# Zooplankton/Food Web Monitoring for Adaptive Multi-Species Management

January 12-13, 2005

Smithsonian Environmental Research Center
Edgewater, MD

Sponsor
Chesapeake Research Consortium

## Chesapeake Research Consortium
## Zooplankton/Food-Web Workshop
## January 12-13, 2005 SERC Edgewater, MD

*DAY 1*     *January 12, 2005*

8:30-8:45    Welcome..................................................................................................Sellner

8:45-9:15    Management Applications of Zooplankton/Foodweb Indicators and
Metrics ...............................................................................................Batiuk & Wood
Includes reference to Background Information in Booklet
Review of the roles played by zooplankton/food-web monitoring data indicators/metrics
   in Chesapeake Bay restoration management in the past and potential for future
   applications.

9:15-10:30    External Experts' Presentations:  Management Indicators and Metrics for other
Systems .......................................................................................................Sellner

     Wil Kimmerer, Tiburon Laboratory, San Francisco State University
     Mike Pace, Institute of Ecosystem Studies
     Barbara. Sullivan, Graduate School of Oceanography, University of Rhode Island
     TBD, fish expert

10:30-10:45   BREAK

10:45-12:00   Project Team Presentations of Metrics/Indicators in New Project.........Lacouture et al.
   Fisheries/Ecosystem Management

12:00-1:30    LUNCH

1:30-2:15    Project Team Presentations of Metrics/Indicators in New Project.........Lacouture et al.
   Water Quality Management

2:15-2:30    BREAK

2:30-4:45    Breakout Session: Discussion of New Project from the Fisheries and Water Quality
Management Perspectives ........................................................................ Leads TBD

4:45-5:00    Plenary:  Where do we stand, homework assignments, logistics update ...........Sellner

6:00-8:00    DINNER

**Chesapeake Research Consortium**
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*DAY 2      January 13, 2005*

8:30-8:45      Plenary:  Re-invigorate groups and outline day's program..................................Sellner

8:45-10:00     Breakout 2:  Participants will change groups and continue discussion of the New Food Web Project from the Fisheries and Water Quality Management Perspectives
.................................................................................................... Leads TBD

10:00-10:15  BREAK

10:15-12:00  Breakout 2 continues

12:00-1:30   LUNCH

1:30-3:00     Plenary:  Recommendations from Breakouts presented to all participants and Summary Recommendations derived.................................................................................... Wood

3:00          Adjourn

3:15-4:30     Steering committee and external experts discuss recommendations.

Post-conference:  Woods and the Steering committee will generate the following, Within 2 weeks, recommendations for station or sampling frequency adjustments to 2005 field season; within 6 weeks, summary report of workshop high lights and recommendations.

# Chesapeake Bay Management Information Needs and Underlying Zooplankton Community Metrics

| Category | Data application | Microzooplankton | Mesozooplankton | Macrozooplankton | Gelatinous Zooplankton | Biomass | Species ID Needs | WQ Parameters | Temporal Scale | Location | Other Considerations | Priority (1=LOW TO 5=HIGH) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fisheries Management | Assessing Contributions to Fisheries Production | | | | | | | | | | | |
| | • Zooplankton as Quality Food Index (Fish Species Specific) | | | | | | | | | | | |
| | • Larval Fish Food Availability Index (Fish Species Specific) | | | | | | | | | | | |
| | • Gelatinous Zooplankton Predation Potential Index (Fish Species Specific) | | | | | | | | | | | |
| | Understanding Effects on Fisheries Production Through Zooplankton Community Responses to External Stressors | | | | | | | | | | | |
| | • Zooplankton Habitat Quality Index | | | | | | | | | | | |
| | • Zooplankton as Quality Food Index (Fish Species Specific) | | | | | | | | | | | |
| | • Larval Fish Food Availability Index (Fish Species Specific) | | | | | | | | | | | |

# Chesapeake Bay Management Information Needs and Underlying Zooplankton Community Metrics

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water Quality Management | Determining Attainment of Open Water Designated Use Habitats | | | | | | | | | | | |
| | • Zooplankton Community Index of Biotic Integrity | | | | | | | | | | | |
| | • Zooplankton Habitat Quality Index | | | | | | | | | | | |
| | • Larval Fish Food Availability Index | | | | | | | | | | | |
| | • Zooplankton as Quality Food Index | | | | | | | | | | | |
| | Calibration, Verification and Management Application of Water Quality Models Linked to Lower Trophic Levels | | | | | | | | | | | |
| | • Zooplankton Community Abundance and Composition Measures | | | | | | | | | | | |
| | • Zooplankton Community Rate Process Measures (e.g. filtration, predation rates) | | | | | | | | | | | |
| | Development of New/Refinement of Existing Chesapeake Bay Water Quality Criteria (e.g. DO, Chlorophyll, Clarity) | | | | | | | | | | | |
| | • Zooplankton Habitat Quality Requirement | | | | | | | | | | | |
| | • Zooplankton Habitat Quality Index | | | | | | | | | | | |

# Chesapeake Bay Management Information Needs and Underlying Zooplankton Community Metrics

| Category | Data application | Microzooplankton | Mesozooplankton | Macrozooplankton | Gelatinous Zooplankton | Biomass | Species ID Needs | WQ Parameters | Temporal Scale | Location | Other Considerations | Priority (1=LOW TO 5=HIGH) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ecosystem Management | Communicating the "STATE OF THE BAY" | | | | | | | | | | | |
| | • Zooplankton Community Index of Biotic Integrity | | | | | | | | | | | |
| | • Zooplankton Habitat Quality Index | | | | | | | | | | | |
| | • Larval Fish Food Availability Index | | | | | | | | | | | |
| | Zooplankton Community Index Components of an | | | | | | | | | | | |
| | • Encompassing "STATE OF THE CHESAPEAKE BAY ECOSYSTEM" reporting system | | | | | | | | | | | |
| | Understanding Current and Projecting Future Ecosystem Response to Restoration Efforts | | | | | | | | | | | |
| | Zooplankton Community Abundance and Composition | | | | | | | | | | | |
| | • Diagnostics (Detecting and Explaining Community Composition/Abundance Shifts) | | | | | | | | | | | |
| | Exotic Species Detection | | | | | | | | | | | |
| | • Zooplankton Species Indentificatin and Enumeration | | | | | | | | | | | |

# Historic Monitoring Program

# Living Resources Monitoring Data Time Line
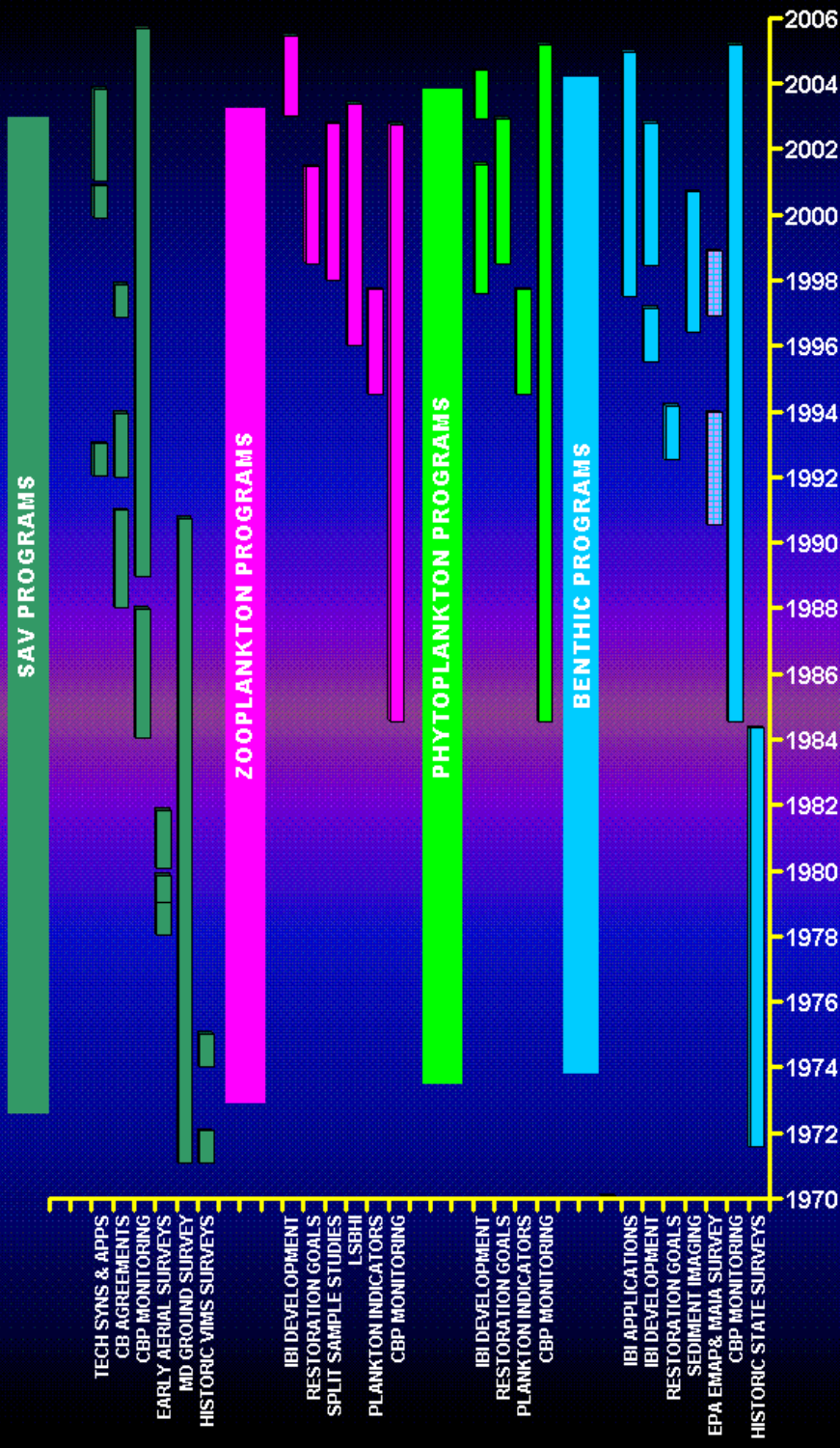
The Chesapeake has become one of the best-studied estuarine systems in North America for all aspects of estuarine ecology and modeling. The basin jurisdictions and NOAA have supported long-term monitoring of commercially valuable living resources (fish and shell-fish). Coordinated bay-wide monitoring efforts for many of the ecologically valuable lower trophic levels in the Bay began in the early 1980s, and are partially funded by the EPA Chesapeake Bay Program (CBP). Submerged aquatic vegetation (SAV), benthic macroinvertebrates, zooplankton, and phytoplankton are routinely monitored and the results are augmented with analysis projects designed to make the primary monitoring results more useful to resource managers.

