diet composition studies of fishes in the Chesapeake Bay have documented a diverse array of food web interactions. A few particular relationships among predators and prey have been identified, however, including bay anchovy (*Anchoa mitchilli*) and Atlantic menhaden (*Brevoortia tyrannus*) as primary forage fishes for striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), and bluefish (*Pomatomus saltatrix*), summer flounder (*Paralychthys dentatus*) predation on bay anchovy and weakfish, and weakfish consumption of conspecifics. Because each of the aforementioned predators and prey are important in the Chesapeake Bay from a fishery and/or ecological perspective, we derived estimates of total consumption of these prey species by the four major predators listed.

The Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP), a fishery-independent monitoring survey utilizing bottom trawl gear designed to capture the late juvenile and adult stages of fishes throughout the mainstem of the Chesapeake Bay, was the source of the predator abundance, water temperature, and diet data for this study. Predator stomachs were analyzed using standard methods, and diet compositions were calculated using cluster sampling estimators. Predator consumption over a given time period was generated by combining the number of days in that period, daily predator consumption (derived from mean stomach contents and evacuation rate), and an estimate of predator abundance. Consumption was calculated under a variety of scenarios where one or more of the model input parameters were allowed to vary. Estimates of total and prey-specific consumption by each predator were given both annually (2002-2006) and seasonally for each year.

Predatory impacts on forage species were shown to fluctuate seasonally, likely due to the seasonal variability in the abundances of the predator and prey populations. Striped bass, weakfish, and bluefish generally exerted the highest impacts later in the year when the abundance of these predators was high. In most years, summer flounder demand on both bay anchovy and weakfish was highest during the period between July and October.

Estimates of prey stock size and predator demand were compared to both verify the reasonableness of results (demand should be less than stock size) and give an indication as to whether prey abundance may be limiting to predators. For the scenario believed to represent the most reasonable or likely set of assumptions, estimates of predator consumption were significantly lower than the estimates of prey abundance in all but one case, indicating at least some level of soundness in the assumptions and calculations. The results of the scenario believed to represent maximum predatory impact indicated that Atlantic menhaden predation impacts averaged about 67% of purse seine landings, while the total potential predatory impacts from the four predators on bay anchovy averaged about 5% of the estimated standing stock.

## Predatory-Prey Interactions among Fish-Eating Birds and Selected Fishery Resources in the Chesapeake Bay

*Greg Garman, Stephen McIninch, Cathy Viverette (Center for Environmental Studies, Virginia Commonwealth University)*
*Bryan Watts, Adam Duerr (Center for Conservation Biology, College of William and Mary)*
*Stephen Macko (Department of Environmental Science, University of Virginia)*

Populations of fish-eating birds within the Chesapeake Bay and its major tributaries have increased exponentially during the past 40 y, resulting in a novel—and potentially significant—source of predation mortality for Chesapeake Bay finfish stocks. In spite of dramatic population growth and geographic expansion by piscivorous birds, the impact of avian predation and competition on marine and estuarine fish assemblages and on the Chesapeake Bay ecosystem has not been quantified. Similarly, the potential effect of fish stocks in regulating populations of bird species that are of national conservation concern (e.g., bald eagles) has never been evaluated for the region. Historical and well-documented shifts in the spatial distribution, abundance, and reproductive output of bald eagles in the Chesapeake Bay are associated with concomitant changes in distribution and abundance of important prey fish species in tidal tributaries. Thus, fish eating birds, which have long been used as a sentinel species for tracking ecosystem health, may also serve as an appropriate indicator species for fishery population status and community monitoring. This multidisciplinary, multi-species study of the relationships among fish-eating birds and selected fishery resources within the Chesapeake Bay includes a retrospective analysis of bird and fishery interactions across long (decadal) and short (seasonal) temporal scales, analyzes the current geospatial distribution and abundance of major fish-eating bird species, estimates total fish prey consumption Bay-wide, and includes avian diet composition studies combined with temporally and spatially synoptic estimates of fish prey availability and the development of a fishery-independent stock assessment tool for Atlantic menhaden based on unique stable isotope and compound-specific biochemical markers in avian predators. Specific research goals include: 1) developing a spatially explicit predictive model of consumption rates of fish prey based on published, energetic requirements of selected avian predators; and 3) identifying appropriate avian indicators in support of ecosystem-based fishery management. The results of this study will elucidate the complex—and potentially significant—interactions among historical and novel avian predators and selected fishery resources of the Chesapeake Bay. These outcomes will allow natural resource managers to forecast responses of both avian and fish communities to management and restoration efforts. The results will also contribute substantially to the accuracy of existing Chesapeake Bay ecosystem and fishery management models.

