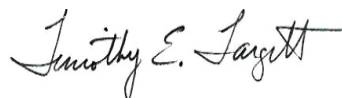


**Ingress of larval fishes through Indian River Inlet:
patterns of abundance and development of a Juvenile
Fish Index to assess water quality in the Inland Bays
system**

Final Report

Organization: University of Delaware
Graduate College of Marine Studies
Lewes, DE 19958



Project Manager: Timothy E. Targett
302-645-4396
ttargett@udel.edu

Graduate Student: Michael P. Rhode
302-645-4378
mrhode@udel.edu

Submitted to the Delaware Center for the Inland Bays
February 2008

Report No.	CIB Project ID	CIB Grant No.(s)
CIB Funding Amount \$19,995		Total Match Funding Amount By Source \$7,953
Title and Subtitle Ingress of larval fishes through Indian River Inlet: patterns of abundance and development of a Juvenile Fish Index to assess water quality in the Inland Bays system		Report Date February, 2008
Project Start Date October 1, 2006	Project Completion Date September 30,2007	
Authors Timothy E. Targett Michael P. Rhode		
Performing Organization Name and Address University of Delaware Graduate College of Marine and Earth Studies Lewes, DE 19958		
Numerical List of Project Objectives 1) Quantify larval fish ingress into the Inland Bays from offshore spawning by conducting weekly ichthyoplankton collections on flood tides at Indian River Inlet. 2) Describe temporal variation in abundance and diversity of larval supply and couple this with assessments of subsequent juvenile abundance to develop Juvenile Fish Indices (JFI) for Atlantic menhaden, summer flounder, Atlantic croaker, spot, and American eel. 3) Use the JFI indices as measures of environmental quality for these young fishes in the Inland Bays by beginning to a) determine whether variability in juvenile abundance is determined largely by larval influx or by process affecting survival within the bays and b) assess how abundance changes over time relate to changes in water quality components.		
Acres Restored or Enhanced by Habitat Type	# of Individuals Informed By Year	No. of Pages

Abstract:

Indian River Inlet is the primary location for tidal exchange of water between Indian River and Rehoboth Bays, Delaware, and the coastal ocean (Wong 2002). All fish larvae from species spawning in the coastal ocean (and beyond) therefore enter the Inland Bays through this inlet. Abundance and inter-annual variability of these fishes in the bays is determined in part by larval supply. During the period of October 2006-September 2007 weekly ichthyoplankton collections were conducted from an established monitoring station at Massey's Landing. Seasonal dynamics in the supply of young fishes such as Atlantic menhaden (*Brevoortia tyrannus*), summer flounder (*Paralichthys dentatus*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), and American eel (*Anguilla rostrata*) to the Inland Bays system was documented and species-specific estimates of larval abundance (larval supply) were linked with existing DNREC juvenile fish (young-of-the-year (YOY)) survey results to begin to determine whether variability in abundance of the above species in the Inland Bays is determined largely by larval influx or by process affecting subsequent survival within the bays.

Introduction:

The only published data on larval fish ingress through the inlet was collected ~50 years ago by de Sylva et al. (1962). Biweekly collections ($\frac{1}{2}$ hour tows with a 0.3m diameter plankton net (either 153 μ or 585 μ mesh netting)) were made at Indian River Inlet on nighttime flood tides from July 1956 through July 1958 (Hopkins 1958, 1965). This work shows that a) flood tide ichthyoplankton has greatest species diversity during summer and fall and b) larvae of important offshore spawners (e.g. Atlantic menhaden, summer flounder, Atlantic croaker, spot, and American eel) collectively enter the Inland Bays during all seasons, although all have at least part of their influx during wintertime. Larval Atlantic menhaden and American eel are the most abundant species ingressing during winter and spring. The data indicate considerable intra- and inter-annual variation in magnitude of larval ingress.

