Final Report

1 October 2011 - 30 September 2013

Project Title: **Estimating Abundance of Atlantic Menhaden in Chesapeake Bay: Comparing and Evaluating Methods and Retrospective Analysis**

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Introduction and Background

A. Problem

Recruitment of young-of-the-year (YOY) Atlantic menhaden to Chesapeake Bay has been persistently low for more than two decades. The causes of low recruitment that contrast with high levels observed in the 1970s and 1980s are not known but could be related to (1) lower adult abundance and egg production, (2) poor survival and growth of early-stage larvae on the continental shelf, or (3) poor survival and growth of juveniles after larvae ingress into Chesapeake Bay. In our earlier research (NCBO Grant NAO7NMF4570340) we recorded 9-fold variability in ingress of larvae to the Bay mouth over a three-year period (2006-2008; Houde et al. 2009; Lozano 2011; Lozano and Houde 2013) but the variability in larval ingress was not concordant with the relatively constant and low YOY index of juvenile menhaden abundance values (1.5-fold variability among years) recorded in the Maryland DNR seine surveys (Figure 1; *http://www.dnr.state.md.us/fisheries/juvindex*).

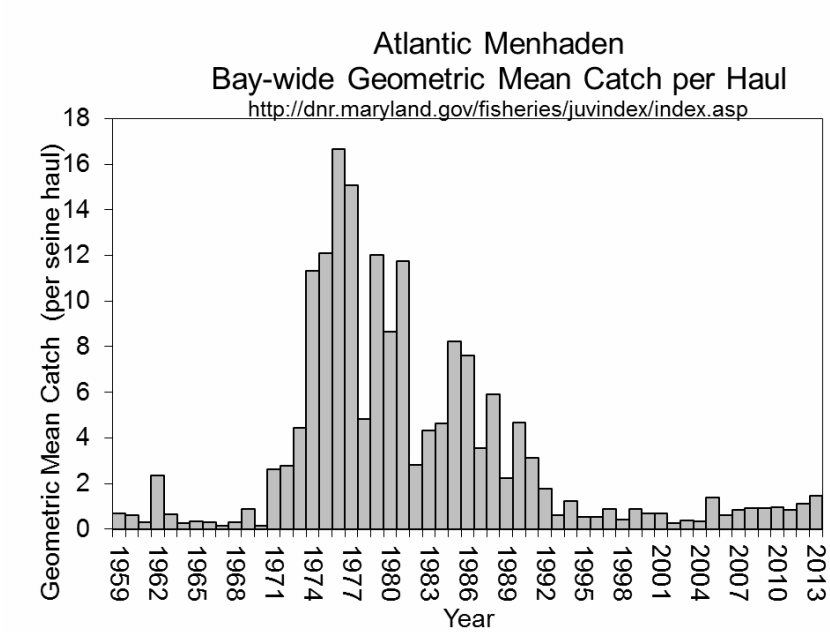


Figure 1. Trends in young-of-the-year (YOY) Atlantic menhaden catches made in the Maryland Department of Natural Resources seine survey.

In addition to evidence of controls acting on abundance of ingressing larvae, we found that recruitments of YOY menhaden in Chesapeake Bay since the 1980s are positively correlated with phytoplankton standing stock and levels of primary production and that growth of juveniles was positively related to temperature (Houde and Harding 2009; Annis et al., 2011; Houde et al., 2011, *in prep*), indicating that the control over juvenile production and recruitment might be strongest during the early juvenile period when menhaden are resident in the Bay. Finally, from, 2006-2011 our weekly seining efforts at a site in the lower Patuxent River indicated substantially

higher inter-annual variability in catches than was reported in the Maryland DNR survey that is conducted on a monthly basis. The DNR seine survey provides a reference index of recruitment to support menhaden stock assessments, but may be relatively insensitive to spatial and inter-annual variability that occurs in the Chesapeake Bay.

In our research, we directed our effort towards estimating YOY juvenile abundance and factors that control recruitment of menhaden in the Chesapeake Bay. We investigated (1) the relative abundance and ecology of YOY menhaden, (2) whether pelagic midwater trawling can provide an improved indicator of YOY menhaden abundance compared to seine surveys, and (3) how the manner in which seine and trawl gear are deployed affects relative abundance indices and inferred ecological attributes of YOY menhaden. Further, because it is recognized that not only menhaden but schooling pelagic fishes in general may be under-sampled in seines, we also compared relative catches of other principal pelagic species, i.e., bay anchovy and alosines, in the midwater trawl and seine samples.

We continue to investigate how juvenile recruitment of menhaden is related to characteristics of larvae at ingress and to nursery conditions for juveniles by estimating growth rates and hatch dates of the juveniles and relating these attributes to environmental conditions they experienced since ingress. In earlier research, we found that hatch dates of most otolith-aged YOY menhaden from seine collections in the period 2005-08 were substantially later (mostly Jan-Feb) than hatch dates of larvae at ingress (mostly late Oct-Dec), indicating selective mortality on menhaden larvae that arrived in early winter during these years (Lozano et al. 2012). The continuing, related research is supported by funds administered through the Maryland Department of Natural Resources and Atlantic States Marine Fisheries Commission (Maryland DNR Contract No. K00B3400024).

B. Goals and Objectives

Accurately estimating relative abundance of YOY juveniles is central to understanding (1) the issue of recruitment decline; (2) how recruitment is related to ecosystem attributes of the Chesapeake Bay; and (3) the accuracy of recruitment estimates in current menhaden stock assessments. The juvenile index values now available from the MD DNR seine survey, when averaged over regions, provide a measure of inter-annual variability in recruitment level for the Bay as a whole, but one where variability is likely dampened because menhaden are not captured at most of the designated survey sites. Further, there is evidence that recruitment potential has varied spatially over the years (e.g., Love et al. 2009) and that some tributaries may be more variable than others with respect to production of YOY pre-recruits. We suspect that a substantial part of the variability is associated with the seine-survey sampling approach that may not provide consistent estimates of relative abundances of young pelagic fishes such as menhaden, bay anchovy and alosines. Sampling conducted in 2012, supported by this grant from the NOAA Chesapeake Bay Office (NCBO), represented the first year of a two-year field effort.

The second field year, conducted in summer 2013, was supported by funds from the Atlantic States Marine Fisheries Commission and Maryland DNR (Maryland DNR Contract No. K00B3400024). This report refers only to the 2012 field season results.

Project **Objectives:**

- Compare seining and trawling methods to estimate abundance of YOY menhaden.
- Evaluate within-tributary temporal and spatial variability in YOY menhaden abundances and demographic characteristics and compare results for the seine and trawl gears.
- Identify hydrographic and environmental correlates associated with YOY menhaden catches and abundance.
- Determine size and age structure, hatch dates and growth histories of YOY menhaden and compare by sampling method in two tributaries and the Upper Bay.
- Compare the precision of relative abundance estimates of YOY menhaden sampled by seining and trawling gears.
- Conduct a retrospective analysis on sizes, ages, and spatial variability of YOY menhaden in past Maryland DNR juvenile index surveys.
- Also compare the efficacy of seine and trawl gears for other pelagic fishes, e.g., bay anchovy, YOY alosines.
- Build upon analysis, modeling, and synthesis efforts on larval-stage and juvenile menhaden funded previously by NCBO (NA10NMF4570451) and MD DNR (K00B0400126 and K00B1400058).