**Key Findings**

- Total estimated consumption (based on bioenergetics models) of fish by avian predators in the Chesapeake Bay and major tributaries is over 16 million kg/y and is increasing.
- Contribution of Atlantic menhaden to Chesapeake Bay osprey diets (Mobjack Bay) declined from 75% to 28% (by mass) during the period 1985-2007, with a concomitant decline in osprey condition and reproductive success in the bay mainstem.
- Based on stable isotope analysis of bald eagle and osprey feathers between ca. 1840 and 2007, primary prey resources for both avian species in the Chesapeake Bay region have shifted from anadromous and estuarine fishes to resident freshwater species, including introduced taxa.
- Significant progress has been made on developing a fishery-independent stock assessment tool for Atlantic menhaden, based on species-specific, isotopic markers in the feathers of sentinel avian predators, including osprey.

## Menhaden Abundance and Productivity: Linking Recruitment Variability to Environment and Primary Production in the Chesapeake Bay

*E. D. Houde, E. Annis, L. W. Harding, Jr., M. J. Wilberg (Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science)*

The relationship between recruitment of young-of-the-year (YOY) Atlantic menhaden in the Chesapeake Bay and measures of primary productivity was evaluated. There is a positive relationship between YOY menhaden recruitment (seine-survey YOY abundance data) and both annually-integrated primary production (AIP) and euphotic layer chl-a (derived from aircraft remote sensing) for the period 1989-2004, years when recruitments were well below the long-term average. There was no significant relationship during an earlier period (1966-1988) when menhaden recruitments were higher. In a seasonal analysis, recruitment was positively related to chl-a for spring months (April-June) in 1989-2004. It is during these months that larval menhaden make the transition from feeding on particulate zooplankton to filter-feeding on phytoplankton. Diatoms dominate the phytoplankton community during spring months and presumably are important in supporting growth and production of YOY menhaden. Multivariate statistical and ordination analyses indicated that temperature and euphotic chl-a were important variables affecting YOY menhaden recruitment. Bioenergetics modeling that included chl-a, temperature, and body size variables, successfully described and predicted growth of YOY menhaden. New functional responses for filtering efficiency and swimming speeds were developed for our bioenergetics model. Based on the model, carrying capacity was estimated to be approximately 27 billion individuals in November, at the end of the first growing season. The bioenergetics model predicted fastest growth in the oligohaline upper Bay, in accord with observed sizes of menhaden from fall trawl samples and with results of independently fit growth models.

- **Key Findings**
- YOY menhaden recruitments are positively related to chl-a, annually-integrated primary production, and negatively related to temperature for the period 1989-2004.
- A newly parameterized, bioenergetics model that included chl-a, temperature and body size successfully described and predicted growth of YOY menhaden.
- The bioenergetics model predicted faster growth of YOY menhaden in the upper Bay compared to the mid-Bay and lower Bay, in accord with observations.
- There is evidence that growth of YOY menhaden is density dependent in the Bay.

**Management Implications**

- Water quality has a substantial bottom-up effect on YOY menhaden productivity and recruitment potential. Statistical and bioenergetics models have potential to describe and predict recruitment success.
- Based on the bioenergetics model, the carrying capacity of the Chesapeake Bay may be 27 billion YOY menhaden in November (end of the growing season). Higher recruitments of YOY menhaden are associated with low growth rates.

# Age, Growth, Hatch-Date Distributions and Otolith Chemistry of Young-of-Year Atlantic Menhaden in the Chesapeake Bay

*David H. Secor, Rebecca L. Wingate, Carlos Lozano, Edward D. Houde (Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science)*

Objectives and Approach

The Chesapeake Bay is thought to be a primary juvenile nursery for Atlantic menhaden. Bioenergetics models have been applied to predict growth potential of Atlantic menhaden, but actual estimates of growth and its variability on inter-annual and regional scales are not available for the Chesapeake Bay. The wide range in sizes of young-of-the-year (YOY) menhaden observed during their first summer of life suggests high variability in growth rates and/or variability in ages at which larvae enter the Chesapeake. As part of CBL's overall goal to link the ecology and dynamics of YOY menhaden production with production of eggs and larvae on the continental shelf, the objectives of our study were to 1) test whether hatch-dates were differentially represented between newly ingressed larvae and summer-collected YOY using otolith daily increments; 2) compare YOY growth rates among subestuaries and years; and 3) evaluate otolith microprobe analysis of Sr:Ca as a means to hindcast YOY dispersal patterns along the Chesapeake Bay's salinity gradient.

