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Trends in Abundance Indices of Fishes in Maryland's Coastal Bays During 1972–2009

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Abstract Maryland's coastal bays provide habitat for juveniles of many commercially and recreationally important species of shellfish and finfish. Since 1972, the Maryland Department of Natural Resources has conducted the Maryland Coastal Bays Trawl and Seine Survey to monitor the populations of key species. The survey has undergone substantial spatial and methodological changes affecting the interpretation of simple indices of abundance. We developed generalized linear models to standardize the indices of abundance of five commonly caught fish species: Atlantic menhaden *Brevoortia tyrannus*, weakfish *Cynoscion regalis*, spot *Leiostomus xanthurus*, bay anchovy *Anchoa mitchilli*, and summer flounder *Paralichthys dentatus*. Density declined significantly since 1972 for menhaden, bay anchovy, and spot in at least one region within the coastal bays. The northern bays had significantly higher densities than the southern bays for all species. Changes in abundance indices of the five species examined were not related to sea grass coverage, temperature, salinity, nitrogen-to-phosphorus ratios, and other habitat variables but were likely a result of stock-wide recruitment processes.

Keywords Index of abundance · Long-term survey · Coastal bays · Generalized linear model · Spatial Analysis · Population dynamics

Introduction

Long-term studies are necessary to determine changes in abundance and the effects of changes in habitat on marine populations (Peterson et al. 2003). However, sampling methods often change over time, complicating the interpretation of the trends in abundance. Survey catch per unit effort (CPUE) is frequently used as an index of abundance to monitor fish populations (Ricker 1975; Maunder and Punt 2004), but CPUE may not be proportional to abundance if changes in survey methods occur. For example, changes in the spatial distribution of the sampling sites or amount of effort over time can cause misleading indices of abundance unless methods are used to correct for survey changes (Arreguín-Sánchez and Pitcher 1999; Wilberg et al. 2010).

Habitat quality in coastal environments has significant effects on the density of fish those environments can support (Gibson 1994). However, identifying key features that relate to the ability of the habitat to support fish populations is challenging because of effects of multiple biological and physical variables (Imhof et al. 1996; Rose 2000). In particular, sea grass is thought to be an important nursery habitat for many juvenile fishes in the Mid-Atlantic (Orth et al. 1984; Nagelkerken et al. 2002). Fish densities are higher in sea grass beds than over unvegetated areas (Guidetti 2000; Jackson et al. 2001; Orth et al. 2006) because sea grass may serve as a refuge from predation or as a source of prey (Harris et al. 2004). Because of the purported link between juvenile fish and sea grass, the decline in sea grasses around the world has caused concern in conservation and fisheries' monitoring agencies (e.g., Wazniak et al. 2007; Waycott et al. 2009).

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The science and management community has long endeavored to link sea grass meadows and other habitat characteristics to commercial fish production, often classifying sea grass as "essential habitat" to protect their role as nursery areas (Heck et al. 2003). Water quality conditions such as nutrient concentrations and water flow are also important in defining the quality of habitat and interact with other habitat characteristics. The loss of submerged aquatic vegetation (SAV) in coastal areas is associated with declining water quality documented in estuarine and lagoonal ecosystems (Lotze et al. 2006; Waycott et al. 2009). In eutrophic systems where symptomatic algal blooms can prevent light from reaching submerged vegetation, hypoxic or anoxic waters may develop or increase in areal extent when the algae decompose.

The relationships among fish populations, sea grass, hypoxia, and algal blooms have long intrigued ecologists. Estuaries rank as the most productive ecosystems in terms of autotroph and fish biomass. Nixon et al. (1986) and Houde and Rutherford (1993), among others, have presented an array of case studies that suggest increasing nitrogen input to N-limited coastal waters can result in higher fish biomass as an "agricultural paradigm" for coastal productivity. However, Caddy (1993) proposed that this paradigm is subject to thresholds, beyond which secondary effects such as habitat loss and anoxia negatively affect fish populations in a parabolic response termed "Caddy's curve" that was confirmed in at least one marine ecosystem (Oczkowski et al. 2008).

Maryland's coastal bays have experienced increased nutrient loading over the past 20 years that have accompanied water quality changes, including an increase in macroalgal biomass in the northern bays and recent loss of sea grasses (Wazniak et al. 2007). The coastal bays can therefore provide an opportunistic case study for evaluating how the agricultural paradigm and related water quality feedbacks impact fishes. In particular, the pattern of recent sea grass loss followed a period of colonization and expansion between 1986 and 2004 that contrasts with regional long-term trends of steady decline, especially for *Zostera marina*, the dominant species in the coastal bays (Wazniak et al. 2007). By encompassing a period of time when potential habitat availability was increasing, this dataset is uniquely suitable for analyses exploring the effects of sea grass habitat on fishes.