# CHRONOLOGY OF LIVING RESOURCES MONITORING PROGRAMS



## ZOOPLANKTON PROGRAMS

**CPB MONITORING-** The Chesapeake Bay Water Quality Monitoring Program included a Zooplankton monitoring component from 1984-2002.  Mesozooplankton and Microzooplankton samples for species enumeration were collected at up to 36 fixed monitoring stations in the main stem and tidal tributaries of the bay. Microzooplankton sampling was conducted in Virginia only from 1989-2002 and gelatinous zooplankton occurred only in Maryland. Monitoring usually occurred concurrently with water quality monitoring.  Staff from Old Dominion University performed monitoring for the Virginia Department of Environmental Quality and by staff from Versar, Inc and Morgan State University Estuarine Research Center (formerly the Academy of Natural Sciences Benedict Estuarine Research Center) for the Maryland Department of the Environment/Maryland Department of Natural Resources. Monitoring data is available at http://www.chesapeakebay.net/. Virginia collected between 1999 and 2002 is also available at http://www.chesapeakebay.odu.edu/.

**PLANKTON INDICATORS PROJECT-** A multi-phased zooplankton indicator project begun in 1994 paralleled a similar phytoplankton indicator project.  The zooplankton project identified zooplankton community metrics that were sensitive to water quality conditions, especially eutrophication and anoxia/hypoxia. The project also identified linkages between zooplankton and fish consumers of zooplankton. The project relied primarily on multi-variant analysis techniques, and identified many potential indicators, including a food available index for larval striped bass.  Data comparability issues caused by laboratory methodology differences seriously hampered the project, and eventually prevented its completion.  Indicator development was also hampered by the fact that early zooplankton sample collection in Virginia a) was sometimes not coordinated with the water quality sampling cruises, and b) did not accurately measure water volumes filtered by the towed plankton nets prior to 1992 (this precludes accurate density calculations).

Buchanan, C. (ed.). (1993). Development of Zooplankton Community Environmental Indicators for Chesapeake Bay.  Report for US EPA Chesapeake Bay Program and Maryland Department of the Environment.  ICPRB Report 93-2.
Buchanan, C. (ed.). (1996). Zooplankton Indicators of Chesapeake Bay. Report for CBP Living Resources Subcommittee and the US EPA Chesapeake Bay Program.  ICPRB Report 96-5.
Buchanan, C.(ed.)  (1997).  Methods Used to Calculate Microzooplankton and Mesozooplankton Bay-Wide Indicators from the Chesapeake Bay Program Zooplankton Monitoring Data.  Draft ICPRB Report.

**LSBHI-** A Larval Striped Bass Habitat Index (LSBHI) was developed to assess the suitability of annual environmental conditions several Chesapeake Bay tributaries with the respect to recruitment of striped bass larvae. LSBHI index scores are calculated from water quality and zooplankton monitoring data. The LSBHI provides a measure of potential of each tributary to support recruitment of striped bass in a given year.  This index was developed primarily for Maryland tributaries but could be applied to Virginia waters.

Heimbuch, D G., , F. Jacobs, J. C. Seibel, C.K. Stoll and H. T. Wilson. (in review).  A Larval Striped Bass Habitat Index for Chesapeake Bay Tributaries.  Journal of Environmental Indicators.

**SPLIT SAMPLE STUDIES** State-related biases in the data were discovered during the indicator project, and led to a series of split sample studies beginning in 1998.  The split sample studies demonstrated that differences in the enumeration methodologies used by Maryland and Virginia laboratories to process zooplankton samples produced results that were not comparable, primarily because the Virginia method significantly underestimated mesozooplankton species abundances. Intermittent problems with the microzooplankton data were also identified. The studies eventually led to laboratory method changes in both states, and resolution of the incompatibilities in 2000.

Buchanan, C. (ed.). (2000.) Split Sampling Study for the Maryland and Virginia Mesozooplankton Monitoring Programs. Final Report, June 2000.  ICPRB Report 00-3.
Ley, M.(ed.)(2003)  The 2001 Inter-laboratory Comparison of Chesapeake Bay Mesozooplankton Samples Draft Report, US EPA Chesapeake Bay Program.

**PLANKTON RESTORATION GOALS-**   The zooplankton restoration goals project began in late 1998, in parallel to another similar phytoplankton restoration goal effort. The zooplankton component this program was intended to quantitatively characterize desirable, or "reference," zooplankton communities in bay waters.  Multivariate analyses were performed on the Maryland data to confirm the identities of sensitive metrics, and the habitat conditions that supported desirable levels of the metrics.  Work was halted when split sample studies revealed that the different sample enumeration methods between the states had produce data that were not comparable.

# CHRONOLOGY OF LIVING RESOURCES MONITORING PROGRAMS
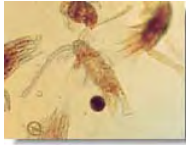


### ZOOPLANKTON PROGRAMS

**IBI DEVELOPMENT-** Despite the data limitations, zooplankton indexes of biotic integrity for the summer mesohaline and summer polyhaline communities were developed and validated.  The indexes generally agree with the phytoplankton IBI results, and have relatively high classification efficiencies. The polyhaline index was based only on selected Virginia data; reference habitat conditions were defined by dissolved inorganic nitrogen (DIN), orthophosphate $PO_4$), and Secchi depth – the same parameters used to classify phytoplankton habitat quality.  The mesohaline index was based only on Maryland data and post-1999 Virginia data; reference habitat conditions were defined by DIN, $PO_4$, chlorophyll *a*, dinoflagellate biomass, diatom biomass and Secchi depth.  A tidal fresh/oligohaline index was not possible due to the lack of both monitoring data and samples with good water quality

Carpenter, K.E., C. Buchanan, and J. M. Johnson (in review).An index of biotic integrity based on the summer polyhaline zooplankton community of the Chesapeake Bay. Journal of Marine Environmental
Research
Sillet K., W. Burton C. Buchanan, and J. M. Johnson (in prep) Development of a Summer Mesohaline Zooplankton Index of Biotic Integrity.

# Overview of Previous Chesapeake Bay Monitoring Programs

## Maryland Mesozooplankton Survey

**The Program.** Data had been collected at fixed sampling stations in the upper Chesapeake Bay, tributaries in Maryland and in the Potomac River since August 1984. Measurements made as part of this survey include identifications of mesozooplankton species (>202 microns) to the lowest practical taxonomic level, measurements of mesozooplankton biomass, and measurements of gelatinous zooplankton biovolumes. Samples were collected at 16 stations (CB1.1, CB2.2, CB3.3C, CB4.3C, CB5.2, EE3.1, ET4.2, ET5.1, ET5.2, LE1.1, LE2.2, RET2.2, TF1.5, TF1.7, TF2.3, WT5.1) once a month from August 1984 to June 1986. Sampling at stations ET4.2 and EE3.1 was discontinued after June 1986. In 1992, mesozooplankton sampling was discontinued January and February, but increased in May to twice a month in anadromous fish spawning habitats (CB1.1, CB2.2, TF2.3, RET2.2, ET5.1, ET5.2, TF1.5, and TF1.7). In 1993, station CB2.1 was added during the fish-spawning period (April to June). In 1996, three tributary stations (TF2.4, TF1.6, ET5.0) were added uring the spring anadromous spawning season. All Sampling for mesozooplankton ended in September 2002.

**The Protocol:** Two stepped oblique tows with paired bongo nets are taken at each station through the entire water column. Bongo nets used for all sampling were configured as follows: 0.76 m long, with 20 centimeter opening fitted with 202 micron mesh and calibrated flow meters. One of the nets was used for taxonomic purposes (counting), the other for biomass measurements. Replicate tows are taken. After January 1996, the replicate tows were composited into one sample for laboratory analysis of species abundance and biomass.

Gelatinous Zooplankton- When they occur, Cnidarians (true jellyfish, hydromedusae) and ctenophores (comb-jellies) are removed from the zooplankton samples in the field and their numbers and biovolume (settled volume) measured from the count sample bongo net. Prior to July 1987, all gelatinous zooplankton were reported as count and volumes in the two classes- Ctenophores and Cnidarians. After July 1987, all gelatinous zooplankton were reported as count and volumes in the four classes -Beroe, Hydrozoans, Mnemiopsis , and true Jellyfish. All gelatinous zooplankton were removed from samples in the field prior to sample preservation.