For research reported herein, we initiated a program to sample YOY juvenile menhaden during June-September 2012 that emphasized evaluating survey methods and protocols to estimate relative abundances in tributaries and the upper Chesapeake Bay (Figure 2). This overall objective is responsive to the need for better survey methodologies that has been identified for Chesapeake Bay living resources in general (Bonzek et al. 2007) and menhaden in particular (ASMFC 2004). A menhaden stock assessment peer review (ASMFC 2004) concluded that due to survey weighting, the coastwide time series mainly reflects trends in the Maryland [seine] survey. However, the relative productivities of menhaden nursery areas coastwide in recent years are unknown. An ASMFC review panel recommended investigation of existing studies that could assist in evaluating current productivity and development of protocols to quantify contributions of different nursery areas to the adult stock. Accordingly, we undertook a comparison of seine and midwater trawl gears as tools to assess nursery area productivity.

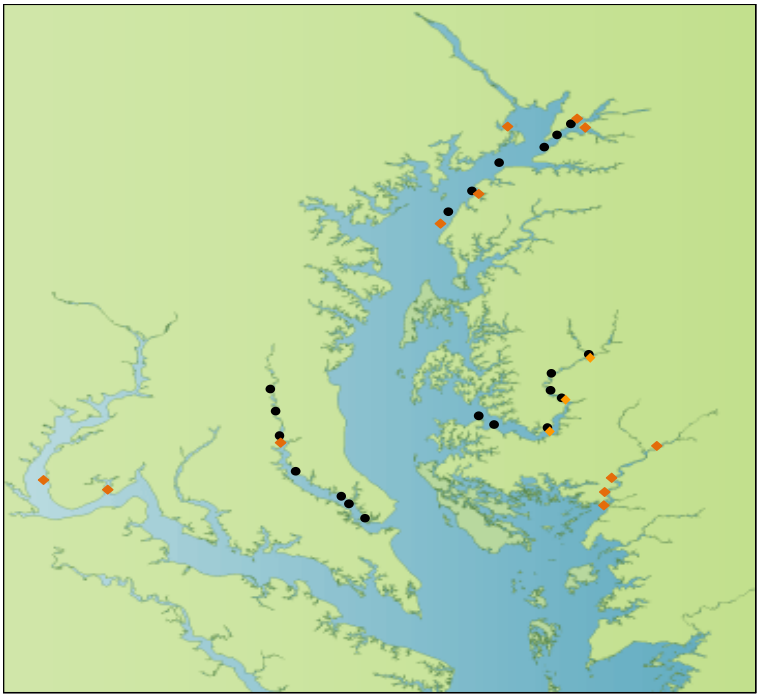


Figure 2. Map of Chesapeake Bay showing sites at which YOY Atlantic menhaden were sampled during May-September 2012 to support gear comparisons and menhaden sampling for age and growth analysis. Sampling sites (MWT and seine) for 2012 gear comparison surveys are shown in black; Maryland Department of Natural Resources seine sites from which we obtained preserved YOY menhaden samples are shown in orange.

Progress

Research Cruises and Seine Surveys

Three research cruises and seine surveys, for the periods 05-06 June, 11-12 July and 07-08 August, were conducted in 2012. Sites in the Upper Bay and in the Choptank and Patuxent Rivers were sampled in June. During July and August, surveys were conducted only in the Choptank and Patuxent Rivers. Five sites were designated in the Upper Bay and Patuxent River while six sites were designated in the Choptank River. Sampling within each tributary was designed to include down-stream and up-stream sites along the salinity gradient. Catches in a 100-ft bag seine with ¼" mesh, identical to the seine used by Maryland DNR in its juvenile index surveys, were compared to catches made in an 18-m^2 mouth-opening midwater trawl that has been used effectively to sample YOY fishes in UMCES surveys since the 1990s (Jung and Houde 2003). Seine hauls were conducted using quarter circle sweeps following the protocol established by MD DNR. Simultaneous trawl tows were conducted from the UMCES, 81-ft RV *Rachel Carson* immediately offshore (< 0.5 km) of the seining sites. The midwater trawl was towed for 20-min, with the net fished obliquely from surface to bottom in 2-min stepped increments. Onboard the research vessel a CTD was deployed at each site to obtain temperature, salinity, dissolved oxygen, and fluorescence (chlorophyll *a*) data. On occasions when a CTD was not available a YSI sonde was used to obtain profiles of temperature, salinity and dissolved oxygen. A YSI sonde was used to obtain temperature, salinity and dissolved oxygen data at each seine site. During the August 2012 survey, a single site was selected to estimate within-gear precision for YOY menhaden catches in both the Choptank and Patuxent Rivers.

Subsamples of YOY menhaden from each of the gears were preserved in ethanol and brought to the laboratory for further analysis. Field capture techniques and the collection of fish for this project were approved by the UMCES Institutional Animal Care and Use Committee (November 11, 2011).

Gear Comparisons of Catches and Lengths

Catches (numbers) of all fish were recorded. Individual lengths and aggregate weights were obtained for menhaden, bay anchovy, and alosines. Catches and lengths of menhaden were compared between the two gears.

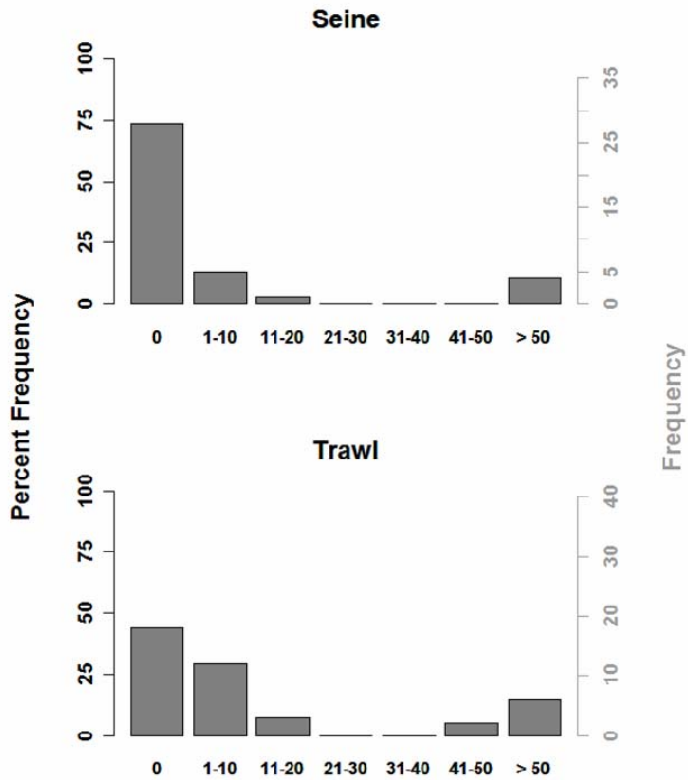
Catches from the seine and trawl were expressed as abundances (numbers per m^2). Abundances from seine hauls were estimated by dividing the catch in numbers by the area swept. Area swept was estimated using a quarter of the area of a circle when the 100-ft seine was fully deployed or the area of a partial trapezoid when the seine could not be fully deployed (Martino 2008). Abundances from the midwater trawl tows were estimated by dividing the catch of YOY menhaden by the volume sampled (Connelly 2011) and then multiplying by the depth (m) of

water at the sampling site. In addition, presence-absence of menhaden was compared between the two gears.