Maryland's coastal bays provide nursery habitat for the young-of-year of many species of fish (Bolinger et al. 2007). Several of the dominant species in the bays, such as Atlantic menhaden (*Brevoortia tyrannus*) and spot (*Leiostomus xanthurus*), are a source of conservation concern in the Mid-Atlantic due to declining abundance and catches (Lipcius and Stockhausen 2002; ASMFC 2010a; b). Since 1972, the Maryland Department of Natural Resources (MD DNR) has conducted the Maryland Coastal Bays Trawl and Seine Survey (MCBTSS) to monitor the populations of fishes and invertebrates in the Maryland coastal bay estuaries (Fig. 1). A particular focus of the survey is juvenile fishes that use these areas as nursery habitats (Bolinger et al. 2007). The MCBTSS methods and sites changed over time, but were standardized in 1989. Before 1989, the time of year, the locations sampled, and the duration of the trawl tows varied substantially from year to year. These methodological and spatial changes make differentiating changes in abundance from changes in survey design difficult.

Our goal for this study was to estimate trends in abundance indices for five fish species in Maryland's coastal bays and test for effects of habitat on the indices of abundance of five fishes in the northern and southern coastal bays of Maryland during 1972–2009. Our specific objectives were to (1) determine the trends in abundance of five fish species in Maryland's coastal bays and (2) determine whether changes in abundance were related to changes in habitat. We used generalized linear models (GLiMs) to standardize abundance indices for changes in the MCBTSS and analysis of covariance (ANCOVA) to test for temporal trends and the effects of habitat on indices of abundance through time.