Zooplankton Settled Volume - In the laboratory, the mesozooplankton taxonomic (count) samples (i.e. samples from which jellyfish have been removed) are poured into Imhoff cones and left undisturbed for 2 - 4 days as plankton settles to the bottom of the cone. Sample volumes are then either concentrated or diluted to achieve efficient sub sample counts. The volume of the total sample from which sub samples are taken is the dilution volume. Sub samples of mesozooplankton are taken with a Hensen-Stemple pipette and counted under a dissecting microscope. In cases where field samples contained large amounts of detritus or algae, the bio-volume could not be determined directly. The settled volumes were estimated by regressing total dry weight versus bio-volume in detritus free samples.

Zooplankton Biomass- Biomass determination of dry weights and ash weights are measured by gravimetric methods for detritus-free samples. Samples containing detritus were not processed and were disposed of after the final report is completed. In detritus contaminated samples, individual species abundances were multiplied by the appropriate conversion factor to obtain taxon-specific dry weights per cubic meter. Average length estimates and dry weight conversion factors for common species found in the zooplankton-monitoring program were identified from the technical literature or determined in-house by the original data generators. After 1997 all biomass was determined by regression. All reporting of biomass estimate stopped in 2001

Zooplankton Species Enumeration- A Henson-Stempel counting method was used for sample enumeration for the entire monitoring period. A hierarchical counting technique was employed to obtain density estimates. This procedure consists of first counting at least 60 individuals of the most dominant forms in a small sub sample (usually 1 - 2 milliliters), followed by 5- and 10- milliliter Sub samples from which all species that had counts less than 60 in the previous sub sample are counted. From July 1984 through January 1990, the entire sample was also scanned under a dissecting microscope and larger macro zooplankton (amphipods, shrimp, fish eggs, fish larvae and juvenile fish, etc). Between January 1990 and January 1998, the scanning of the entire sample for larger macro zooplankton (amphipods, shrimp, etc.) was discontinued. From January 1998 to September 2002, the scanning for Macro-zooplankton was reinstated. In addition, all samples, after the standard hierarchical counting technique, were filtered through an 850-micrometer sieve and mesozooplankton that were retained in the 850-micrometer sieve not previously identified in the sub samples and/or macro zooplankton were counted and identified.
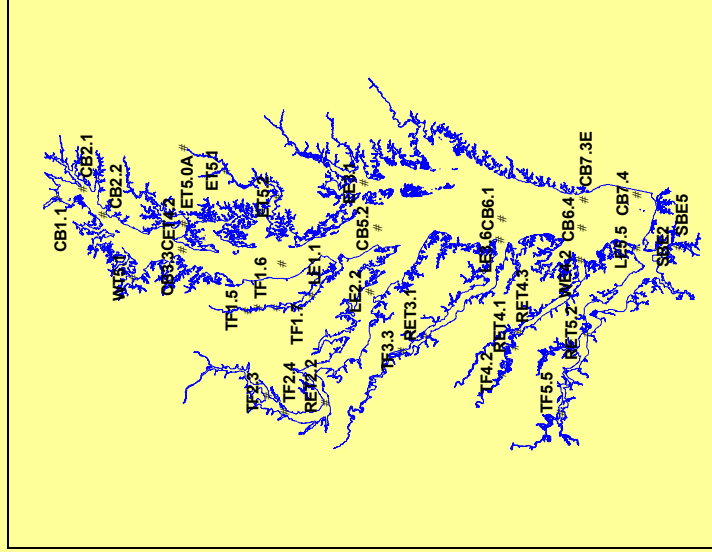


Figure 1. Historic Mesozooplankton Monitoring Station

**All Data On The Web At www.chesapeakebay.net**

# Overview of Previous Chesapeake Bay Monitoring Programs

## Virginia Mesozooplankton Survey

**The Program:** Data were collected at fixed sampling stations in the lower mainstem since July 1985(CB6.1, CB6.4, CB7.3E, CB7.4, LE3.6, LE5.5, WE4.2), at tributary stations since July 1986 (LE3.6, LE5.5, RET3.1, RET4.1, RET4.3, RET5.2, TF3.3, TF5.5) and in the Elizabeth River (SBE2, SBE5) since January 1989. Sampling at Elizabeth River station SBE2 was discontinued in December 1995. Measurements made as part of this survey include taxonomic identifications of mesozooplankton species (>202 microns) to the lowest practical taxonomic level. Biomass determinations were performed sporadically from 1985-1997 and discontinued in 1998. Measurements of gelatinous zooplankton counts and biovolumes began in 1996. All Sampling for mesozooplankton ended in November 2002.

**The Protocol:** Samples were collected with paired 202-micron mesh, 0.5 m diameter, 2 m long plankton nets each fitted with a calibrated flow meter. Nets were towed in a double-oblique pattern from bottom to surface for approximately five minutes. Samples were decanted and preserved in formaldehyde. Samples collected at tributary stations were also stained with Rose Bengal to facilitate organism identification. In the event that gelatinous zooplankton is visible in the nets, total volume is determined for the mesoglea after straining from the normal plankton sample.

Gelatinous Zooplankton- From May 1996-September 2002, when gelatinous zooplankton were visible in the nets, total volume was determined for the mesoglea after straining from the normal plankton sample. Care will be taken to ensure that no residual plankton remains clinging to either the strainer or to the mesoglea. Percent composition of gelatinous zooplankton groups (ctenophore, moon jelly, stinging nettle) is determined in the field and Mesoglea was then discarded.





Zooplankton Biomass- From July 1985- July 1997 sporadic measurement of zooplankton of biomass was made. Ash-free dry weights were determined from detritus free samples by following the normal biomass drying and weighing procedures. Following the initial weighing, samples were placed in a muffle furnace at a temperature of 550 degrees C for 4 hours for incineration. After incineration samples were allowed to cool, and then transferred to desiccators for storage until weighing. Drying, cooling and weighing are repeated until the successive weights vary by less than 5% over a one-day interval. Exposure from the desiccators never exceeds 5 minutes.

Zooplankton Species Enumeration- From July 1985 until April 2000, the processing and analysis of the zooplankton samples were carried on by the coefficient of variation stabilizing (CVS) method. The CVS method involves the size fractionation of the samples into five size classes: 2000, 850, 600, 300, and 200 microns. This method was modified in March of 1998 to include the 75-micron size fraction. In each size class, 20-42 individuals of the dominant species were counted. From April 2000 until November 2002, a Henson-Stempel method employed for sample analysis. A hierarchical counting technique is employed to obtain density estimates for all taxa. This procedure consists of first counting at least 60 individuals of the dominant species in a 1 milliliter sub sample, followed by 5- and 10-ml samples, from which all species that had counts less than 60 in the previous sub sample were counted. After the 10-ml sub sample has been counted, the entire sample is poured through an 850-um sieve. Mesozooplankton that were retained in the 850-micrometer sieve that were not previously identified in the sub samples and/or macro zooplankton were counted and identified.

**All Data On The Web At www.chesapeakebay.net**

# Overview of Previous Chesapeake Bay Monitoring Programs

## Virginia Microzooplankton Survey

**The Program:** This survey was conducted at fixed stations in the lower Chesapeake Bay and 4 major tributaries in Virginia from January 1993-November 2002. All microzooplankton less than 202 μm in size were counted. Whole water samples were collected and enumerated to major taxonomic group. The enumerated groups included copepod nauplii, barnacle nauplii, rotifers, loricated and non-loricated ciliates, polychaete larvae, cladocerans, and sarcodinids. Sampling began as a preliminary study limited to 10 Stations in 1993 (CB6.1, CB7.4, LE5.5, RET4.3, RET5.2, SBE2, SBE5, TF4.2, TF5.5, WE4.2). After the first year, sampling was expanded to sample 14 stations with the addition of stations CB6.4, LE3.6, RET3.1, and TF3.3. Sampling at Station SBE2 was discontinued in December 1995. Station CB7.3E was sampled briefly between January and June of 1997. All Sampling for microzooplankton ended in November 2002.

**The Protocol:** Monthly composite water samples were collected by pumping collect water from 5 depths above the pycnocline into a carboy. Each carboy was mixed, and two 1-liter samples were taken and preserved with 10-ml of Lugol's solution. In the laboratory each 1-liter sample was allowed to settle for 72 hours and carefully siphoned down to a 300 ml concentrated sample, replicate samples were combined. A two-step settling and siphoning steps followed to produce first a 250-milliliter concentrate, which was next concentrated to 100-ml. This concentrate was sieved through a 73 μm mesh net to trap micro-zooplankton >73 μm which were washed into a beaker, and then placed into a settling chamber #1 for examination and counts. The filtrate was mixed and three 5ml aliquots are removed and placed in settling chamber #2, with a buffered formalin solution (20%) added to bring the total volume to 25 mls. After 5 minutes of settling, 15 mls of the upper concentrate was removed and placed in settling chamber #3. The settling chambers were allowed to settle for 24 hours, and then counts were made. The entire bottom surface of the settling chambers were scanned at 100x for chamber #1 and at 200x for chamber #2 and #3 using an inverted plankton microscope. Chamber #1 provides counts for the larger microzooplankton (>73 μm), Chamber #2 for Microzooplankton groups between 40 and 73 μm s in size, and Chamber #3 for small ciliates < 40 μm.