February 2006, preliminary ichthyoplankton collections made at the inlet on nighttime flood tides were dominated by larval Atlantic menhaden (average = 87/1000m³, 19-22mm), American eel (glass eel stage (average = 15/1000m³, 54mm)), and Atlantic croaker (average = 7/1000m³, 12-13mm). Post-larval Atlantic menhaden, summer flounder, Atlantic croaker, spot, and American eel (the target species in this study) are ecologically and economically significant components of the Inland Bays' fish fauna. Abundances of juvenile (YOY) Atlantic menhaden, summer flounder, Atlantic croaker, and spot from 1986-2005 show substantial fluctuations from year-to-year as well as longer-term abundance trends (data from DNREC's Inland Bays trawl surveys: Michels 2003; Clark 2006; John Clark, DNREC, personal communication). Glass eel abundance is monitored by DNREC using an elver fyke net at the spillway of Millsboro Dam. These data (beginning in 2000) also show significant inter-annual fluctuations in abundance (John Clark, DNREC, personal communication).

It is likely that a large part of the year-to-year variability and longer-term trends in juvenile abundance for these species in the Inland Bays is due to inter-annual differences in larval supply from offshore spawning. Differences in larval 'supply' are the result of variability in offshore spawning intensity, location, and success of larval transport from offshore waters. At present, variability in larval supply makes an unknown contribution

to variability in numbers of juveniles present in the bays system. Estimating species-specific larval ingress will allow the variability in juvenile fish populations explained by larval supply to be distinguished from the portion due to subsequent survival differences in the Inland Bays system itself. Determining whether year-to-year variability and longer-term decreases (or increases) in abundance is due to changing environmental conditions in the Inland Bays system, or to differences in larval influx into the system, requires development of an index relating juvenile abundance to larval supply.

In this study we quantify larval fish ingress into the Inland Bays from offshore spawning by conducting weekly ichthyoplankton collections on flood tides at Massey's Landing. This allows us to describe temporal variation in abundance and diversity of larval supply and couple this with assessments of subsequent juvenile abundance to develop Juvenile Fish Indices (JFI) for Atlantic menhaden, summer flounder, Atlantic croaker, spot, and American eel. Use of the JFI indices as measures of environmental quality for these young fishes in the Inland Bays will allow us to begin determining whether variability in juvenile abundance is a result of larval influx or process affecting survival within the bays. Ultimately, we can begin to assess how abundance changes over time relate to changes in water quality components.

Methods:

Ichthyoplankton collections to assess larval influx were conducted weekly from an established monitoring station at Massey's Landing on nighttime flood tides (≥ 1 h after sunset or before sunrise). A one meter diameter ring plankton net (1 mm mesh) was suspended from a portable davit mounted on the dock railing, and fished at ~ 1 m depth for 30 minute sets in replicate series, yielding three samples on each sampling date. On several occasions, when anchovy and goby abundances were high, tows were shortened (10-15 minutes). A flow meter (General Oceanics model 2030R) was centrally fixed in the mouth of the net to estimate volume of water filtered. Surface water temperature and salinity were measured using a field thermometer and refractometer at the beginning and end of each sampling event. Ichthyoplankton were sorted immediately in the laboratory (in shallow clear Pyrex pans), and preserved in 95% ethanol. This protocol followed that of an established, successful 20 year larval sampling time series in Little Egg Inlet, NJ (Witting *et al.*, 1999). Fish were then identified, counted, and the lengths of up to 20 randomly selected individuals were measured.

Abundances of the target species was expressed as $1000(\text{fish}/\text{m}^3)$ for each collection date. Weekly abundances were plotted for each species and total abundance estimated by calculating the area under the larval abundance/date curves (AUC). These values were then used with the juvenile abundance estimates (based on DNREC's calculated CPUE) from the subsequent summertime DNREC trawl surveys to calculate a JFI for each species. DNREC's juvenile fish abundance data ($\#/\text{minute}$ trawl time) were collected by Stew Michels with a 3m trawl (5min tows) at 15 sites in Herring, Love, Pepper, and White Creeks, and upper Indian River. Surveys were conducted every two weeks in June, July, and August, and monthly in May, September and October). JFIs are ratios and were created by scaling juvenile abundance per unit effort by larval abundance per unit effort. [$JFI = \# \text{juveniles per min} / \# \text{larvae per } 1000\text{m}^3$] It should be noted that the magnitude of larval influx was driven almost exclusively by the larval concentrations

that were measured in this research; intra- and inter-annual differences in inflow volume have only minor influence (Richard Garvine, UD, personal communication).