Length-frequency distributions of menhaden were compared among surveys and tributaries and between gears. Mean total lengths were compared among surveys, tributaries and between gears.

Catches

A total of 5,792 YOY menhaden were collected in the two gear types during the three surveys conducted in 2012; 3,447 were collected in the midwater trawl and 2,345 in the seine. The overall mean abundance of menhaden estimated from seine hauls (151 menhaden/10,000m^2) was nearly 14 times higher than the mean abundance estimated from midwater trawl tows (11 menhaden/10,000m^2) (Table 1). This difference, however, was not significant (ANOVA; $p > 0.05$) because of high variability in catches among deployments (trawl CV = 385%; seine CV = 321%).



fish intervals. June to August 2012.

The highest catch in a seine set was 1,463 menhaden while the highest trawl catch was 882 menhaden. More than 80 % of the catches in each gear had 20 or fewer menhaden. A few large catches tended to inflate the overall means in both gears, but disproportionately so for the seine.

We also examined presence-absence of menhaden in catches by the two gear types. The frequency of catches with 0 menhaden was high (Figure 3). There were relatively more zero catch observations in the 38 seine hauls (74 %) compared to the 41 trawl tows (44 %). The probability of catching at least one menhaden in a trawl tow (0.56) was significantly higher than the probability of catching a menhaden in a seine haul (0.26) (logistic regression (*logit* link): $p < 0.01$).

In our surveys bay anchovy, alewife, blueback herring, gizzard shad and hickory shad also were sampled. Except for bay anchovy, mean abundances of these species were low compared to menhaden (Table1). Excluding menhaden, bay anchovy was most abundant in both gears, followed by alewife, blueback herring, gizzard shad and hickory shad. Except for bay anchovy

and hickory shad, estimated abundances were higher for the seine method compared to the trawl. No hickory shad were captured in seine hauls (Table 1).

Table 1. Mean abundance, coefficient of variation and probability of catching at least one individual (Prob, Pos) for pelagic fishes sampled by trawl and seine gears. Abundances are estimates of fish numbers per 10,000 m^2. Data summarized from three surveys conducted in June – August 2012.

	Trawl			Seine		
Species	Abundance	CV	Prob, Pos	Abundance	CV	Prob, Pos
Menhaden	10.98	385%	0.56	150.98	321%	0.26
Anchovy	207.18	259%	0.95	37.82	288%	0.53
Alewife	0.01	502%	0.05	1.11	244%	0.24
Blueback	< 0.01	640%	0.02	0.13	616%	0.03
Gizzard	0.01	447%	0.05	0.10	437%	0.08
Hickory	<0.01	484%	0.05	0	--	< 0.01

Bay anchovy and hickory shad were the only species that had higher estimated abundances in the trawl compared to the seine. Most tows and hauls of the gears in these surveys resulted in zero catches of alewife, blueback herring, hickory shad, and gizzard shad. The probability of catching at least one alewife in the seine (0.24) was significantly higher than the probability of catching an alewife in the trawl (0.05) (logistic regression (logit link: $p < 0.05$). The probability of catching blueback herring, hickory shad and gizzard shad was low and similar for the two gears (logistic regression (logit link: $p > 0.05$). Bay anchovy commonly occurred in both gears but with significantly higher probability of occurrence and abundance in the trawl. The probability of capturing at least one bay anchovy was 0.95 for the trawl and 0.53 for the seine.

For each survey, numbers of menhaden from trawl and seine subsamples are being compared among sites, tributaries, and months. To build greater statistical power, we will combine data from field seasons 2012 (this award) and 2013 (ongoing ASMFC-DNR award) in our continuing analysis. Incidence data are being examined by cross tabulation to evaluate incidence of positive occurrences for each tributary x month combination across gear type. Additionally, we will conduct an analysis of variance to evaluate relative catchability across length classes of YOY menhaden in paired gear comparisons.

Lengths

Mean and modal lengths of YOY menhaden captured in each gear increased as the summer progressed (Figure 4; Table 2). Overall, mean lengths were 68.3 mm (± 0.8 SE) total length in

June, 108.5 mm (± 1.3 SE) in July and 124.0 mm (± 1.1 SE) in August. Over the three surveys in 2012 the mean length of menhaden was slightly but significantly longer in samples from the seine compared to mean lengths from the trawl (Table 2) (nested ANOVA: $p < 0.01$). However, mean lengths within each of the three surveys did not differ significantly between gears (nested ANOVA: $p > 0.05$).