## Maryland Microzooplankton Survey

**The Program:** This survey collected data at fixed sampling stations in the upper Chesapeake Bay, tidal tributaries in Maryland and in the Potomac River from August 1984- September 2002. All microzooplankton between 202 and 44 μm enumerated to genus and species where possible. The enumerated groups included including copepod nauplii, rotifers and protozoans. Beginning in August 1984, composite samples were collected monthly from waters above and below the pycnocline at 16 stations (CB1.1, CB2.2, CB3.3C, CB4.3C, CB5.2, EE3.1, ET4.2, ET5.1, ET5.2, LE1.1, LE2.2, RET2.2, TF1.5, TF1.7, TF2.3, WT5.1). After June 1986, stations ET4.2 and EE3.1 were no longer sampled. In May 1992, 1993 & 1994 stations CB1.1, CB2.2, TF1.7, TF1.5, RET2.2, TF2.3, ET5.1 and ET5.2 were sampled twice to coincide with white perch and striped bass spawning periods. Additionally in April through June of 1993, 1994 & 1995 station CB2.1 was also sampled to coincide with the spawning periods. In April 1996, sampling in April, May, and June was added at stations TF2.4, TF1.6, and ET5.0. Stations CB2.2, CB2.1, TF2.3, TF2.4, RET2.2, TF1.5, TF1.6, TF1.7, ET5.1, and ET5.0 were sampled twice in April and May, again to coincide with white perch and striped bass spawning periods. Sampling at stations CB1.1 and CB5.2 was discontinued in March 1996. All sampling in November was discontinued in 1996. All sampling for microzooplankton ended in September 2002.

**The Protocol:** Composite water samples were collected by pumping 10 liters of water from 5 equidistant depths above or below the pycnocline and were filtered through a 44-μm mesh net. All samples collected in 44-μm mesh net were decanted into a jar containing buffered formaldehyde and transferred to the laboratory. This effort was then repeated to obtain a field replicate for each depth. After March 1985, replicate samples from above and below pycnocline samples were combined at each station yielding one above or below pycnocline sample. After July 1989, entire water column samples were collected for the tidal fresh and oligohaline stations (RET2.2, TF1.7, TF1.5, ET5.1, CB1.1 and CB2.2). In the laboratory, samples were mixed and a 1-ml aliquot was removed with a Stempel pipette and put into a Sedgewick-Rafter cell for enumeration with a compound microscope at 100X magnification. Numbers and species identifications were subsequently made using repeated counts on 1 ml aliquots in Sedgewick-Rafter cells until 250 organisms or 3 mls were counted. Beginning in April 1986, a small drop of concentrated Rose Bengal in formaldehyde was added to the Sedgewick-Rafter cell before adding the sample. The counting chamber was allowed to set for 10 minutes before counting.
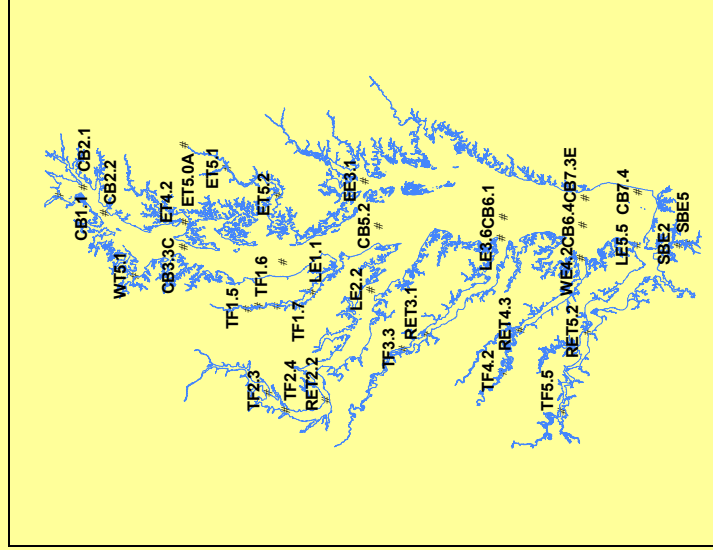


Figure 1. Historic Microzooplankton Monitoring Station

# Major Findings of the 1984 - 2002 CBP Zooplankton Monitoring Program

***Zooplankton*** status in Chesapeake Bay is generally not good, although there are improving trends in anadromous fish spawning and nursery areas. Water quality improvements in the future are expected to create more favorable habitat conditions for zooplankton communities bay-wide. Zooplankton such as copepods are food for important fish species in Chesapeake Bay, and healthier zooplankton communities will support more fish. Resource management strategies must balance the improving capacity of the Bay to support zooplankton with increasing food demands of restored fish stocks.

### *Status and trends in the upper Bay mainstem and upper tributary reaches ...*

- Significant increases in mesozooplankton abundance occurred, indicating an improving trend in the overall food base for fish in these areas (see Figure). Increases were strongest where water quality significantly improved, as in the Patuxent River.
  - ➤ These areas are seasonal spawning and nursery habitat of migratory fish, and zooplankton food is important to their recruitment and growth. Blueback herring, alewife, and shad rely on mesozooplankton food their entire lives. Striped bass, white perch, and yellow perch depend on meso- and micro zooplankton as larvae, and shift to larger prey as they grow.

- The Food Availability Index (FAI) assesses total zooplankton food for larvae of migratory fish. During 1999-2002, Patuxent and Choptank had optimal FAI. Potomac had borderline minimal/below-minimal FAI. The upper Bay, and the James, York, and Rappahannock had below-minimal FAI.
  - ➤ Despite universal improving trends, zooplankton food levels for migratory fish larvae are currently inadequate in most major spawning/nursery areas.

### *... and in the middle and lower Bay mainstem and lower tributary reaches*

- Sharp declines in mesozooplankton abundance occurred at almost all stations in these areas (see Figure). In contrast, abundances of the smaller microzooplankton increased in the mid Bay.
  - ➤ The overall zooplankton food base for important forage fish such as bay anchovy, menhaden, Atlantic silversides, and immature stages of other resident species is declining and shifting to smaller sizes.

- The Zooplankton Index of Biotic Integrity (IBI) changed from Fair in the late 1980's to Poor in 1999-2002. The IBI combines multiple indicators of zooplankton community health, such as total abundance and taxonomic composition, into a single index that can be scored.
  - ➤ The zooplankton component of the Bay's food web is not healthy and its condition is worsening.

### *Linkages to water quality and predators*

- Zooplankton status and trends are not related in a straightforward way to a single factor such as phytoplankton food quantity, or fish or jellyfish predator abundance, although the Bay mainstem declines parallel declines in water clarity.

- The 1999-2002 drought did not reverse the downward mesozooplankton trends in the mainstem. It may have reenforced the improving mesozooplankton trends at some tidal fresh stations.
  - ➤ Changes in freshwater flows are apparently not the primary cause of the trends. Possible effects of climate-related temperature changes cannot be explored because winter zooplankton monitoring data is lacking.

- Microzooplankton are closely correlated with total phytoplankton food biomass (expressed as chlorophyll *a*) while mesozooplankton are more closely correlated with specific phytoplankton groups such as diatoms.

***Types of Zooplankton***
Megazooplankton (20 cm - 2 m)
- cnidarian "true" jellyfish

Macrozooplankton (20 mm - 20 cm)
- ctenophore "comb" jellyfish
- shrimp
- amphipods
- euphausiids
- larval fish

Mesozooplankton (0.2 - 20 mm)
- copepods
- cladocerans
- benthic invertebrate larvae, or meroplankton

Microzooplankton (20 um - 0.2 mm)
- rotifers
- protozoans, such as ciliates
- copepod nauplii

➢ Phytoplankton food quality, which is influenced by water quality, appears to be an important factor affecting mesozooplankton. High phytoplankton biomass does not necessary produce high mesozooplankton abundances.
➢ Rotifer and ciliate microzooplankton are increasing in areas experiencing more frequent algal blooms.