Results:

A three day intensive comparison study was conducted from January 16, 2007-January 18, 2007 to investigate the composition of samples collected at Massey’s Landing (Figure 1). This was in order to evaluate the possible differences between the study site and Indian River Inlet. A net was deployed at the mouth of Indian River Inlet for three successive half-hour tows on three successive night flood tides. Approximately one hour later, three successive half-hour tows were conducted from the pier at Massey’s Landing. The delay at Massey’s Landing was owing to the amount of time it takes a water mass to travel from the inlet to Massey’s Landing (Wong, personal

communication) in an attempt to sample the same water mass. The same six species made up 99-100% of the overall abundance at both sites on all three nights.

Overall species abundance was compared between each site for each of the six species using ANOVA’s, and abundances at Indian River Inlet were significantly higher for Atlantic menhaden only. Forward *et al.* (1999), concluded after the SABRE that due to current flows and turbulence which overwhelm larval swimming ability in inlets, patterns of abundance are often inconsistent and become evident only once inside the inlets; thus patterns of abundance rely heavily on sampling location.

During the period of October 2006-September 2007 fifty-two weekly ichthyoplankton samples, each consisting of three replicate tows, were collected. A total of 8,943 fish larvae were collected, sorted, identified, and a random subset of twenty individuals of each species measured on each sample date. Project target species

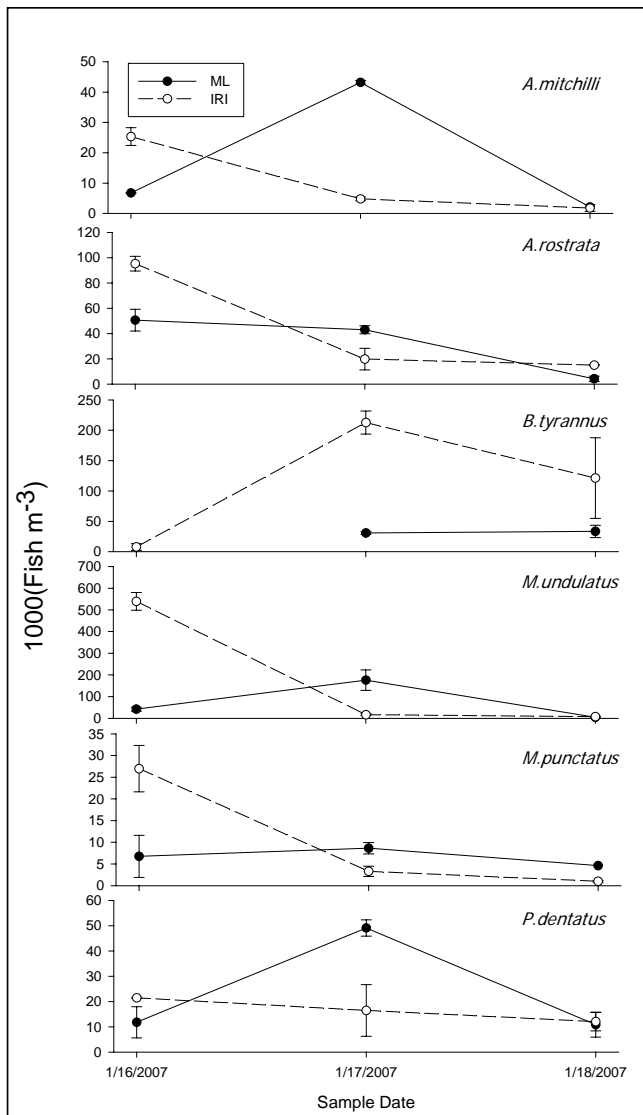


Figure 1. Total abundance of species caught during Massey’s Landing vs. Indian River Inlet intensive study January 16-18, 2007.

comprised 33.1% of the overall catch: Atlantic croaker (*Micropogonias undulatus*) 26.5%,

Atlantic menhaden (*Brevoortia tyrannus*) 2.5%, summer flounder (*Paralichthys dentatus*) 2.4%, American eel (*Anguilla rostrata*) 1.5%, and spot (*Leiostomus xanthurus*) 0.2%; with other major contributions (41.0%) coming from anchovies (*Anchoa* spp.). Abundances of the target species expressed as 1000(fish/m³) for each collection date (Figures 2 and 3a-e) are shown below.