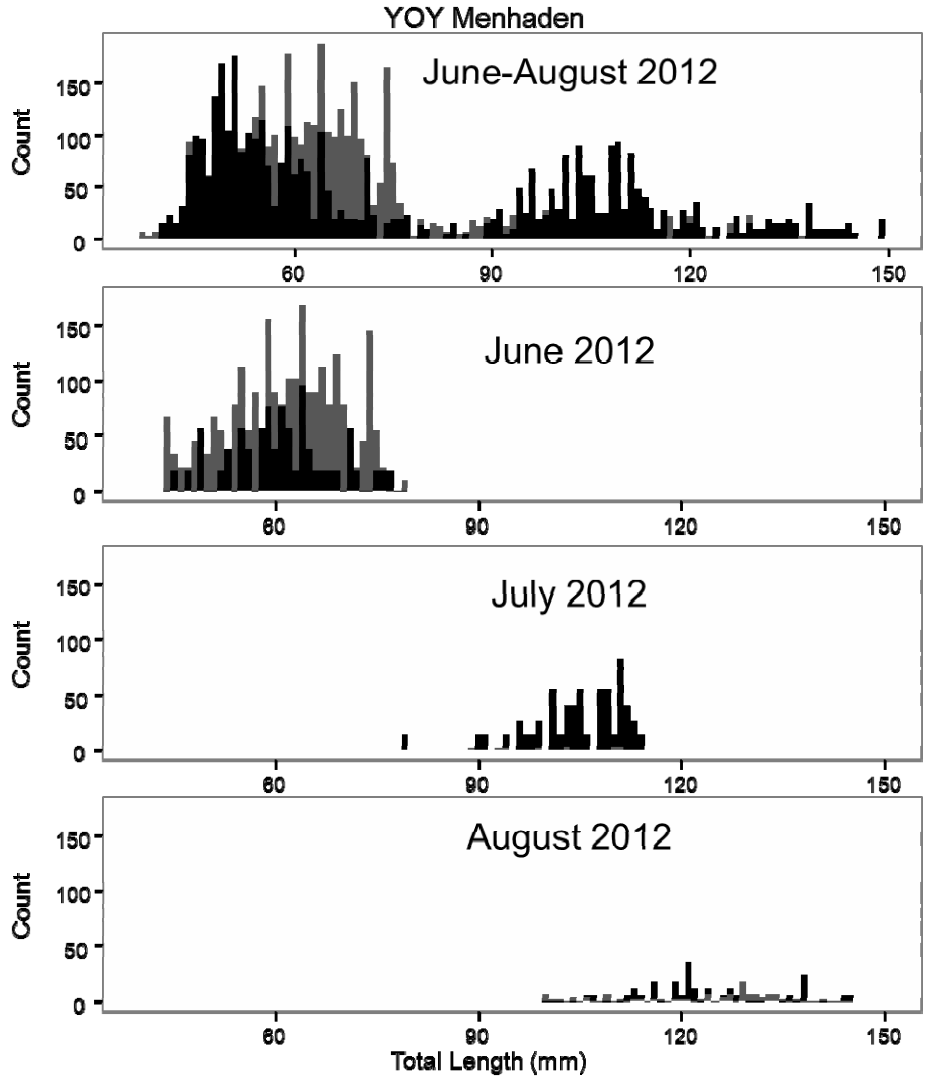


Figure 4. Length frequency distributions for YOY Atlantic menhaden collected in 2012 (tributaries combined), plotted by month. Seine samples are coded as grey fill; Midwater trawl samples are coded as black fill.

Mean total lengths of YOY menhaden were compared among tributaries for each survey. In June, the mean total length was significantly longer in the Patuxent River and significantly smaller in the Upper Bay (nested ANOVA: $p < 0.05$) (Table 3). Mean length in the Choptank River during June was intermediate. Mean lengths of menhaden tended to be longer in the

Patuxent River than in the Choptank River in all three months but the difference was significant ($p < 0.05$) only in August (Table 3).

There were differences in mean lengths among tributaries when examined by gear type within each survey (nested ANOVA: $p > 0.05$). No menhaden were caught in the seine gear in the Patuxent River during the June and July surveys; therefore, only midwater trawl comparisons are reported here. In the first survey, menhaden from the Patuxent River were significantly longer (Tukey HSD: $p < 0.05$) (78.7 ± 1.9 mm SE) than menhaden from the Choptank River (64.6 ± 0.9 mm SE) and upper Chesapeake Bay (60.1 ± 0.8 mm SE). This was the only survey that sampled all three sites and for which lengths could be compared. The observed lengths indicated a south-to-north decreasing trend of menhaden size in the Chesapeake Bay. During August, YOY menhaden from the Patuxent River were significantly longer (Tukey HSD: $p < 0.05$) (129.9 ± 0.9 mm SE) than menhaden from the Choptank River (108.6 ± 1.6 mm SE). YOY menhaden in the Patuxent River were longer (117.5 ± 2.9 mm SE) than those from the Choptank River (96.6 ± 5.5 mm SE) in the July survey but the difference was not significant (Tukey HSD: $p > 0.05$) in that month.

Table 2. Mean total lengths (mm) of trawl- and seine-captured YOY Atlantic menhaden for the three surveys combined and for each survey in 2012. MWT = Midwater trawl. SE = standard error

	Gear	Mean	n	SE
2012	MWT	78.7	320	1.4
	Seine	96.8	152	2.1
05-07 June	MWT	66.9	249	0.8
	Seine	73.6	67	2.5
11-12 July	MWT	111.4	17	3.2
	Seine	107.5	48	1.4
07-08 August	MWT	123.2	54	1.6
	Seine	125.0	37	1.6

Table 3. Mean total lengths (mm) of Atlantic menhaden from each tributary during three summer surveys in 2012. Upper = Upper Bay, Chop = Choptank R., Pax = Patuxent R. SE = standard error

	River	Mean	n	SE
05-07 June	Upper	60.7	103	0.7
	Chop	69.2	150	1.3
	Pax	78.7	63	1.9
11-12 July				
	Chop	106.5	53	1.3
	Pax	117.5	12	2.9
07-08 August				
	Chop	119.6	53	1.6
	Pax	130.1	38	0.9

Retrospective Analysis of MD DNR Seine Survey Data

In a retrospective analysis of YOY menhaden from past MD DNR seine-survey collections, we evaluated how the annual mean abundance (Maryland DNR, menhaden YOY juvenile index) is influenced by the distribution of catches made across tributaries and months. Within tributary analyses of spatial distributions and variability among years and among surveys within years were evaluated by applying multivariate statistical approaches. Continuing analysis of YOY

menhaden size variability is being conducted for years that menhaden lengths have been measured in the DNR surveys (since 2005).

MD DNR provided us with its full Juvenile Striped Bass Seine Survey database from which we calculated mean catches of YOY menhaden per seine haul for each decade from 1960 to 2009, using the survey stations with the longest sampling history. There are decadal changes in YOY menhaden spatial distributions that may be related to decadal trends in overall abundance (Figure 5). During the period of very low abundance in the 1960s, YOY menhaden were collected principally in Maryland's southernmost tributaries, at sites in the Nanticoke and Potomac Rivers. During the two-decade (1970-1989) period of high juvenile abundance, YOY were concentrated principally in the eastern shore Choptank and Nanticoke rivers throughout that period and in the Upper Bay during the 1970s. During those decades very high abundances were recorded at several sites in the Nanticoke River, but high catches were made only at particular sites in the Choptank River and Upper Bay. During the 1980s, when the survey expanded to include the Patuxent River, YOY menhaden were more equitably distributed throughout the tributaries, with highest concentrations in the Choptank and Nanticoke Rivers. During the recent period of low juvenile menhaden abundances, 1991-2009, catch levels were again fairly equitably distributed throughout all MD tributaries, with highest abundances in the Choptank and Nanticoke Rivers. The results suggest that the overall bay-wide juvenile abundance index is largely driven by YOY menhaden in the Choptank and Nanticoke Rivers.