Methods

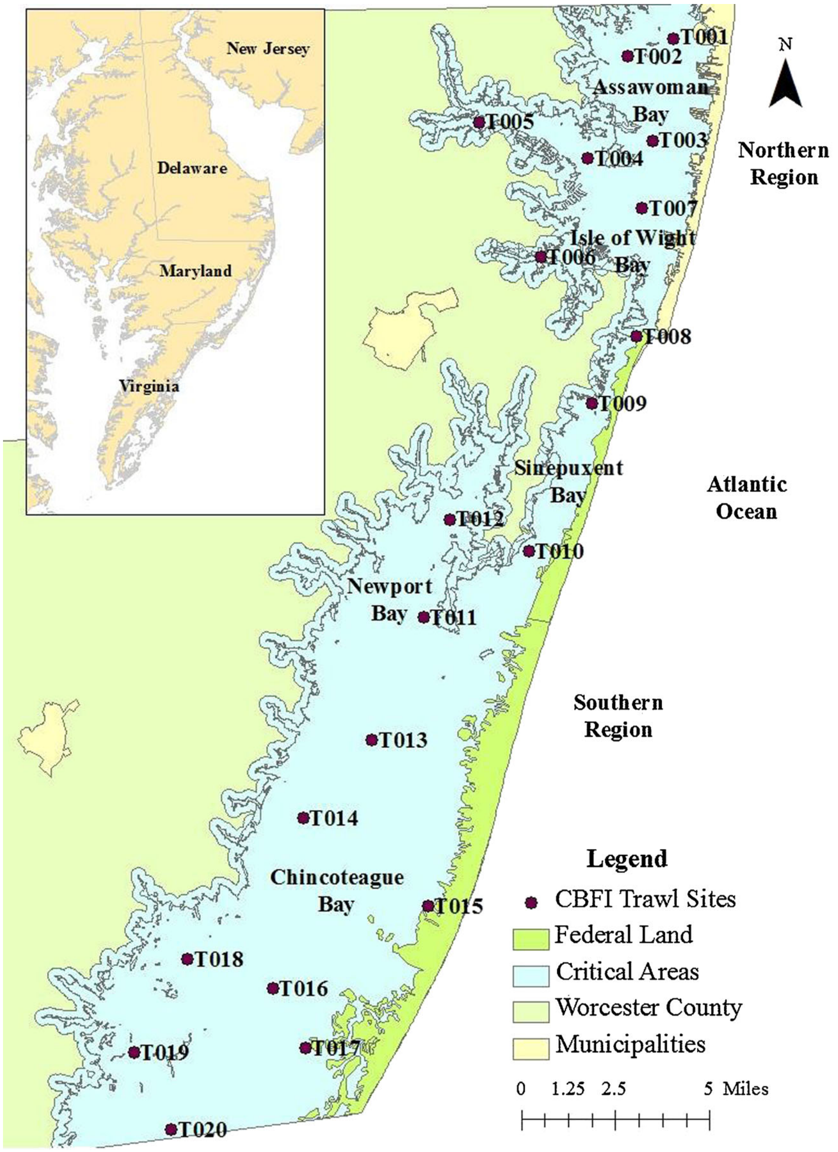
Study Site

Maryland's coastal bays are located on the eastern side of the Maryland portion of the Delmarva Peninsula and are separated from the Atlantic Ocean by two barrier islands (Fig. 1). We divided the coastal bays into two regions by using the inlet to the Atlantic Ocean as a boundary condition. The northern region included Assawoman and Isle of Wight Bays and the southern region included Newport, Sinepuxent, and Chincoteague Bays. The northern bays are connected to the southern bays by a narrow inlet at the north end of Sinepuxent Bay. Land use in the northern bays watershed includes more residential and urban development than the southern bays, so anthropogenic eutrophication from wastewater is more prevalent in the northern region (Murphy and Secor 2006), with agricultural nitrogen inputs more prevalent in the southern region (Wazniak et al. 2007). The bays are largely well-mixed, with average salinities in all bays ranging between 27 and 31.

Data

The MCBTSS samples with a bottom trawl in 20 different sites across the five coastal bays (Fig. 1). The trawl survey sites are placed in the middle of the coastal bays in depths of 0.75 to 2 m, and a fixed-site design is used. Sites were initially chosen to represent the range of trawlable sites, but the location of some sites changed over time. Since the survey was standardized in 1989, MD DNR has trawled at each site once a month from April to October. The trawls are conducted with

Fig. 1 Map of Maryland's coastal bays and the trawl sites of the MCBTS Survey



4.9 m (16 ft) of semi-balloon trawl with 3.18 cm (1.25 in.) of stretch mesh in the outer net, 2.86 cm (1.13 in.) of stretch mesh in the cod end, 1.27 cm (0.5 in.) of stretch mesh inner liner, and a tickler chain (Bolinger et al. 2007). Before standardization, the trawls varied in tow length and area covered; some samples were taken in winter months between November and March, and the sites were not sampled every month during the other times of the year. In 1989, the deployments were standardized to a 6-min tow of the net at a speed of approximately 5.2 km/h, for an area swept of about 17, 040 m^2. The number of fish by species, temperature, salinity, depth, and weather conditions were recorded (Bolinger et al. 2007).

We examined data for five commonly caught species: Atlantic menhaden, weakfish (*Cynoscion regalis*), spot, bay anchovy (*Anchoa mitchilli*), and summer flounder (*Paralichthys dentatus*). We selected these species because they were the only ones for which enough data were available to apply the statistical models to correct for changes in the MCBTSS. All of these species except bay anchovy support important recreational or commercial fisheries and use Maryland's coastal bays as nursery habitat. Bay anchovy is an important forage species and thus provide a link between plankton and upper trophic levels (Newberger and Houde 1995). Summer flounder and spot are demersal species, while weakfish, bay anchovy, and Atlantic menhaden are pelagic (Froese and Luna 2010; Luna and Froese 2010). The five species were also selected because they represent a variety of life histories, use the coastal bays at different times of the year, and inhabit different areas of the bays. Summer flounder and weakfish are piscivores, Atlantic menhaden and bay anchovy are planktivores, and spot are benthivores.

Data on changes in environmental variables potentially indicative of habitat quality were available from a monitoring program conducted during 1993–2004 by the US National Park Service. Of the numerous environmental variables measured as part of this program, we selected measurements of total suspended solids (milligrams per liter), the ratio of total nitrogen to phosphorus as a representation of nitrogen limitation, silicate concentration (micromolars per liter), chlorophyll a (adjusted for phaeophytin) (micrograms per liter), and dissolved oxygen (milligrams per liter) because there were plausible mechanisms by which they could affect fish production. The majority of these mechanisms are relatively simple: chlorophyll a as a proxy of phytoplankton biomass, dissolved oxygen, and salinity as they affect bioenergetics of fish growth. However, the two nutrient indicators are likely indirectly related to fish abundance. For example, we can hypothesize that silicate concentration serves as a possible indicator of diatom abundance, a preferred food of Atlantic menhaden, and that an indicator of nitrogen limitation provides insight on the role of bottom-up factors affecting primary production and nutrient status of the lagoons.