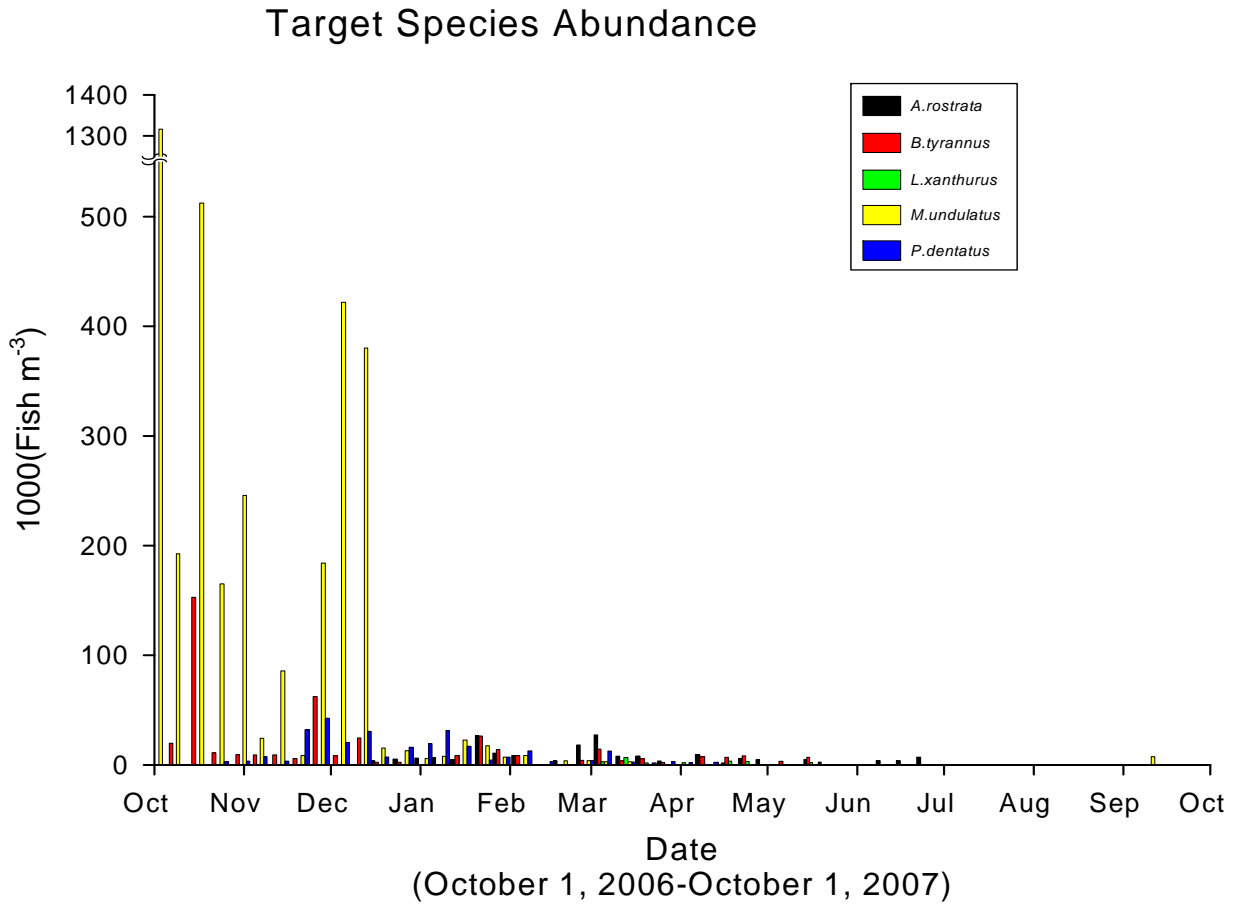


Figure 2. Total abundance of target species expressed as average 1000(fish/m³) for each collection date.

It is evident Atlantic croaker dominated the winter collections during 2006 (Fig 1). This common, southern Middle Atlantic Bight (MAB), species' spawning activity appeared to peak in October, but larvae persisted in abundance through much of December (Fig 2d). During this period average lengths tripled, increasing from 6.9-8.0 mm to >22mm. Larvae continued to ingress through mid March 2007 and then disappeared completely from collections until mid September. Atlantic menhaden larvae also appeared to peak in October, but continued to ingress through mid May (Fig 2b). This species had a broad time range of ingress, appearing in most winter and spring samples. Average lengths increase slightly in spring collections, peak in February, and slowly begin to decrease. Summer flounder (Fig 2e) typically ingressed in the 10-15mm size range, with little variability among tows on a given date. Peak abundance appeared bimodal during December 2006 and mid-January 2007. Glass eels (Fig 2a) and spot (Fig

2c) arrived late in the collections for winter spawners. Spot larvae, in historical collections, typically appear in low numbers in this region and are usually restricted to southern portions of the MAB. Glass eels averaged between 52-58mm and only early stage (typically 1 and 2) were collected. Eel abundance peaks, also bimodal, occurred in late January and early March.