Trends in YOY menhaden abundance for Maryland tributaries showed peaks in the 1980s based on the MD DNR striped bass juvenile index survey data (Figure 6). The patterns and trends in abundance were similar among tributaries. The fits to a quadratic model (Table 4) showed relatively high peak abundances in the Nanticoke River (39.3 per 100 sq m) and Upper Bay (12.6 per 100 sq m) during the mid-1980s. The Patuxent River peaked in 1986 (4.9 per 100 sq m). Peak abundance in the Potomac River (4.0 per 100 sq m) was estimated to have occurred

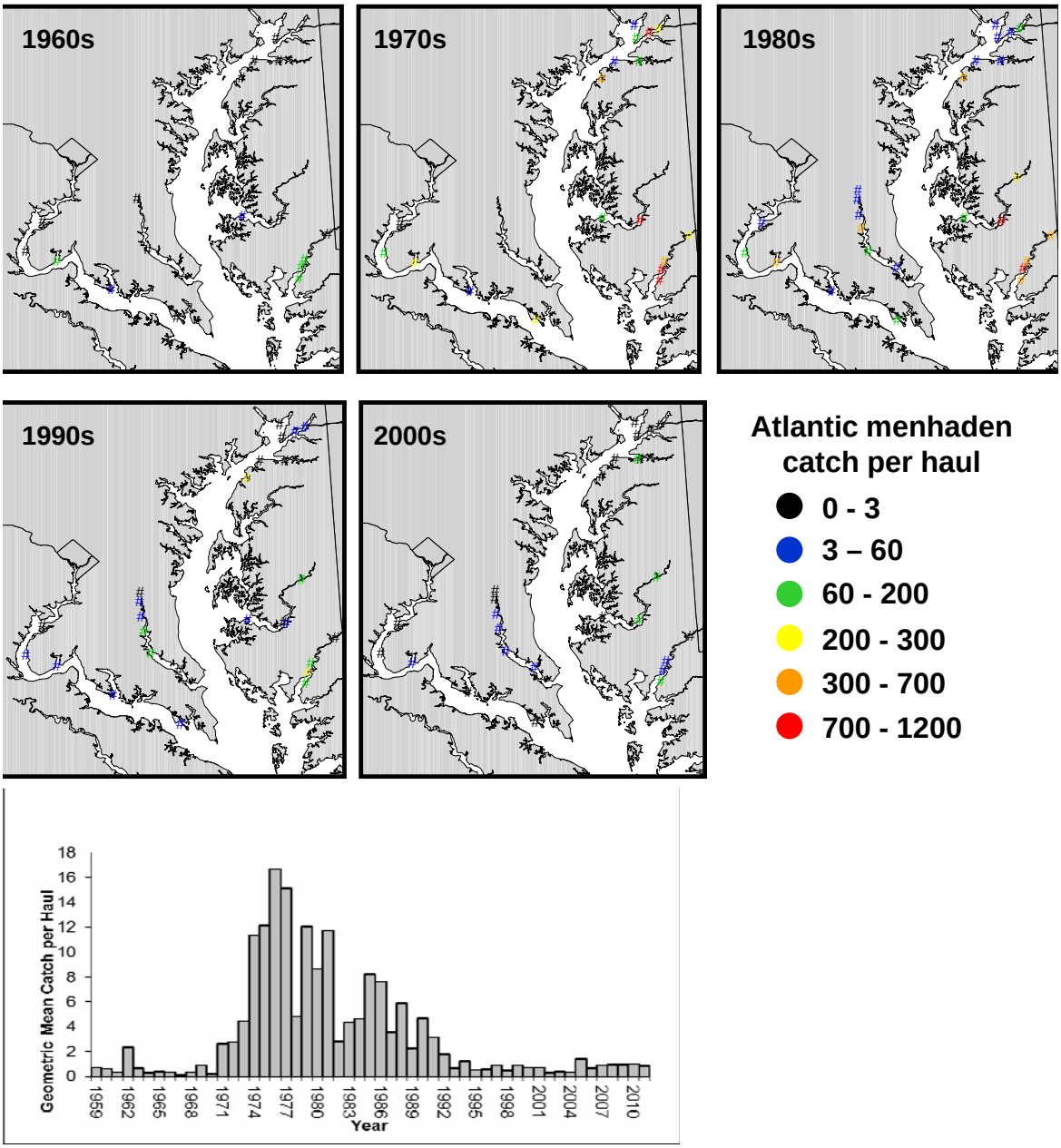


Figure 5. ***Top Panel****: Map of Chesapeake Bay showing sites where YOY Atlantic menhaden were collected by the MD DNR juvenile seine survey for a series of decades, 1960-2009. Mean decadal numbers collected are shown by the colored filled circles. Note that prior to 1983, the Patuxent River was not included in the DNR survey.* ***Bottom Panel****: Annual geometric mean abundance of YOY menhaden: bottom panel data and figure are from MD DNR juvenile seine survey (http://dnr.maryland.gov/fisheries/juvindex/) for the entire MD portion of the Chesapeake Bay.*

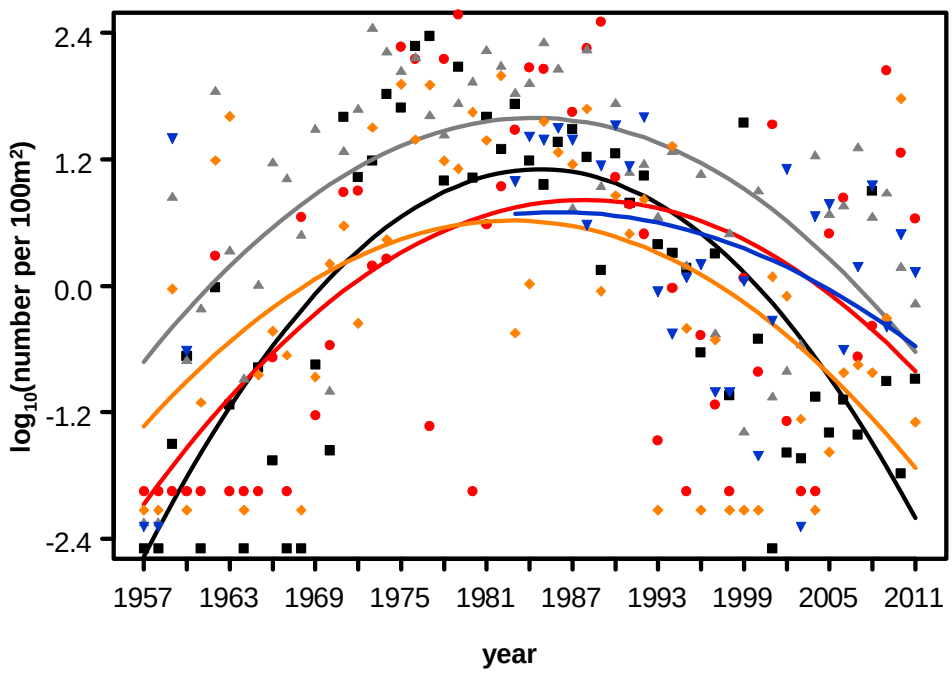


Figure 6. Trends in abundance of YOY menhaden in five tributaries of Chesapeake Bay. Quadratic regression fits. See Table 4 for equations describing the fits. The black line is the upper Bay, Choptank is red, Nanticoke is gray, Patuxent is blue and Potomac River is orange.

in 1983 but the Choptank River peak (6.6 per 100 sq m) did not occur until 1988. Abundances were highest in the Nanticoke River where estimated peak abundances in the 1980s were approximately 10 times higher than in the Potomac, Patuxent and Choptank rivers, and 3 times higher than peak abundances in the upper Bay (Figure 6).