All of these were measured in surface samples except for dissolved oxygen, which was taken in the bottom half meter of the water column. For our analyses, we used these variables from 16 sites in the southern region and summarized the yearly medians. The environmental variables were also available for two sites in the northern bays, but both of these were close to the Ocean City inlet, and Murphy and Secor (2006) found that the sites closest to the Ocean City Inlet were the least similar to the rest of the northern bays. Therefore, we only included the southern region in our analyses of the environmental variables. The area of submerged aquatic vegetation (SAV) in each region was obtained for each year from 1993 to 2004 (Orth et al. 2005). Using ESRI ArcGIS, we clipped SAV coverages to the boundaries delineating the northern and southern regions and then computed corrected polygon areas to calculate total hectares of SAV. We calculated the monthly average for surface temperature and salinity for the sites in each region and then calculated a yearly average from the monthly averages.

Standardizing Indices of Abundance

We use generalized linear models with a negative binomial distribution and a log link function to standardize indices of abundance for each of the species for changes in the MCBTSS (McCullagh and Nelder 1989; Maunder and Punt 2004). The negative binomial distribution allows for zero catches, which was necessary for this survey because about two thirds of the observations for each species were zeros. The model was

$$E(\log(C)) = \beta_0 + \beta_{\text{Year}} + \beta_{\text{Site}} + \beta_{\text{Month}} + \beta_{\text{Region} \times \text{Year}} + \beta_5(\text{Effort})$$

where $E(\log(C))$ is the expected natural logarithm of catch per trawl for the given species; and year, site, month, a year-by-region interaction, and effort are main effects. The site effects accounted for spatial variation across sites. The location of several sites changed over time; sites where the location was changed were treated as separate sites. A region effect was not necessary because the site effects from a region averaged together equaled a region effect. The categorical month effect accounted for variation in catch due to time of year, and the continuous effort effect accounted for different lengths of trawls before the survey was standardized. All of these terms were included to capture every recorded difference between the unstandardized and standardized trawls. Therefore, we assume that any changes in the index of abundance reflect proportional changes in real density and are not due to changes in the survey. One unit of effort was an 8,520-m^2 area swept or one half of a standardized trawl tow. The year effects combined with the year-by-region interactions provided indices of abundance for the northern and southern bays, respectively.

We included data only from months when a species was expected to use the coastal bay habitat (Table 1). All five species enter the coastal bays as larvae or early juveniles (Able and Fahay 1998), although summer flounder can also enter as adults in the summer. Weakfish are present in the coastal bays from late July until November (Able and Fahay 1998). Similarly, spot are present during April-November, and summer flounder are present between March and November (Murdy et al. 1997). Atlantic menhaden larvae begin entering the estuary in the fall and remain throughout the summer and fall (Murdy et al. 1997; Able and Fahay 1998). Likewise, bay anchovy are present in Maryland's coastal bays during all months. Some sites and years were excluded from analysis for a given species because large proportions of zero catches cause year or site effects to not be estimable in the standardization model, or too few samples were collected to have a representative sample size (Deroba and Bence 2009; see Barkman 2010 for a full list of excluded sites and years).

Table 1 The months of the year included in the models for each species according to their expected inhabitation of the estuaries and the literature used to arrive at the included periods

Species	Months in model	References
Atlantic menhaden	January–December	Murdy et al. 1997; Able and Fahay 1998;
Weakfish	July–November	Able and Fahay 1998; Nemerson and Able 2004
Summer flounder	March–November	Murdy et al. 1997
Bay anchovy	January–December	Murdy et al. 1997
Spot	April–December	Murdy et al. 1997

Characterizing trends Over Time and Effects of Habitat

We tested for linear trends in the indices of abundance over time and differences in density between the northern and southern regions using ANCOVAs and regressions for each species. The ANCOVAs were species-specific with region as a categorical variable and year as a continuous covariate,

$$I = \beta_0 + \beta_{\text{Region}} + \beta_1(\text{Year}) + \varepsilon,$$

where I is the species-specific index standardized by the GLiM, β_0 is the intercept, β_{Region} is the categorical region effect, and β_1 is a continuous year effect. We estimated trends in abundance in each region over time by regressing the index of abundance against year. We used a Bonferroni correction for multiple comparisons to determine the critical p value associated with an α level of 0.05 (Abdi 2007). The critical p values for multiple comparisons were 0.01 for comparing differences between regions and 0.005 for comparing the slopes of region-specific trends over time. We tested whether changes in abundance were related to changes in habitat using multiple linear regressions of indices of abundance against all habitat variables for each species. We used a Bonferroni correction for the habitat variable multiple regressions to determine the critical p value of 0.01 to correspond to an overall α level of 0.05.