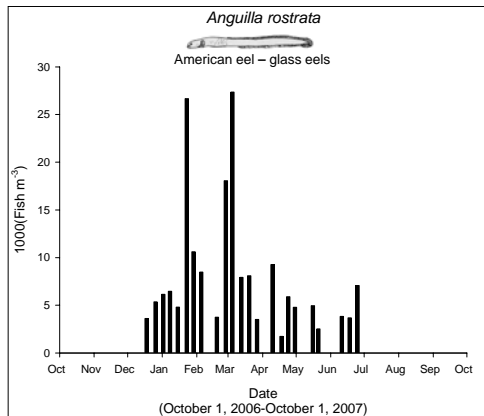


Figure 3a

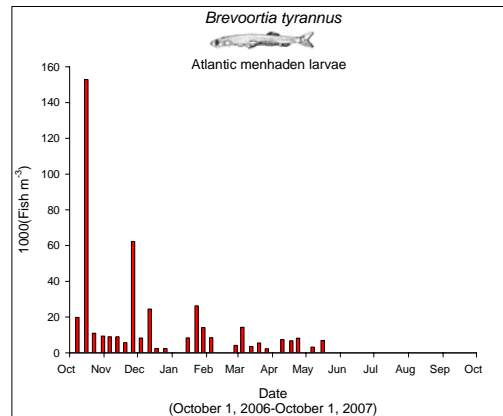


Figure 3b

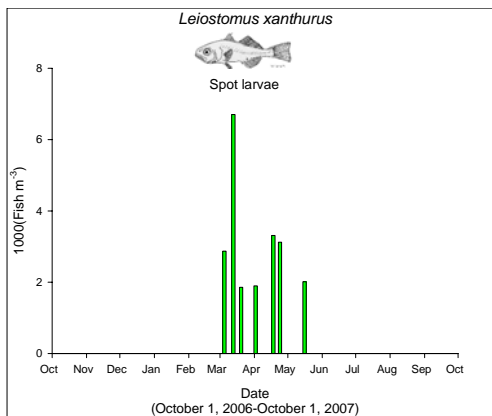


Figure 3c

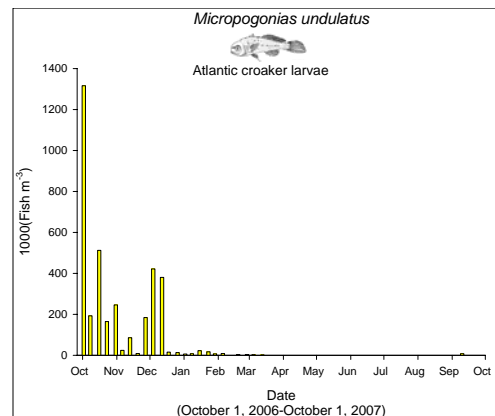


Figure 3d

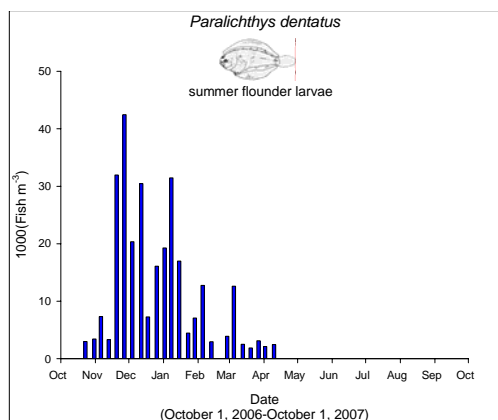


Figure 3e

Plots of each target species' weekly abundance were then used to estimate total abundance by calculating the area under the larval abundance/date curves (AUC). This was done by using the 2-point Newton-Cotes formula or the trapezoidal rule:

$$\int_{x_1}^{x_2} f(x) dx = \frac{1}{2} h (f_1 + f_2) - \frac{1}{12} h^3 f''(\xi),$$

where $f_i \equiv f(x_i)$, h is the separation between the points, and ξ is a point satisfying $x_1 \leq \xi \leq x_2$. Picking ξ to maximize $f''(\xi)$ gives an upper bound for the error in the trapezoidal approximation to the integral. Calculated AUC for each species, based on larval abundance/date curves (Figures 4a-e) are American eel=1294.0, Atlantic menhaden= 3143.1, spot=152.6, Atlantic croaker=20,864.0, and summer flounder=2027.6.