- Ctenophore "comb" jellyfish, which are significant predators on mesozooplankton and fish larvae, have gradually increased in the middle Bay while populations of the forage fish species that eat zooplankton have been declining. Saltier conditions during the 1999-2002 drought period did not reverse these trends.
  ➢ The combined effect of increasing ctenophore and decreasing forage fish may have resulted in no significant change in overall predation pressure on mesozooplankton in the last two decades.
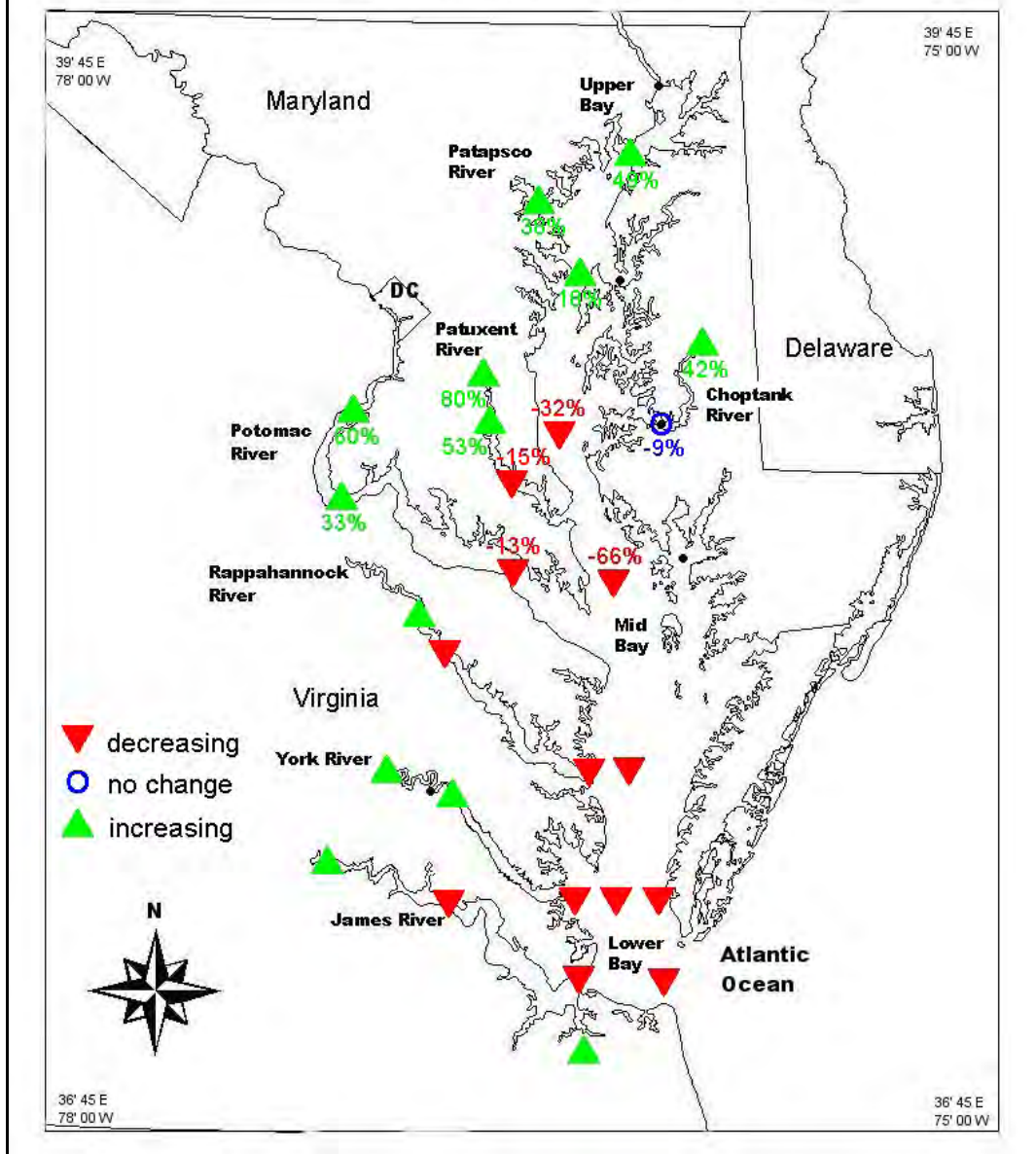


*Figure.* Comparison of mean (geometric) mesozooplankton abundances at the beginning (1984 - 1989) and end (1999 - 2002) of the previous CBP zooplankton monitoring program in Chesapeake Bay and its tidal tributaries. Declines occurred at almost all stations in the middle and lower Bay mainstem and lower tributary reaches (mesohaline and polyhaline waters), while increases occurred at all stations in the upper Bay and upper tributary reaches (tidal fresh and oligohaline waters). This pattern was becoming apparent as early as 1997, and the trends have persisted across wet and dry periods. Note: Changes in Virginia laboratory methodology during the monitoring program preclude calculation of absolute % change, but allow determination of a general trend.

Contact Mike Fritz, Living Resources Subcommittee (LRSC) Coordinator (fritz.mike@epamail.epa.gov) or Claire Buchanan, Co-Chair of the LRSC Monitoring and Modeling Workgroup (cbuchan@icprb.org) for further information.

An Index of Biotic Integrity Based on the Summer Polyhaline Zooplankton Community of the Chesapeake Bay

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Keywords: Chesapeake Bay, estuaries, eutrophication, microzooplankton, zooplankton.

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**Abstract**

A zooplankton index of biotic integrity is developed for the polyhaline segments of the Chesapeake Bay. The data come from a long-term environmental assessment program in which both zooplankton and water quality were regularly monitored. Sampling events were classified as either coming from impaired or reference (least-impaired) conditions based on water quality criteria. Seventeen zooplankton community metrics were evaluated under these criteria and nine were chosen for a composite index. These were the Simpson diversity index, and abundance of barnacle larvae, rotifers, cladocerans, copepods, total mesozooplankton, and predators. The composite index of biotic integrity correctly classified about 94% of the impaired samples and about 82% of the reference samples. Average classification efficiency was 88%. This index appears to be an effective measure of eutrophication for the Chesapeake Bay ecosystem.

# Development of a Summer Mesohaline Zooplankton Index of Biotic Integrity for the Chesapeake Bay

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**ABSTRACT:** A zooplankton Index of Biotic Integrity (IBI) that responds to eutrophication parameters was developed from existing long-term monitoring data for summer (July-September) mesohaline conditions in Chesapeake Bay. The selected metrics for the IBI are abundance based and represent diverse elements of the zooplankton community. Higher abundances of total mesozooplankton, the dominant calanoid copepod *Acartia tonsa*, and the cyclopoid copepods are associated with "least-impaired" or reference habitat conditions. Higher abundances of rotifers and balanid larvae, and higher ctenophore biovolume are associated with "impaired" or degraded habitat conditions. The IBI is composed of six metrics and correctly classifies 80% of the least-impaired sampling events and 75% of the impaired sampling events. The overall IBI is more effective at correctly characterizing environmental conditions than the individual metrics. The results suggest that nutrient and sediment load reductions will have positive impact on the summer mesohaline zooplankton community, an important food source for upper trophic levels.

# A Larval Striped Bass Habitat Index for Chesapeake Bay Tributaries

By

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**ABSTRACT**

A Larval Striped Bass Habitat Index (LSBHI) was developed to assess the suitability of annual environmental conditions in three Chesapeake Bay tributaries with the respect to recruitment of striped bass larvae. LSBHI values were calculated for the Potomac, Patuxent and Choptank Rivers for each year from 1986 through 2000, using Maryland water quality and zooplankton monitoring data from the Chesapeake Bay Program. The LSBHI is intended to provide an indicator of the quality and potential of each tributary's striped bass spawning and nursery habitat for each year of available data. The LSBHI incorporates components of the Individual Based Model (IBM) of Rose and Cowan (1993) to score annual conditions with regard to initial spawning success, early survival of eggs and pre-feeding larvae, and feeding larval growth and production as a function of zooplankton availability. The annual LSBHI for a tributary is composed of three sub-indices, each calculated for regional semi-monthly cohorts: 1) a spawning sub-index, 2) an early survival sub-index, and 3) a zooplankton (food) availability sub-index. The spawning sub-index uses temperature and salinity data, as well as literature based relationships of these parameters to striped bass spawning to determine the suitability of the habitat for a successful spawn. The early survival sub-index uses temperature to assess the habitat with respect to egg and early larval survival. The zooplankton availability sub-index is based on a comparison of the available zooplankton (a function of zooplankton abundance and predator searching ability given relative sizes of predator versus prey and water clarity), the minimum food requirement based upon metabolic relationships, and the maximum consumption possible. To independently verify the LSBHI, annual values were quantitatively compared with annual juvenile abundance measures from beach seine surveys conducted by Maryland Department of Natural Resources. Application of the LSBHI was successful for the Potomac River ($R=0.62$, $p<0.01$), Patuxent River($R=0.55$, $p=0.03$), but did not correlate well with the beach seine data for the Choptank ($R=-0.14$, $p=0.61$). Possible reasons for this lack of fit and recommendations for expanding the LSBHI to include additional factors (e.g. flow, pH) are discussed.

# Food-Web Monitoring Program

# Mesozooplankton Component of the Food-Web Monitoring Program

## Background:

Zooplankton are an important link in the food web of the Chesapeake Bay Estuary. These communities serve as trophic intermediates between the bacteria and primary producers and the higher trophic levels, which include numerous economically valuable species of shellfish and finfish. Mesozooplankton, hard-bodied zooplankton > 200 µm, prey upon phytoplankton, microzooplankton and other mesozooplankton, and conversely are preyed upon by other mesozooplankton, gelatinous zooplankton, larval fish and adult stages of planktivorous foraging fish. Plankton can be considered initial integrators of water quality and can be used as likely indicators of potential effects that water quality changes might have on higher trophic levels.

Since 1984, micro-, meso- and gelatinous zooplankton abundance and species composition have been monitored as part of the Chesapeake Bay Water Quality Monitoring Program. The objectives of the zooplankton monitoring were to characterize zooplankton communities, conduct status and trend analyses on these long-term data, and to identify pertinent associations with water quality

and living resources. The original program was designed primarily to assess changes in the zooplankton communities relative to changes in water quality conditions. The proposed zooplankton monitoring program includes a spring and summer sampling plan for microzooplankton and mesozooplankton, and summer season gelatinous zooplankton component. Specific objectives and uses of sampling data are listed on the following page.

## Proposed Sampling:

- Species composition, abundance (ml/m$^3$)
- biomass (µgC/m$^3$) estimates of mesozooplankton

Current proposed sampling will provide whole water column estimates of mesozooplankton species composition, abundance and biomass in the Bay and its tributaries during spring and summer months (March –September). Spring stations will be sampled starting in March or April on three separate cruises (start month will vary annually based on seasonal temperature; see Figure 1). Summer stations will be sampled monthly May through September (Figure 2).