Results

The five species included in our analyses had different trends within each region over time (Fig. 2). Spot and menhaden declined significantly since the early 1970s in the northern region, and bay anchovy and Atlantic menhaden declined significantly in the southern region (Table 2). For Atlantic menhaden, the northern region showed a greater rate of decline than the southern region (northern bays=−0.152 year^{-1}, $p<0.001$; southern bays=−0.132 year^{-1}, $p<0.001$). Similarly, spot declined more rapidly in the northern region (slope=−0.102 year^{-1}, $p=0.001$) than the southern region (slope=−0.078 year^{-1}, $p=0.009$). In both species, the regional rates of decline were significantly different from each other ($p<0.05$). Bay anchovy, alternatively, had a greater rate of decline in the southern bays than the northern bays (northern bays=−0.037 year^{-1}, $p=0.017$; southern bays=−0.065 year^{-1}, $p<0.001$). The decline in bay anchovy occurred primarily after 1987 and 1989, the peak years in the southern and northern regions, respectively (Fig. 2). The lowest densities occurred in 2001 and 2002. Atlantic menhaden showed several years of extremely high abundance in the 1970s and early 1980s, but have been at low levels since then (Fig. 2), with the lowest densities occurring in 2001 in the northern region and 2009 in the southern region.

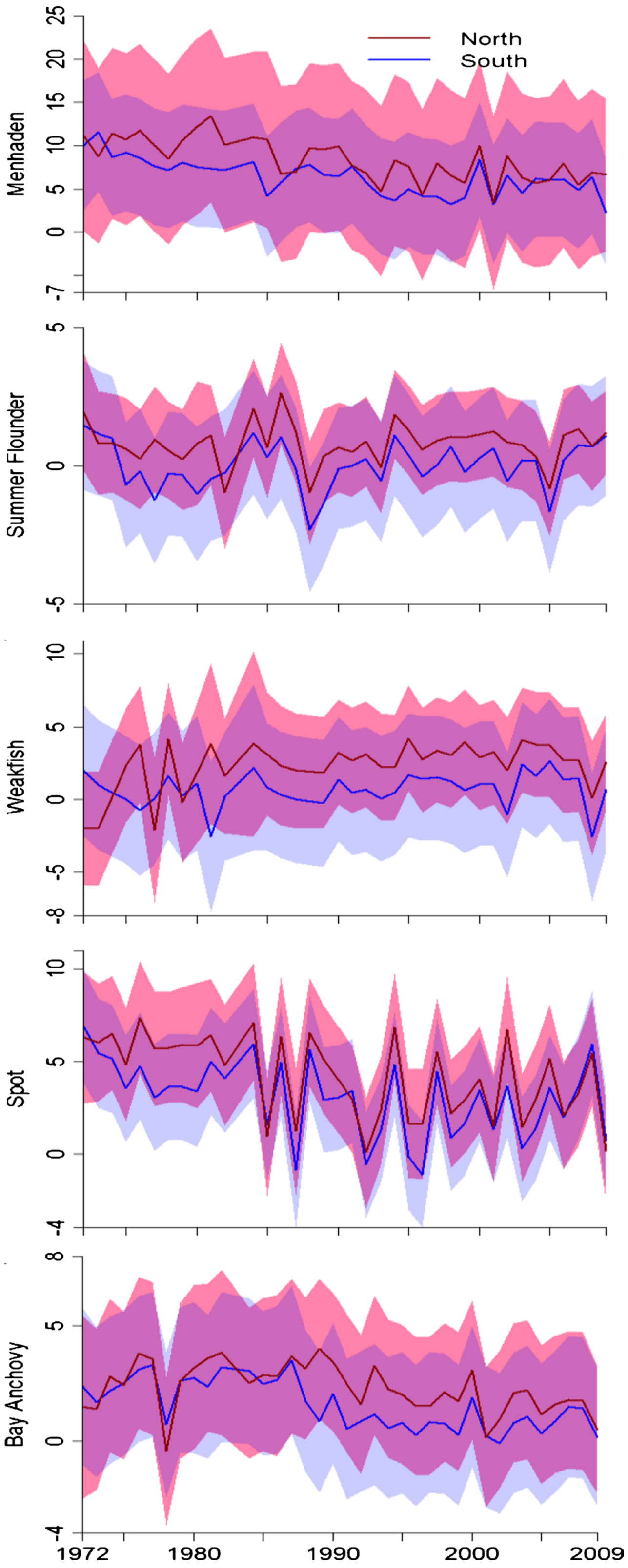


Fig. 2 Natural log-scale GLiM-corrected indices of abundance of Atlantic menhaden, summer flounder, weakfish, spot, and bay anchovy in Maryland's coastal bays. *Shaded areas* are 95 % confidence intervals