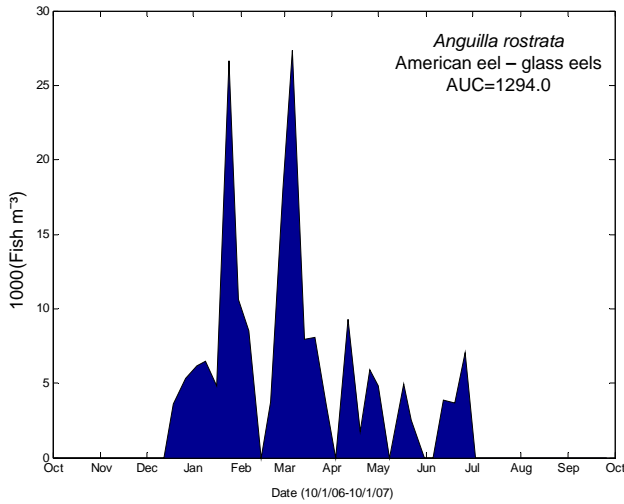


Figure 4a

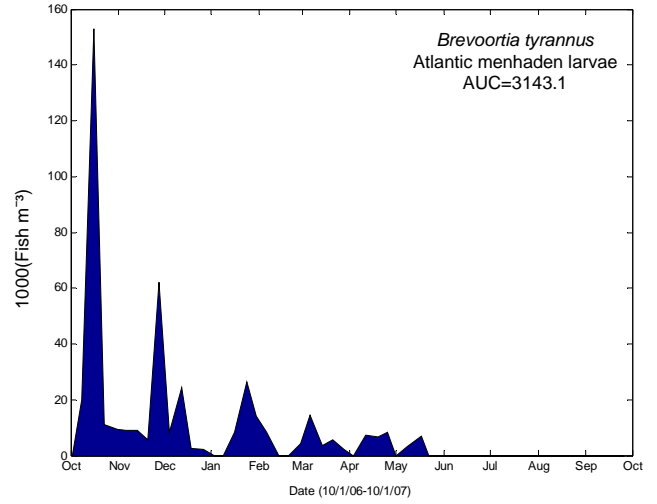


Figure 4b

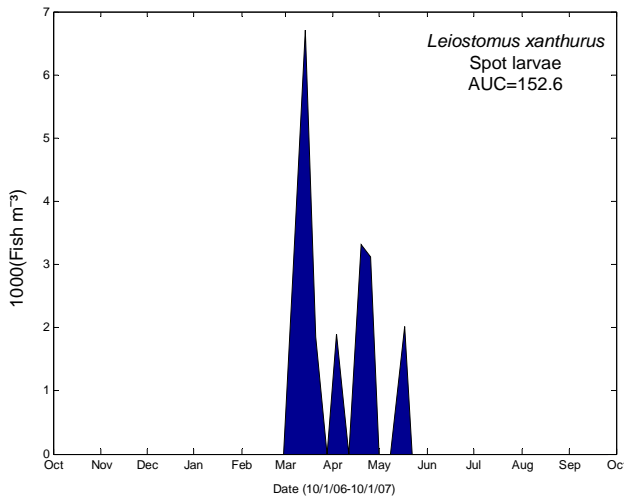


Figure 4c

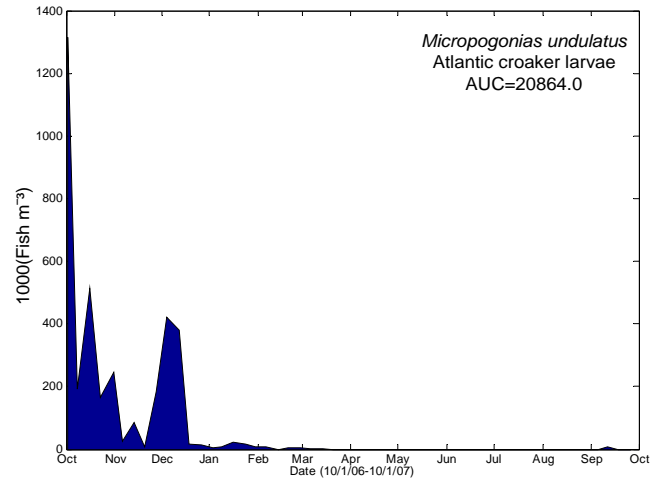


Figure 4d

Abundances of juvenile (YOY) Atlantic menhaden, spot, Atlantic croaker, and summer flounder from 1986-2005 show substantial fluctuations from year-to-year as well as longer-term abundance trends (Figure 5)(data from DNREC's Inland Bays trawl

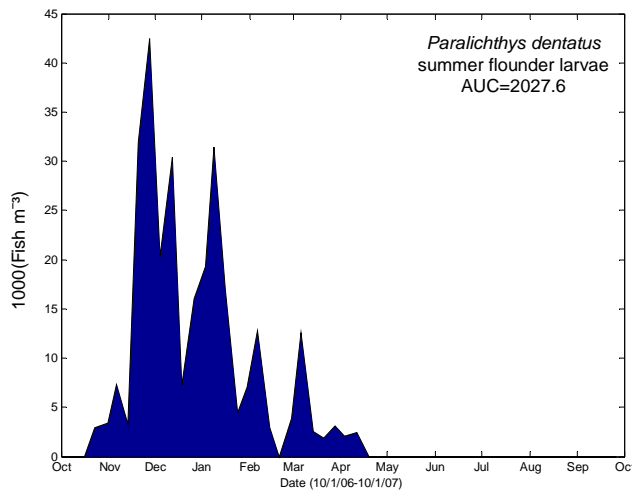


Figure 4e

AUC the variability in juvenile fish populations will be explained. This provides us with the unique ability to explain the year-to-year variability and longer-term decreases (or increases) in abundance, whether it is due to changing environmental conditions in the Inland Bays system, or to differences in larval influx into the system. In order to determine survival differences in the Inland Bays system itself further data collection is needed. We have provided the baseline JFI values for five target species (Table 1). By correlating increases and decreases in our JFI to water quality measurements in the Inland Bays, variability can be attributed to either changing environmental conditions in the Inland Bays system, or to differences in larval influx into the system

surveys: Michels 2003; Clark 2006; John Clark, DNREC, personal communication). Glass eel abundance is monitored by DNREC using an elver fyke net at the spillway of Millsboro Dam. These data (beginning in 2000) also show significant inter-annual fluctuations in abundance (Figure 6) (John Clark, DNREC, personal communication). The ASMFC has not settled on an index for glass eel abundance so DNREC uses geometric means in order to factor out the high amount of variability found on a daily basis. By comparing the ratio of the juvenile CPUE and the larval