**Key Findings**

- Otolith increment analysis for YOY menhaden collected in June in the Choptank, Nanticoke, and Patuxent Rivers, and Pocomoke Sound from 2006-2008 yielded age estimates of 96-200 days.
- Hatch dates of newly-ingressed larvae in 2005-2006 overlapped but differed from YOY juvenile hatch-dates. Most ingressing larvae hatched in November and December but juveniles collected in June were represented by peak hatch dates in January and February. In contrast, peak hatch dates of ingressing larvae from 2006-2007 surveys were similar to hatch dates of YOY juveniles.
- Growth rates were significantly higher in 2006 (0.45 mm d-1) than in 2007 and 2008 (0.23 and 0.26 mm d-1), and higher in the Patuxent River (0.56 mm d-1) than in all other systems (0.12-0.23 mm d-1). Growth rates estimated for spring months were within the range predicted using modal sizes from survey data, and bioenergetic and cumulative growing degree-day models.
- Otolith Sr:Ca was positively correlated with ambient salinity, but the relationship was variable. For YOY collected in the most up-estuary regions, life-history profiles on otoliths generally showed a decrease in otolith Sr:Ca, consistent with gradual up-estuary dispersal and residence in lower salinity zones.

**Implications**

- Fishing effort that now is concentrated in the Chesapeake Bay and near its mouth raises concern among anglers and managers that the forage base necessary to sustain piscivore production is being eroded. This research contributes to improved under-standing of recruitment processes that underlay menhaden's role as forage fish in the Chesapeake.

## Factors Influencing Growth of Young-of-Year Atlantic Menhaden in the Chesapeake Bay

*Michael Wilberg, David Secor, Edward Houde (Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science)*

Atlantic menhaden (Brevoortia tyrannus) is an important forage fish in the Chesapeake Bay and supports its largest commercial fishery. Although the Chesapeake Bay is thought to be one of the primary nursery grounds for menhaden, factors that influence growth during their juvenile stage are not well understood. Our objectives were to evaluate factors that affect inter-annual and spatial variability in young-of-year (YOY) menhaden growth. We developed statistical models to relate spatio-temporal variability in growth to spatial and environmental factors (temperature, primary producer biomass, and year-class strength), which included modified von Bertalanffy growth models, logistic growth models, and cumulative growing degree-day models. Growth models were fitted to mean length data from the TIES-CHESFIMS trawl surveys, VIMS trawl survey, and the Virginia striped bass seine survey. We explored spatial differences in YOY Atlantic menhaden growth in four well-sampled regions of the Chesapeake Bay: Upper Bay, Rappahannock River, York River, and James River.

**Key Findings**

- Seasonal growth clearly follows a sigmoid pattern, and growth rates peak in mid-summer before abating under dropping temperatures in fall months. On average, growth rates are near zero (~0.05 mm·d-1) in the early part of the year, peak near 1.0 mm·d-1 in summer and decline to ~0.2 mm·d-1 in fall.
- There is little evidence of growth between January and April, which may indicate poor conditions for growth during this period.
- Temperature, primary production, and year-class strength had important effects on growth. Models that included environmental factors were clearly superior to the model that included no environmental factors. Cumulative growing degree days were able to explain much (80-90%) of the inter-annual variability in growth, highlighting the importance of temperature in controlling growth and production of YOY menhaden.
- Patterns of growth during the year were substantially different among regions. The estimated day at which 50% of maximum length was reached increased from south to north. YOY menhaden in the James River reached 50% of maximum length significantly sooner than YOY menhaden in the upper Bay, and menhaden in the Upper Bay appeared to grow to larger sizes.

**Implications and Future Work**

- Production of menhaden in the Chesapeake Bay is influenced by density dependent and density independent factors. Size-selective mortality may be an important factor affecting apparent growth during the year. Future research will attempt to disentangle effects of growth and size-selective mortality using length-frequency data and information on the hatch date distributions on ingressing larvae and summer YOYs.