Table 4. Quadratic regression equations describing trends in mean abundance (number per 100m^2) of YOY Atlantic menhaden. Data are from the MD DNR juvenile striped bass seine survey (1957 to 2011). All p-values for the regressions are significant ($p < 0.05$). t = year.

System	**Equation**	**r^2 (%)**	**p-value**
Bay	$\log_{10}(\text{density}) = -0.00479t^2 + 19.0245t - 18877.9$	25.35	0.0005
Choptank	$\log_{10}(\text{density}) = -0.00304t^2 + 12.07218t - 11998.1$	53.28	<0.0001
Nanticoke	$\log_{10}(\text{density}) = -0.00311t^2 + 12.3495t - 12250.8$	37.10	<0.0001
Patuxent	$\log_{10}(\text{density}) = -0.00203t^2 + 8.0655t - 8008.3$	21.52	0.0264
Potomac	$\log_{10}(\text{density}) = -0.00295t^2 + 11.6794t - 11578.1$	24.28	0.0007

The spatial distribution of YOY menhaden in Maryland tributaries of Chesapeake Bay has been relatively stable since the 1960s (Figure 7). The center of abundance was calculated as a

weighted mean location (distance from the mouth of each tributary to each survey sampling site) with the location weighted by the density of each species collected at each site. Only the Choptank River experienced a substantial shift in the center of distribution of YOY menhaden, which is now approximately 10 miles farther upstream than in the 1960s. Although there has been little net change in center of distribution in the Nanticoke River since the 1960s, it appears that, on average, abundance was centered farther upriver in the 1970-80s during years of high overall YOY menhaden abundance in Chesapeake Bay.

YOY Menhaden and YOY Striped Bass

Historically, the abundances of YOY Atlantic menhaden and YOY striped bass in Chesapeake Bay have been inversely correlated (Houde, 2009). The relationship is a reflection of different responses to climatic conditions in which menhaden recruitment success historically was favored by warm and dry winter-spring conditions and the reverse was true for striped bass and other anadromous fishes (Wood and Austin, 2009). In the past two decades this relationship is no longer apparent. Abundance of YOY striped bass continues to be favored in cold-wet, winter-spring conditions, but YOY menhaden abundance has been consistently low across a spectrum of climate conditions (Figure 8). Causes of this shift in menhaden reproductive success are not understood, although variability in survival during the late winter, larval to juvenile transition stage or responses of juveniles to variable levels of primary production in Chesapeake Bay have been implicated (Houde et al., 2011).

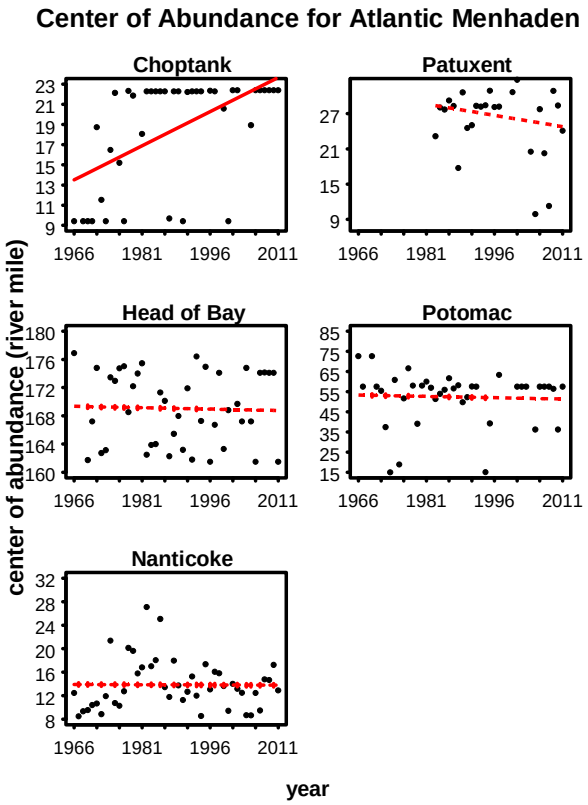


Figure 7. Centers of abundance for YOY menhaden surveyed in five tributaries of Chesapeake Bay based on data from the MD DNR juvenile striped bass seine survey. A significant shift in spatial distribution during the survey time period was apparent only in the Choptank River. Solid line indicates significant regression relationship ($p < 0.05$). (Because only two sites were sampled during many years in the Choptank River, the significant relationship must be interpreted with caution).

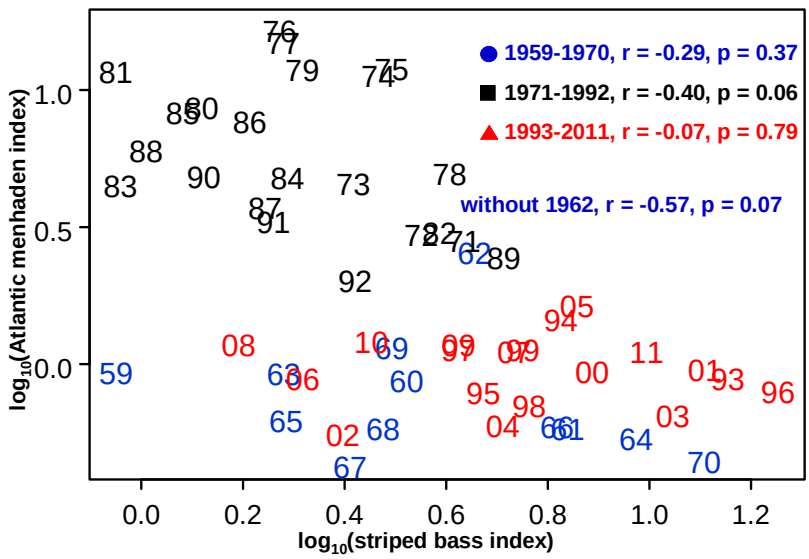


Figure 8. Relationship between log_{10} abundances of YOY striped bass and YOY Atlantic menhaden in the Maryland portion of the Chesapeake Bay for three time periods. Data are from the MD DNR striped bass juvenile seine survey.

<u>Chesapeake Biological Laboratory (CBL) Pier Survey</u>

We conducted a retrospective analysis of juvenile Atlantic menhaden sampled at the mouth of the Patuxent River (the CBL Pier Survey). This survey has been conducted on a near weekly basis during mid-May to mid-October, 1999-present. Atlantic menhaden is a dominant member of the assemblages observed at CBL, representing 52.1% of all fish sampled and occurring on 21.3% of the dates sampled over the 14-year survey. Excluding 1999, when few weeks were sampled (n=4), juvenile Atlantic menhaden occurred in the seine samples in all but two years (2000 and 2012; Figure 9). In most years (8 of 11) when menhaden occurred, they were observed prior to week 31 (3rd week of July), and in approximately half of these years, peak abundance occurred prior to week 26 (3rd week in June). Two noteworthy years were 2005 and 2010 when Atlantic menhaden juveniles occurred in high abundance throughout summer months (last week in May to first week in September).