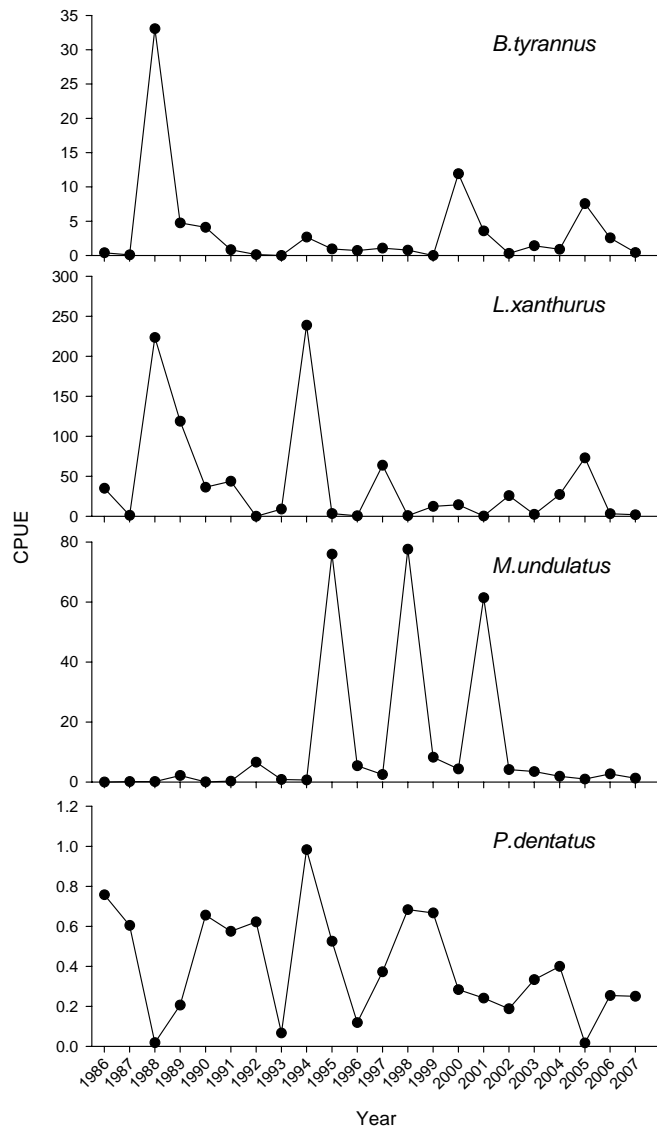


Figure 5 DNREC CPUE values 1986-2007

Anguilla rostrata

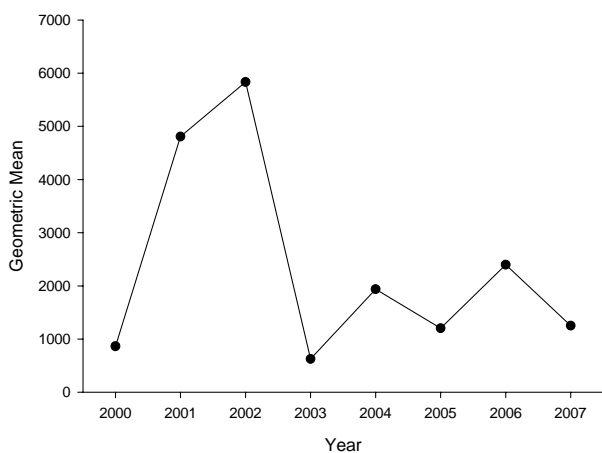


Figure 6 Geometric mean of glass eel abundance

Table 1 Calculated JFI's for five target species

	<i>A.rostrata</i>	<i>B.tyrannus</i>	<i>L.xanthurus</i>	<i>M.undulatus</i>	<i>P.dentatus</i>
DNREC CPUE	1252	0.4167	1.917	1.2917	0.25
Larval AUC	1294	3143.1	152.6	20864	2027.6
JFI	0.9675425039	0.0001325761	0.0125622543	0.0000619105	0.0001232985

REFERENCES

- Clark, J.H. 2006. Current and historical habitat utilization of Delaware's tidal tributaries and wetlands by fish species managed under interstate fisheries management plans (FMPs). Report, Job I-2. In: Fish habitat considerations for Delaware's tidal tributaries. DNREC Report, Project F-56-R-10. 54pp.
- de Sylva, D.P., F.A. Kalber, Jr., and C.N. Shuster, Jr. 1962. Fishes and ecological conditions in the shore zone of the Delaware River Estuary, with notes on other species collected in deeper water. University of Delaware Marine Laboratories Information Series. Publication #5. 164pp.
- Forward RB, Reinsel KA, Peters DS, Tankersley RA, Churchill JH, Crowder LB, Hettler WF, Warlen SM, Green MD (1999) Transport of fish larvae through a tidal inlet. *Fisheries Oceanography* 8(Suppl. 2):153-172
- Hopkins, T.L. 1958. On the breeding and occurrence of opossum shrimp (Mysidacea) in Indian River Inlet, Delaware. M.S. Thesis. University of Delaware. 36pp.
- Hopkins, T.L. 1965. Mysid shrimp abundance in surface waters of Indian River Inlet, Delaware. *Ches. Sci.* 6: 86-91.
- Michels, S.F. 2003. Bottom trawl sampling of juvenile fishes in Delaware's estuaries. DNREC Report, Job I-3. 76pp.
- Witting, D.A., Able, K.W., Fahay, M.P. 1999. Larval fishes of a Middle Atlantic Bight estuary: assemblage structure and temporal stability. *Canadian Journal of Fisheries and Aquatic Sciences* 56:222-230