# Mesozooplankton Component of the Food-Web Monitoring Program

## Potential uses:

- Characterize zooplankton communities in the tidal fresh and oligohaline regions of the Bay and tributaries during spring to estimate prey available to early life stages of important finfish species;

- Characterize zooplankton communities in the mesohaline and polyhaline reaches of the estuary in late-spring and summer to describe prey available to summer breeding fishes, juvenile fish and planktivorous forage fish;

- Detect and monitor changes in zooplankton abundance, species composition, community structure, and biomass in relation to future water quality conditions that may result from proposed management actions;

- Refine current zooplankton "bio-indicators" of water quality and Bay health in order to make this a useful management tool;

- Provide a data base that is consistent with those prepared for other study elements, thereby providing a mechanism for examining and establishing relationships between zooplankton, other trophic levels, and water quality parameters;

- Enhancement of zooplankton data for use in water quality and ecosystem models; and

- Detection and identification of invasive species of zooplankton that appear in samples
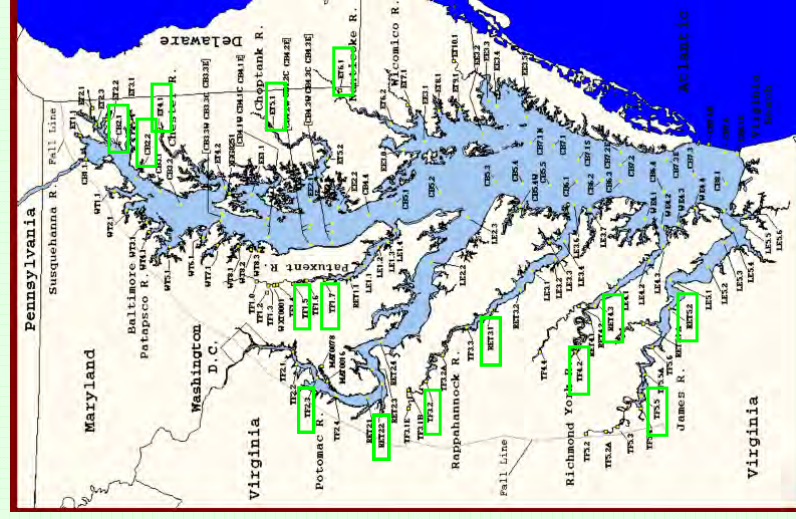


**Figure 1** Location of Maryland and Virginia spring zooplankton sampling stations
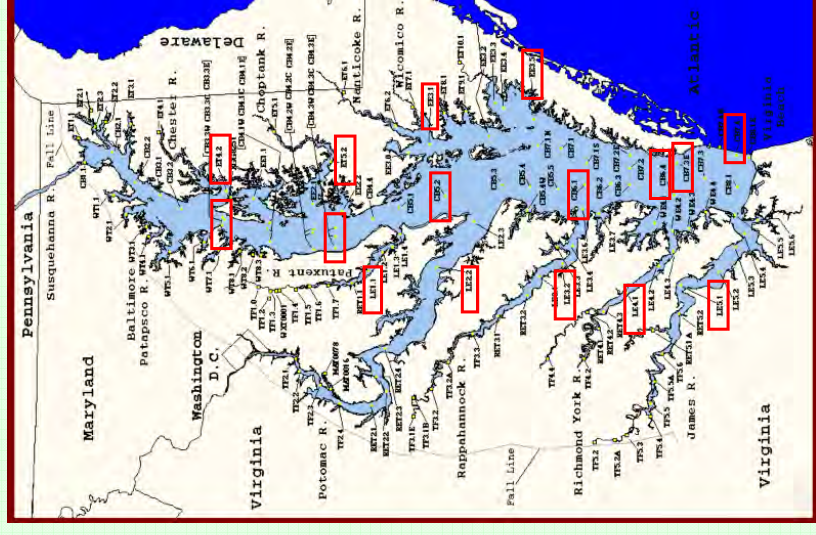


**Figure 2.** Location of Maryland and Virginia summer zooplankton sampling stations

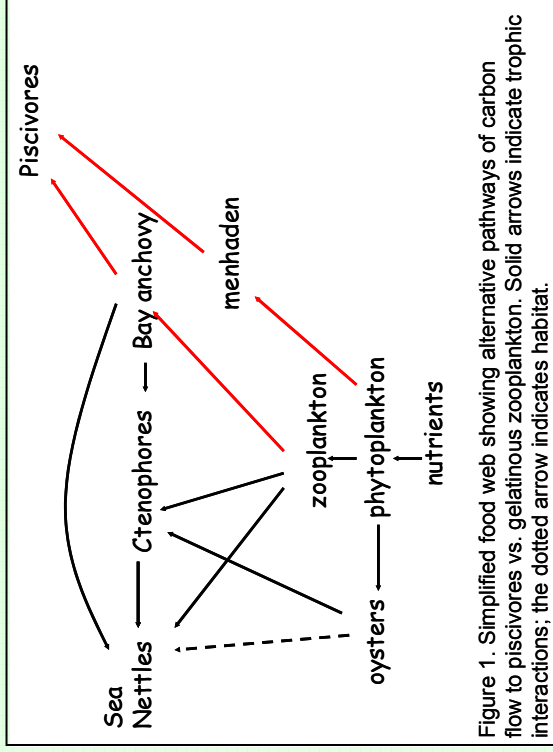# Gelatinous Zooplankton Component of the Food Web Monitoring Program



Figure 1. Simplified food web showing alternative pathways of carbon flow to piscivores vs. gelatinous zooplankton. Solid arrows indicate trophic interactions; the dotted arrow indicates habitat.
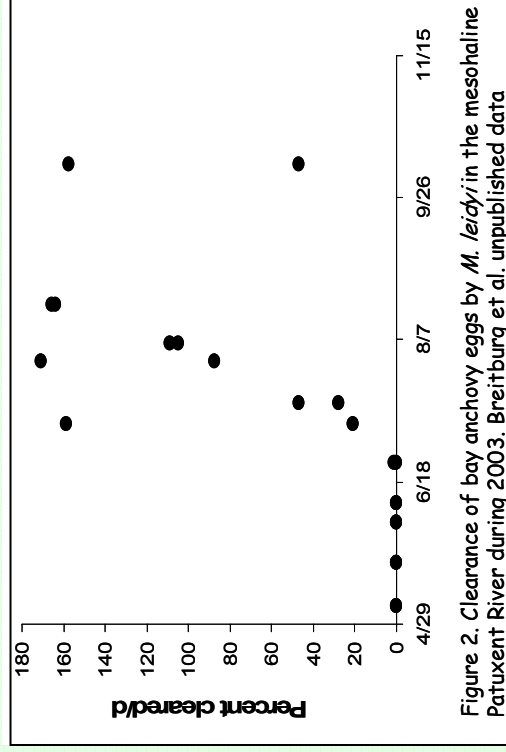


Figure 2. Clearance of bay anchovy eggs by *M. leidyi* in the mesohaline Patuxent River during 2003. Breitburg et al. unpublished data

**BACKGROUND:**

Two species of gelatinous zooplankton are dominant consumers in the Chesapeake Bay food web – the ctenophore *Mnemiopsis leidyi* and the schyphomedusa *Chrysaora quinquecirrha* (the sea nettle). Both species are important predators of zooplankton and ichthyoplankton in Cheseapeake Bay, and important competitors of other zooplanktivores. In addition, sea nettles are the primary consumer of ctenophores.

Gelatinous zooplankton abundances are highly variable, both spatially and temporally. Both ctenophores and sea nettles can sometimes reach sufficient abundances to clear 100% of zooplankton, fish eggs, and bay anchovy larvae, and 50% of oyster larvae per day, and particularly in mesohaline tributaries and subtributaries, sea nettles can consumer 100% of ctenophore biomass per day (e.g., Purcell 1992; Purcell et al. 1991, 1994, 2001; Purcell and Decker, in press; Breitburg et al. unpublished [Fig. 2, above]; Cowan and Houde 1993). Abundances of *M. leidyi* in Chesapeake Bay have generally increased in Chesapeake Bay since the mid-1980. In contrast, sea nettle abundances appear to have declined, perhaps as a result of declining oyster habitat for the sessile polyp stage (Breitburg et al., in prep).

Because of their dominant position in the trophic structure of Chesapeake Bay, food web models for use in multi-species fisheries management (e.g., EcoPath, CASM), estimates of effects of suspension feeders on Chesapeake Bay (Fulford et al., in prep.), and predictions of the relationship between water quality and living resources, will have poor predictive capabilities and are unlikely to be successful unless data on gelatinous zooplankton consumption are included.

# Gelatinous Zooplankton Component of the Food Web Monitoring Program

## PROPOSED SAMPLING:

- Mnemiopsis leidyi ctenophore biovolume (ml/m3), density (number/m3) and size distribution.
- Chrysaora quinquecirrha (sea nettle) biovolume (ml/m3), density (number/m3) and size distribution.

Proposed sampling will provide estimates of ctenophore and sea nettle biovolume, density and size distributions at oligohaline, mesohaline and polyhaline stations in tributaries and the mainstem throughout the Chesapeake Bay system during May – October. These data will allow researchers and managers to calculate ctenophore clearance rates and biomass.
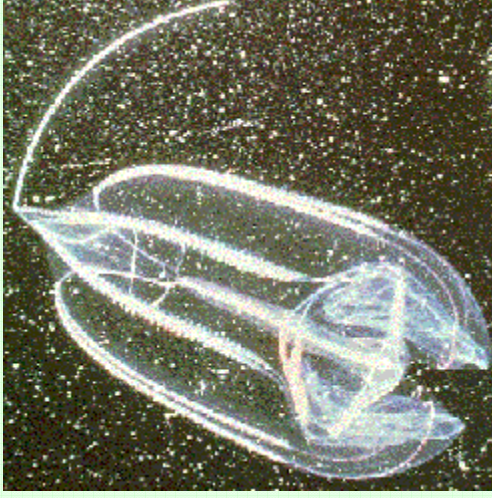
## POTENTIAL USES:

*Ecopath with Ecosim* (Multispecies fisheries management model under development by the NOAA Chesapeake Bay Office in collaboration with regional researchers.):

*Data requirement addressed:* wet weight (calculated from biovolume) of ctenophores

*Issues to consider:* EWE uses annual average wet weight/km2. The current sampling does not sample gelatinous zooplankton during Nov – April. Under current budget constraints, this problem could be resolved either statistically or by educing spatial coverage to increase temporal coverage.