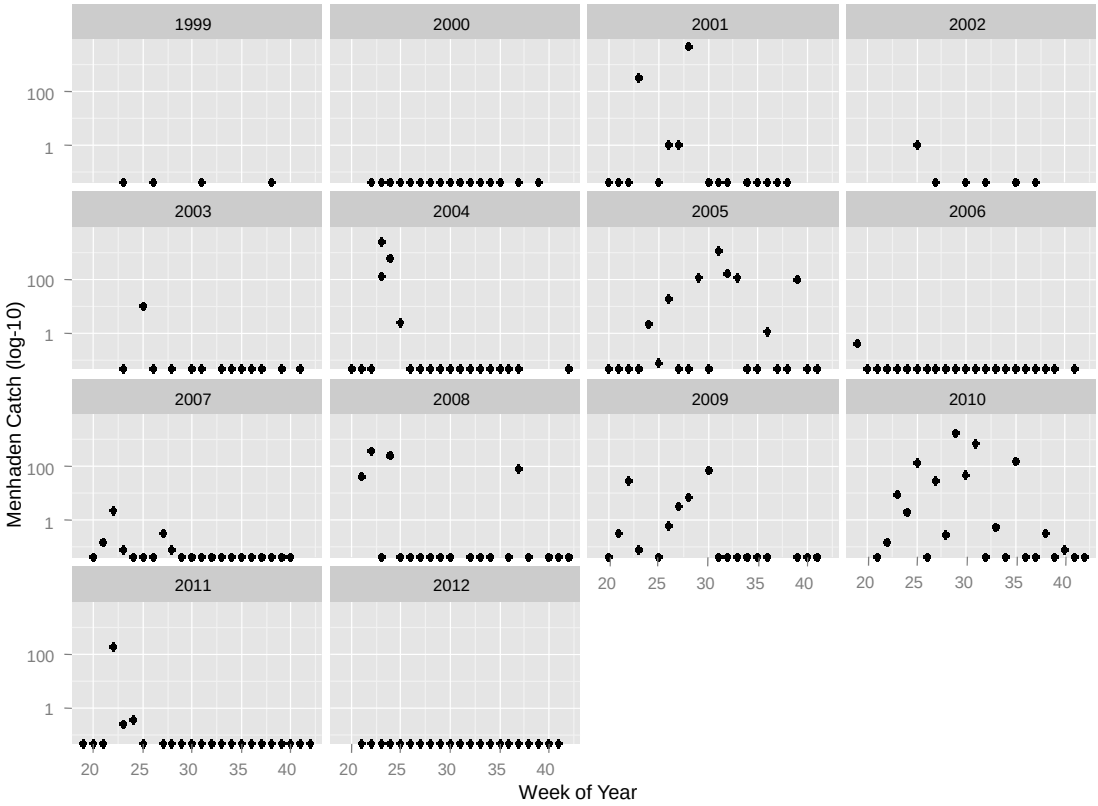


Figure 9. Log_{10} – transformed catches of YOY Atlantic menhaden sampled in the CBL Pier Survey. The weekly survey comprises three seine hauls on either side of CBL's research pier. For this analysis, seine haul abundances were weighted by area swept and combined into a weekly abundance statistic.

In general, the CBL Pier Survey catches were more variable than those in the Maryland DNR Seine Survey of the Patuxent River, but there was a degree of correspondence (Figure 10). Mean catches were approximately 10-fold greater for the CBL Survey over the time series, but years represented by zero catches (1999, 2000, 2012) were more frequent than in the DNR survey (2003). Correspondence between the surveys in years with relatively high catches occurred for 2004, 2005, 2008, and 2010; mismatches occurred in 2001 (CBL peak catch) and 2002 (third highest DNR catch). Comparison of catches between the two surveys indicates that more frequent sampling in the DNR survey could improve the contrast of catch levels among years. Mismatched years could result from CBL not being representative of the Patuxent River in those

years, sampling error associated with small sample sizes, or some combination of the two.

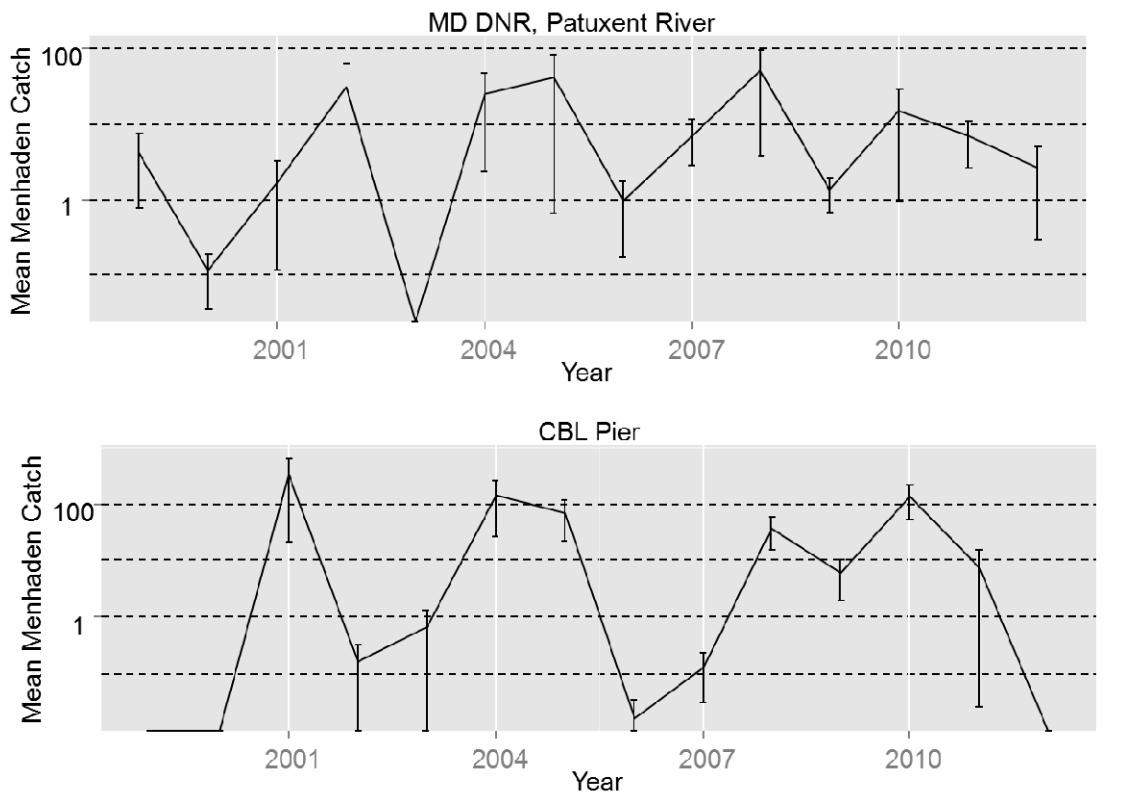


Figure 10. Log_{10} - transformed catches (mean ± 1 standard error) of Atlantic menhaden juveniles sampled in the Patuxent River as part of the Maryland DNR Seine Survey and as part of the CBL Pier Survey.