Table 2 Results of regressions for trends by species and region over 1972–2009

Species	Region	Slope	p value
Bay anchovy	North	−0.037	0.017
Bay anchovy	*South*	*−0.065*	*0.001*
Atlantic menhaden	*North*	*−0.153*	*<0.001*
Atlantic menhaden	*South*	*−0.132*	*<0.001*
Summer flounder	North	<0.001	0.992
Summer flounder	South	0.005	0.698
Spot	*North*	*−0.102*	*0.001*
Spot	South	−0.078	0.009
Weakfish	North	0.048	0.058
Weakfish	South	0.015	0.440

Italicized entries indicate statistically significant trends at $p<0.005$, the level that corresponds to $\alpha=0.05$ when corrected for multiple comparisons

Abundance of summer flounder and weakfish did not trend significantly in either region, but both species exhibited periods of increasing abundances in the 1990s and early 2000s. Summer flounder had spikes in density in 1984 and 1986 in the northern region, but 1972 and 1973 had the highest densities in the southern region (Fig. 2). Weakfish had highly variable indices of abundance, especially in the northern region. The highest densities occurred in 1995 and 1978 in the northern region and 2005 and 2003 in the southern region (Fig. 2). The lowest densities occurred in 2008 in both regions for weakfish and 1988 in both regions for summer flounder.

Most of the species' indices of abundance over time were positively correlated between regions, showing consistency in the trends of fish density across all five bays. Bay anchovy had a correlation of 0.63 ($p<0.001$), summer flounder had a correlation of 0.66 ($p<0.001$), weakfish had a correlation of 0.57 ($p=0.001$), and spot had a correlation of 0.43 ($p=0.008$). Only Atlantic menhaden had a low correlation between regions (−0.02, $p=0.896$), though the log-transformed indices of abundance had a relatively high correlation through time (0.66, $p<0.001$).

The variability of the indices of abundance differed among species and regions, with Atlantic menhaden indices varying by four orders of magnitude (when back-transformed to an absolute scale, a 10,000-fold difference) over the time series, while summer flounder and bay anchovy varied by only two orders of magnitude (100-fold difference) during the same period. The coefficients of variation (CV) were higher in the southern region for all species, and the median of the CVs in the southern region were 2.5 times those of the northern region. All species showed significantly higher indices of abundance in the northern bays than the southern bays ($p<0.001$ for menhaden, flounder, and weakfish; $p=0.010$ for spot; $p=0.001$ for bay anchovy).

While each of the habitat variables showed interannual variation, most of them did not exhibit significant trends over time (Fig. 3). The exception was sea grass cover, which increased significantly from 1993 through 2004 ($p<0.001$; Fig. 3). Abundance indices were not significantly related to any of the habitat variables for any of the fish species for the period during which habitat data were available (Table 3).