*CASM* (Food web model linking phytoplankton, oysters, gelatinous zooplankton and planktivorous fishes to predicting effects of changing suspension feeder abundance on the Bay ecosystem.)



*Statistical models linking water quality and zooplankton abundance.*

*Data requirements addressed:* Biovolume, density and mean size allow development of statistical relationships and estimates of gelatinous zooplankton consumption of other organisms.

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Purcell, J. E., T. A. Shiganova, M. B. Decker, and E. D. Houde. 2001. The ctenophore *Mnemiopsis* in native and exotic habitats: U.S. estuaries versus the Black Sea basin. Hydrobiologia 451: 145-176.

Purcell, J.E. and M.B. Decker. In press. Effects of climate on predation by ctenophores and scyphomedusae on copepods in Chesapeake Bay during 1987-2000. Limnology and Oceanography.

*Data requirements addressed:* Density and mean size of ctenophores by salinity zone, mainstem vs. tributaries and upper vs. lower Bay.

*Issues to consider:* Year-round data are needed to calibrate the model for applications in which full-year simulations are desirable. In general, the issues and potential solutions are the same as for EcoPath. However, CASM can be run for specific seasons if year-round data are not available.

# Microzooplankton Component of the Food-Web Monitoring Program – Whole Water Samples

## Background:

Historically, microzooplankton samples collected as part of the Chesapeake Bay Water Quality Monitoring Program have been pumped through a 44µm mesh net, missing the fraction which is too fragile or small to be collected with a net. These organisms, often smaller than the defined size range for microzooplankton of 20-200µm, are composed primarily of ciliates and other protozoa. They are an important food source for mesozooplankton, significant grazers on phytoplankton, valuable recyclers of nutrients, and mediators of bacterial production flow through the microbial loop (Coats and Revelante, 1998). Because of their significance in these functions, they are important links in the food web structure of the Chesapeake Bay.

Brownlee and Jacobs (1987) compared netted and whole water samples taken from two stations used in the Monitoring Program and found that netted samples which retained the larger, less fragile organisms, lost approximately 95% of the total numbers and 45% of the total biomass of the microzooplankton community, either through breakage or loss through the net. Because of the low numbers found for the larger organisms (rotifers, copepod nauplii, large tintinnids and various larvae) using the whole water method, numbers of the larger organisms were overestimated. For a good representation of the entire assemblage, both methods need to be used and the results combined.

Figure 1 shows the importance of the smaller sized and fragile microzooplankton fraction to the whole community at station CB3.3C (mesohaline Bay) for spring and summer, 1998-2001. The organisms counted in the whole water samples contributed 95%-98% of the total density over the two seasons. As shown in Figure 2, the contribution to biomass was less but still important, making up 20%-65% of the total carbon, consistent with results of Brownlee and Jacobs.

Protozoans have been shown to be important prey items for zooplankton (Stoecker and Cappuzzo, 1990; Gifford, 1991). Along with rotifers, they have been found to be a good source of food for *Acartia* (Stoecker and Egloff, 1987; Gifford and Dagg, 1991). Verity (1987) discussed the idea that an estuarine ecosystem out of balance selects for gelatinous zooplankton, which can then compete with higher trophic level organisms for zooplankton as food. Relating this to findings from the monitoring program, a decrease in *Acartia* density would remove grazing pressure on its prey (rotifers and protozoans), resulting in an increase in density of these groups. Changes in the abundance of these organisms can then be seen as a signal



*Tintinnopsis sp.*



Figure 1. Mean monthly microzooplankton abundance at station CB3.3C for netted and whole water samples, 1998-2001.
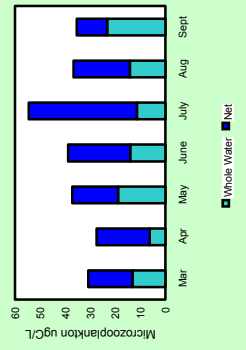


Figure 2. Mean monthly microzooplankton biomass at station CB3.3C for netted and whole water samples, 1998-2001.

# Microzooplankton Component of the Food-Web Monitoring Program – Whole Water Samples

the system is changing, a potential problem since their increase is probably a result of a decrease in their predator which supports important fish populations is the Bay.

## Proposed Sampling:

- Taxonomic identification to lowest possible level. Since the samples are only stained with Lugol's preservative, identification may be impossible. Organisms will then be grouped according to shape and size.
- Density (number/L) for species or groups, and total population.
- Biomass (μgC/L) for species or groups.

Taxonomic identifications to the lowest possible level and length and width measurements are necessary for accurate biomass estimates as well as detection of population changes. The proposed spatial and temporal sampling scheme will be the same as that described in the Mesozooplankton Metrics.

## Potential Uses:

Zooplankton Index of Biotic Integrity (developed to characterize environmental conditions at different sites in summer mesohaline Chesapeake Bay and tributaries) – ciliate data from net samples has not been included in the IBI but the

potential is there to explore the use of ciliate biomass as a metric.

Trophic Interactions (relationships to upper trophic levels and water quality, leading to data that are useful for food web models) – establishment of trophic linkages through changes in microzooplankton as an evaluation tool for changes in the system. Figure 3 illustrates an inverse relationship between *Acartia* and ciliates in the mesohaline Bay.
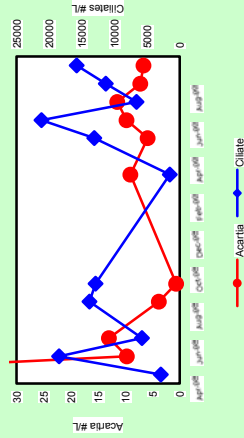


Figure 3. Ciliate and *Acartia* densities at station CB3.3C for 1998-1999.

## Food Web Models-(See Issues to consider in Gelatinous Zooplankton Metrics)

Ecopath with Ecosim (trophic mass balance model being developed to guide multispecies management and research) – requires total microzooplankton biomass for use in the model.

Zooplankton Suspension Feeder Model (a spreadsheet model to provide estimates of zooplankton impacts on phytoplankton in Chesapeake Bay) – to calculate grazing pressure of the major groups within the microzooplankton, abundances and clearance rates for these organisms are needed.

CASM (being developed as a food web model linking trophic levels to predict effects of changing suspension feeder abundance on the Bay ecosystem) – requires group specific microzooplankton biomass.

## Literature cited:

Brownlee, D.C. and F. Jacobs. 1987. Mesozooplankton and microzooplankton in the Chesapeake Bay. Pages 217-269 in: Contaminant Problems and Management of Living Chesapeake Bay Resources. The Penn. Acad. of Science.

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Gifford,D.J. and M.J. Dagg. 1991. The microzooplankton-mesozooplankton link: consumption of planktonic protozoa by the calanoid copepod *Acartia tonsa* Dana and *Neocalanus plumchrus* Murukawa. Mar. Microb. Food Webs. 5:161-177.

Stoecker, D.K. and J.M. Cappuzzo. 1990. Predation on protozoa: its importance to zooplankton. J. Plank. Res. 12:891-908.

Stoecker, D.K. and D.A.Egloff. 1987. Predation by *Acartia tonsa* Dana on planktonic ciliates and rotifers. J. Exp. Mar. Biol. Ecol. 110:53-68.

Verity, P.G. 1987. Factors driving changes in the pelagic trophic structure of estuaries, with implications for the Chesapeake Bay. Pages 35-56 in: Perspectives on the Chesapeake Bay: Recent Advances in Estuarine Sciences. Chesapeake Research Consortium Publication Number 127.

# Microzooplankton Component of the Food-Web Monitoring Program – Netted Samples
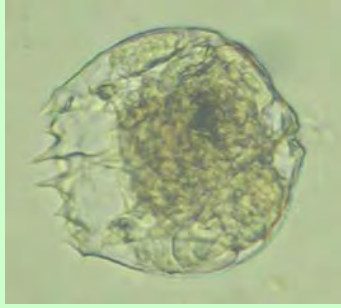
## Background:

Microzooplankton, zooplankton taxa that are <200µm in size, are dominated by ciliated protozoans, rotifers, larval stages of copepods (nauplii), as well as larval stages of various other organisms. Microzooplankton typically feed on bacteria, heterotrophic nanoflagellates, phytoplankton, and smaller microzooplankton (Sherr et al. 1986; Brownlee and Jacobs 1987). They are prey for mesozooplankton, gelatinous zooplankton, and early stages of larval fish (Stoecker and Egloff 1987; Heinbokel et al. 1988; White and Roman 1992).

From 1984 until 2002, microzooplankton samples were collected as part of the Chesapeake Bay Water Quality Monitoring Program. In Maryland, these samples were pumped through a submerged 44µm net to insure quantitative sampling of the larger organisms within this group, predominately copepod nauplii and rotifers, considered to be important links between water quality and living resources. Large tintinnine ciliates and various larvae were also represented in these samples.