Canonical correspondence analysis (CCA) was conducted on environmental correlates of YOY Atlantic menhaden abundance and assemblage structure for the CBL Pier Survey database (Figure 11). In keeping with a past study on assemblage structure at this site (Wingate and Secor 2008) we addressed how the preceding winter and spring conditions affected summertime assemblage and abundance of YOYAtlantic menhaden. In the current analysis, winter temperature showed strong inverse correspondence with YOY white perch, and striped bass. Warmer winters were associated with higher abundances of bay anchovy, summer flounder, and yearling white perch, and gizzard shad. Interestingly, YOY menhaden were strongly associated with high summer temperatures, consistent with the role temperature has on YOY growth rate (Annis et al. 2011). In future multivariate analysis of the MD DNR seine survey data set we will focus on similar environmental variables, testing for the effects of preceding (winter and fall) environmental associations on YOY menhaden abundance, together with the strong summertime temperature association observed here.

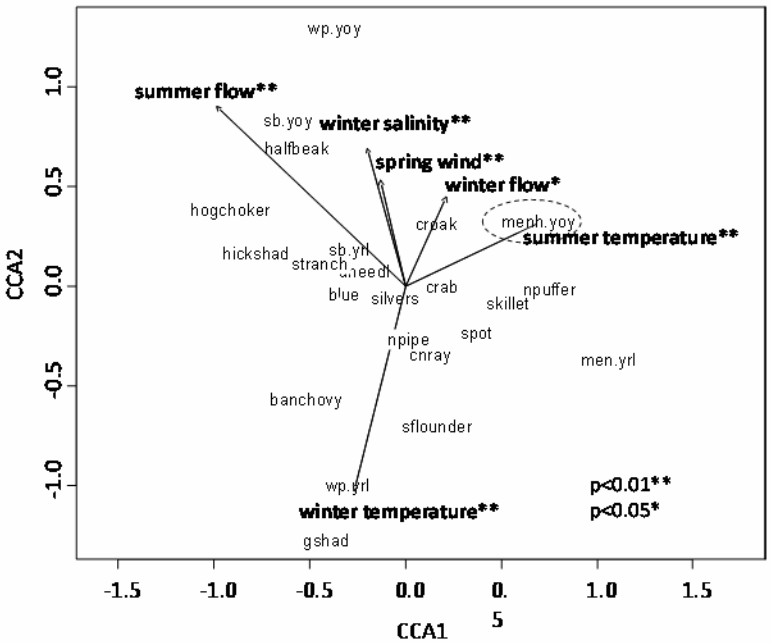


Figure 11. Canonical correspondence analysis of the CBL Pier Survey database (1999-2012). Environmental drivers included winter (January through March) and spring (April through June) flow, temperature, salinity and wind; and summer (July through September) flow, temperature, salinity and wind; and summer (July through September) flow, temperature, and salinity. Only those with significant effects are shown. YOY menhaden are highlighted with a dashed oval. Other dominant species (common name labels) and each week (gray dots) are also shown.

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Products

A. Presentations

Secor, D. H. 2011. How to Align Fisheries and Water Quality Science and Management? A Central Issue in the Chesapeake. Chesapeake Bay Program Fisheries Goal Implementation Team, Habitat and Fisheries Workshop. Alexandria, VA, 19-20 Dec. 2011.

Houde, E. D. 2011. Men and menhaden: declining recruitment challenges management in Chesapeake Bay. Invited Seminar. Scripps Institution of Oceanography, La Jolla, CA, 30 November 2011.

Houde, E. D. and W. J. Connelly. 2012. A retrospective analysis of spatial and temporal patterns of growth and abundance of juvenile anadromous fishes in the Maryland Chesapeake Bay. NOAA Chesapeake Bay Office Workshop on Fisheries Science, Smithsonian Environmental Research Center, Edgewater, MD. 10 January, 2012.

Secor, D. H. and E. D. Houde. 2012. Estimating abundance of Atlantic menhaden in Chesapeake Bay. Comparing and evaluating methods and retrospective analysis. Workshop for NOAA Chesapeake Bay Fisheries Science – Smithsonian Environmental Research Center, Edgewater, MD, 10 January 2012.

Houde, E. D. 2012. Men and menhaden: declining recruitment challenges management in Chesapeake Bay. Invited Seminar. Living Marine Resources Cooperative Science Center- -Institute of Marine and Environmental Technology, Baltimore, MD, 16 March 2012.

Secor, D. H. 2012. Mapping Fish Movements and Migrations onto Seascapes. Plenary Presentation. NMFS National Workshop to Develop a Framework for Quantitative Seascape Ecology, Rutgers University.

Secor, D. H. 2012. Good Fish in Bad Habitats: Conceptual and Empirical Challenges in Linking Land-Use Practices to Coastal Fisheries Management. Invited Presentation. American Fisheries Society Annual Conference, Minneapolis and St. Paul, MN, August 2012.

Houde, E. D., C. Lozano, E. Annis, L. Harding, D. H. Secor, M. J. Wilberg and R. Wingate. 2012. Recruitment variability in Atlantic menhaden: processes acting during the larval-juvenile transition in Chesapeake Bay. Invited Presentation. American Fisheries Society Annual Conference, Minneapolis and St. Paul, MN, August 2012.

Houde, E. D. 2012. Forage fishes and YOY anadromous fishes in Chesapeake Bay: causes of variability in abundance. Invited presentation. Fisheries Goal Implementation Team, Chesapeake Bay Program, Port Isobel, VA. 7 December 2012.

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Houde, E.D., and D.H. Secor. 2013. Estimating abundance of Atlantic menhaden in Chesapeake Bay: Comparing and evaluating methods. Invited presentation to the Atlantic States Marine Fisheries Commission Technical Committee. Arundel Mills, MD. 18 September 2013.

Houde, E.D. 2013. Forage fish in Chesapeake Bay: Status, trends, science and monitoring. Invited presentation to the Chesapeake Bay Program Sustainable Fisheries Goal Implementation Team. Solomons MD. 4 December 2013.

B. Publications (based on partial or full support of this project)

Houde, E. D., C. Lozano, E. R. Annis, L. W. Harding, Jr., D. H.Secor, M. J. Wilberg and R. L. Wingate. 2011. Recruitment of Atlantic menhaden to Chesapeake Bay: ecological processes during the larval-juvenile transition. Theme H, Annual Science Conference, International Council for the Exploration of the Sea, ICES CM/H: 23.

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Personnel

D.H. Secor and E. D. Houde were Co-P.I. s on the project. Together, they were responsible for research cruise plans, products, and reports. Postdoctoral scientist William Connelly assisted with retrospective analyses, cruise planning and participation, data analysis, and report preparation. Carlos Lozano, James Seuberling, Michael O'Brien and Matt Siskey are Faculty Research Assistants who conducted otolith microstructure and aging analyses, participated in research cruises, data management and analysis. Alexandra Atkinson, a Chesapeake Biological Laboratory Graduate Research Fellow, initiated her M.S. thesis research on menhaden data collected with support of this award.