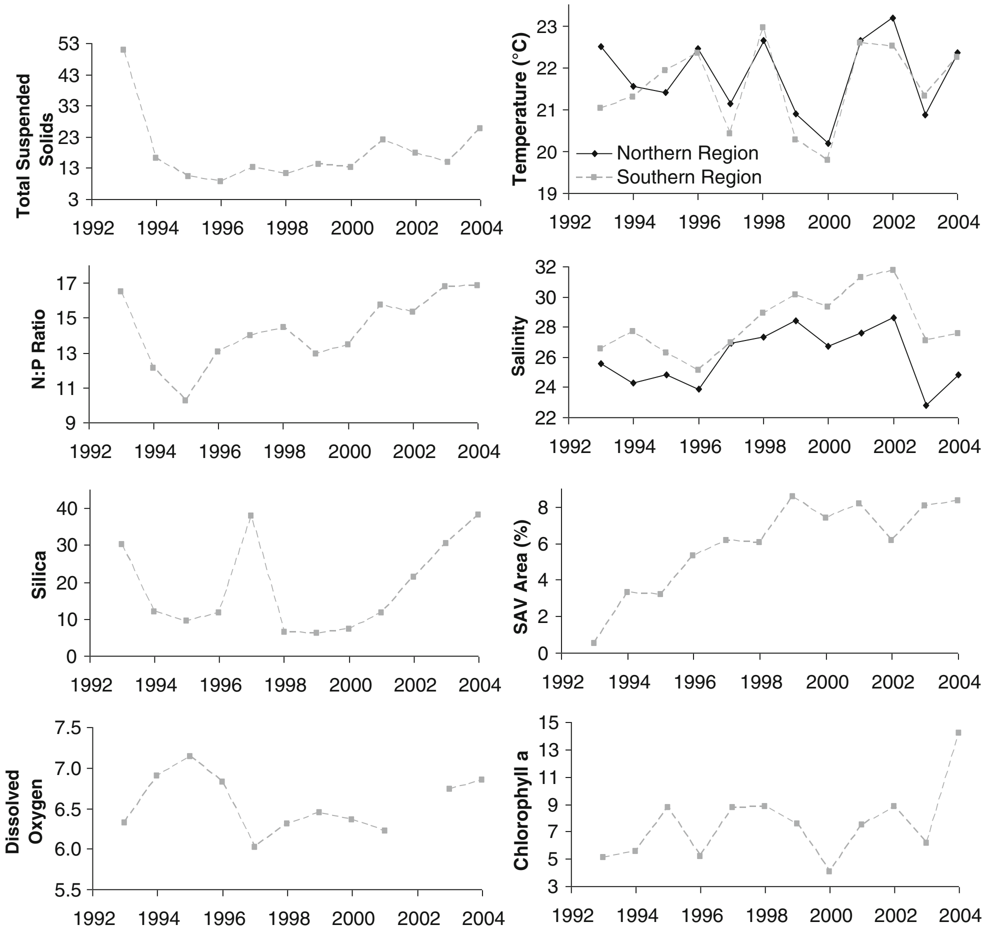
Discussion

Long-term surveys are necessary to determine how populations have changed over time, but survey methods often change. We developed statistically standardized indices of abundance for five fish species in Maryland's coastal bays that explicitly incorporated changes in location of survey sites, times of year sampled, and amount of effort used at each site. These standardized indices indicated significant decreases in spot, bay anchovy, and Atlantic menhaden abundance during 1972–2008, but no significant trends in abundance for weakfish or summer flounder. The declines in abundance of spot and Atlantic menhaden were not detectable if we only used data since 1989, the year the MCBTSS methods were standardized.

The dynamics of several species in the Maryland coastal bays likely reflect coast-wide population trends. Regional recruitment indices for Atlantic menhaden have been relatively low during the last 20 years (ASMFC 2010a), and the coastal bays indices we developed showed the same pattern. The trend in spot abundance has been punctuated periodically by large recruitment events, though the magnitude of the recruitment events has declined over time, so that high recruitment events in recent years are not as large as in early years. These spikes and the overall trend have the same temporal pattern as stock assessments across the east coast of the USA (ASMFC 2010b; Rickabaugh 2010), suggesting that the trends in abundance in Maryland's coastal bays reflect broader-scale trends for spot and menhaden.

The northern coastal bays had higher densities and lower coefficients of variation for all five species in our study than the southern region, which corresponds with previous results from Murphy and Secor (2006). The cause of higher density in the northern bays than the southern bays could include higher primary production in the northern bays (Murphy and Secor 2006; Wazniak et al. 2007) and may indicate a bottom-up effect of production on fish density. Schwartz (1964) also suggested that species composition may differ between the northern and southern bays as a result of physical forces in the larval transport mechanisms from the coast to the bays. He hypothesized that stronger currents force more water, and potentially larvae and juvenile fish, into the northern bays as a result of the hydrodynamics of the Ocean City inlet. However, the differences in density between the two regions

Fig. 3 Trends of habitat variables from 1993 to 2004. *N:P Ratio* is the ratio of total nitrogen to total phosphorus. Submerged aquatic vegetation (*SAV*) area is the percentage of bottom area in the southern region that had sea grass



was opposite of what is expected based on water quality. Two of the southern bays, Chincoteague and Sinepuxent, consistently score better in almost every metric of ecosystem health than the two northern bays (Franks 2004; Wazniak et al. 2007; IAN et al. 2010). Assawoman and Isle of Wight Bays have levels of chlorophyll a, total nitrogen, and total phosphorus above the thresholds for sea grass growth (Wazniak et al. 2007). However, these areas may not have yet reached the threshold observed by Oczkowski et al. (2008) and hypothesized by Caddy (1993) above which fish density is negatively impacted. This unimodal relationship between nutrient loading and fish density may be the reason for the higher densities seen in the northern bays. Unfortunately, the agricultural paradigm would have been best tested in the northern coastal bays by evaluating relationships between chlorophyll a (as a proxy for primary production) and fish abundances to provide a mechanism for the link between nutrients and fish. Chlorophyll data were unavailable for the northern bays to conduct a comparison, and we can only observe that higher fish abundances were detected in the northern region as has been observed in other studies (Murphy and Secor 2006).

Table 3 Results of multiple regressions for each species in the southern region. Variables included in each regression are as follows: dissolved oxygen (milligrams per liter), nitrogen-to-phosphorus ratio, silica concentration, temperature (degrees Celsius), salinity in parts per thousand, concentration of suspended solids, and chlorophyll a (micrograms per liter)

Species	*p* value	*F* value	Degrees of freedom
Bay anchovy	0.77	0.56	8
Summer flounder	0.34	1.78	8
Atlantic menhaden	0.37	1.65	8
Spot	0.26	2.38	8
Weakfish	0.10	5.16	8

Statistical significance was at α=0.01, the level that corresponds to α=0.05 when corrected for multiple comparisons

Changes in abundance of the five species investigated were not related to any of the habitat variables examined. The habitat variables covered a wide range of possible factors, from nitrogen and phosphorus ratios to the abundance of sea grass. In particular, sea grass is often considered “essential fish habitat” for coastal species because it is thought to provide refuge and nursery habitat for the young-of-year fish. However, the documentation of sea grass as essential nursery habitat has not been definitive (Heck and Thoman 1984; Beck et al. 2001). With few exceptions (e.g., Heck and Orth 1980; Deegan et al. 1997), previous efforts to study sea grass–animal interactions were confined to relatively short periods of time and very restricted spatial scales. Short-term studies are limited in their ability to separate population dynamics from the effects of sea grass habitat availability because recruitment, mortality, and seasonality can all influence fish populations. Sea grass may not be as important as overall habitat structure or refuge provided by other sources such as oyster beds or coral reefs (Heck et al. 2003). We did not detect an effect of sea grass coverage on the abundance the five prevalent species in spite of the steady increase of sea grass throughout the 1990s and early 2000s.

Trends in fish abundance in Maryland's coastal bays are most likely driven by forces on a broader scale than trends in local habitat. The habitat variables tested in this study likely have a localized effect on population dynamics of fishes, but the spatial or temporal scales of data collection or analysis may not match the effects of habitat forcing on the populations. Habitat variables are difficult to connect with changes in fish abundance (Minns et al. 1996) because the juvenile populations as a whole may be more closely linked to stock size than local habitat. For instance, abundances of juvenile red drum (*Sciaenops ocellatus*) were positively correlated among estuaries in spite of variable water temperature, suggesting that forces outside the estuaries have at least partial influence on changes of observed juvenile densities from year to year (Scharf 2000). Bi et al. (2008) also found that while determining the changes in good juvenile habitat is helpful in determining the success of Chinook (*Oncorhynchus tshawytscha*) and coho (*Oncorhynchus kisutch*) salmon year classes, larger-scale information on salmon habitats is necessary to understand their population dynamics. Similarly, Maryland's coastal bays provide primarily juvenile habitat, so larger-scale information is needed to assess population dynamics over time. As the scale of environmental processes affecting stock size are likely much larger than the scale of the monitoring programs, detection of the roles of various effects is difficult. Additionally, the power of the analyses to detect relationships between fish abundance and habitat was reduced because we had data only for habitat variables from the southern region for a limited number of years.

Large-scale, stock-wide forces are likely the primary factor affecting the densities of fish in Maryland's coastal bays. The similarity in trends between the juvenile indices for Maryland's coastal bays and the Mid-Atlantic for Atlantic menhaden and spot provide evidence that juvenile and adult populations are connected in both estuaries and the coast (Whitfield 1989). Summer flounder also have similar trends during the last two decades in the Maryland coastal bays' indices and in the stock assessments conducted for the Mid-Atlantic region (SAW 2006). The only species in our study that does not have a broader spawning population offshore is bay anchovy. Bay anchovy dynamics may depend more on abundance of predators than local environmental variables (Wang and Houde 1995). However, most of the populations that inhabit the coastal bays are composed primarily of single year classes that are replaced annually (Bolinger et al. 2007), so the large interannual variability is likely due to the differing strengths of the juvenile year classes.

It is important to consider all of the available data to reach the best conclusions about fishery resources (Myers and Worm 2003). The years included in analyses affect our ability to detect changes in population size and frame our understanding on the magnitude of change. This is called the problem of ”shifting baselines” (Pauly 1995). However, it is also important to recognize potential shortcomings in using older data. Data collected using one set of methods may not be directly comparable to data collected using another set of methods. However, in some situations, approaches are available to correct for past changes in data collection, allowing us to make use of older data and salvaging potentially valuable long time series. In the case of Maryland's coastal bays, only data from 1989 onward are used to inform stock assessments (e.g., ASMFC 2010b). By using a tool such as a generalized linear model, we can glean useful information about the state of the fish population prior to the changes in the survey despite the challenges of changing methods.

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