Figure 1 shows the contribution of microzooplankton to zooplankton biomass in the mesohaline portion of the Bay and tributaries. Microzooplankton contributes 25%-86% of the total zooplankton biomass over the course of the year, averaging 52% during the summer months. The
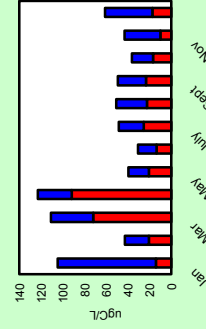
contribution is less in the tidal fresh and oligohaline portions of the system. Using the Choptank River station ET5.1 as an example, microzooplankton biomass makes up 5%-57% of the total zooplankton biomass, averaging 32% during the spring. Throughout the system, microzooplankton biomass is an important part of the total zooplankton community.

Rotifers are a little recognized group of organisms within the estuarine microzooplankton. They have been well studied in fresh water systems and have long been known as an important part of the plankton community where they are diverse and abundant. In the summer mesohaline Bay, rotifers can comprise 15%-70% of total net microzooplankton biomass. Heinbokel et al. (1988) considered them an important link in the Chesapeake Bay food web as they are consumers of smaller phytoplankton and bacteria and in turn are eaten by larger zooplankton. Stoecker and Egloff (1987) found microzooplankton an important part of the diet of the copepod *Acartia* with higher clearance rates for it than for phytoplankton.

The microzooplankton community of tidal fresh and oligohaline areas of Chesapeake Bay is dominated by rotifers and is a much more diverse assemblage than that found in mesohaline regions. As well as prey items for cyclopoid copepods, specific carnivorous rotifers, and first feeding fish, their abundance and species composition have been found to reflect trophic status (Nogrady et al. 1993).



*Acartia* nauplius



*Brachionus plicatilis*



Figure 1. Mean monthly zooplankton biomass for mesohaline region, 1985-2002.

# Microzooplankton Component of the Food-Web Monitoring Program – Netted Samples

## Proposed Sampling:

- Taxonomic identification to lowest possible level
- Density (number/L) for species, groups and total population
- Biomass (µgC/L) for each taxon

Taxonomic identifications to the lowest possible level are necessary for accurate biomass estimates as well as detection of population changes.

## Potential Uses:

Larval Striped Bass Habitat Index (model developed by Jacobs and Heimbuch to assess environmental conditions in three Bay tributaries for striped bass recruitment) – requires spring copepod nauplii and rotifer biomass at spawning stations as part of food required for larval striped bass.

Zooplankton Index of Biotic Integrity (developed by the Chesapeake Bay Water Quality Zooplankton Monitoring team to characterize environmental conditions at different sites in summer mesohaline Chesapeaky Bay and tributaries) – rotifer abundance is one of the six metrics included in the IBI used for summer mesohaline and one of the seven metrics used for the summer polyhaline IBI.

Trophic Interactions (relationships to upper trophic levels and water quality through analyses by the zooplankton monitoring team, leading to data that are useful for food web models) – establishment of trophic linkages through changes in microzooplankton as an evaluation tool for changes is the system. Figure 2 illustrates an inverse

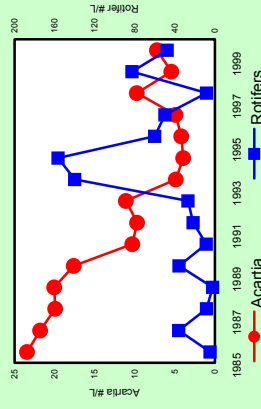relationship between *Acartia* and rotifers at a mesohaline station during the summer.



Figure 2. Mean summer rotifer and *Acartia* densities at station CB4.3C, 1985-

Food Web Models-(See Issues to consider in Gelatinous Zooplankton Metrics)

Ecopath with Ecosim (trophic mass balance model being developed to guide multispecies management and research by the NOAA Chesapeake Bay Office in conjunction with researchers from the Bay area) – requires total microzooplankton biomass for use in the model.

Zooplankton Suspension Feeder Model (ongoing work by Bundy and Jacobs to provide a spreadsheet model of estimates of zooplankton impacts on phytoplankton in Chesapeake Bay) – to calculate grazing pressure of the major groups within the microzooplankton, abundances and clearance rates for these organisms are needed.

CASM (being developed by Breitburg, Fulford, and Bartell as a food web model linking trophic levels to predict effects of changing suspension feeder

abundance on the Bay ecosystem) – requires group specific microzooplankton biomass.

Early Detection of Exotic Species Introduction – from 1991 until 2002, zebra mussel veliger larvae were monitored in the upper Bay by examination of live microzooplankton sample; suggesting no introduction throughout that period.

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Brownlee, D.C. and F. Jacobs. 1987. Mesozooplankton and microzooplankton in the Chesapeake Bay. Pages 217-269 in: Contaminant Problems and Management of Living Chesapeake Bay Resources. The Penn. Acad. of Science.

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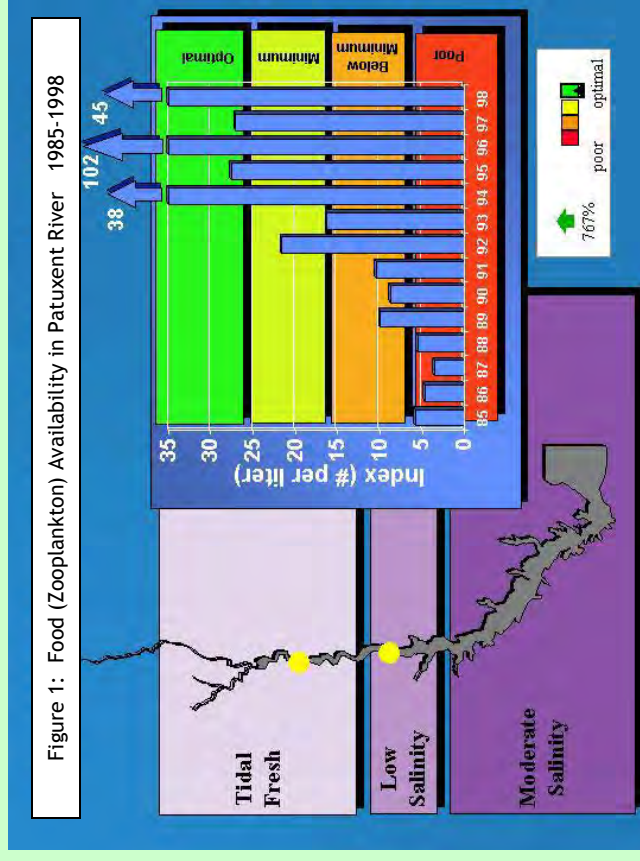
# Larval Striped Bass Food Availability Index for Chesapeake Bay

## Background:

Zooplankton are important food for larval fish (Cushing 1972; Hunter 1981). Numerous studies have documented the vital role which zooplankton serve in the survival and growth of various species of larval fish ( Houde 1978; Hunter 1981; Werner and Blaxter 1980). More specifically, this relationship has been documented for striped bass, *Morone saxatilis* and white perch, *Morone americana* in Chesapeake Bay (Beaven and Mihursky 1980; Miller 1978; Setzler-Hamilton *et al.* 1981; Takacs 1992; Tsai 1991).

## Food Availability Index:

Zooplankton were collected in Chesapeake Bay as part of the Chesapeake Bay Water Quality Monitoring Program from 1984 – 2002. One of the important management consequences of this zooplankton program was the development of an index which described the condition of available zooplankton prey for larval striped bass, the Food Availability Index (FAI) (Versar, Inc. 1999). The different food categories which were formulated for the FAI (Optimal, Minimum, Below Minimum and Poor) were based upon a number of studies which focused on this predator-prey relationship (Beaven and Mihursky 1980; Miller 1978; Setzler-Hamilton et al. 1981; Tsai 1991; Uphoff 1989). The geometric mean densities of mesozooplankton during spring (April-June) for the different categories are: Optimal - > 25·liter[-1]; Minimum – 15-25 ·liter[-1]; Below Minimum – 5 – 15 ·liter[-1]; Poor - < 5 liter[-1]. The results of the FAI for the period 1985-1998 indicated that conditions varied temporally within tributary and spatially between tributary (Versar, Inc. 1999). Overall, the Choptank River consistently met the 'Minimum' striped bass larval food requirements, while the Potomac and Patuxent Rivers and the upper Bay were, until recently, in the 'Below Minimum or Poor' food availability categories (Figure 1). In an attempt to assess the 'validity' of the FAI, it was compared to the MDDNR Striped Bass Juvenile Index, which is an index derived from the beach seine survey results in the different river systems. Based on Spearman's rank correlation test, there were significant relationships between the FAI and the Striped Bass Juvenile Index for the Choptank and Patuxent Rivers but not for the Potomac River and the upper Chesapeake Bay (Figure 2). In an attempt to improve the 'predictability' of the survival of larval striped bass for a given year-class and tributary, additional variables were incorporated into a Larval Striped Bass Habitat Index (Heimbuch et al. 2004).



Figure 1: Food (Zooplankton) Availability in Patuxent River 1985-1998

# Larval Striped Bass Food Availability Index for Chesapeake Bay



Figure 2: Relationship of the Zooplankton Food Availability Index and the Juvenile Striped Bass Index for Patuxent River, 1985-1998

( R=0.72 , p=0.004)

Striped Bass Juv. Index
Food (Zooplankton) Availability Index
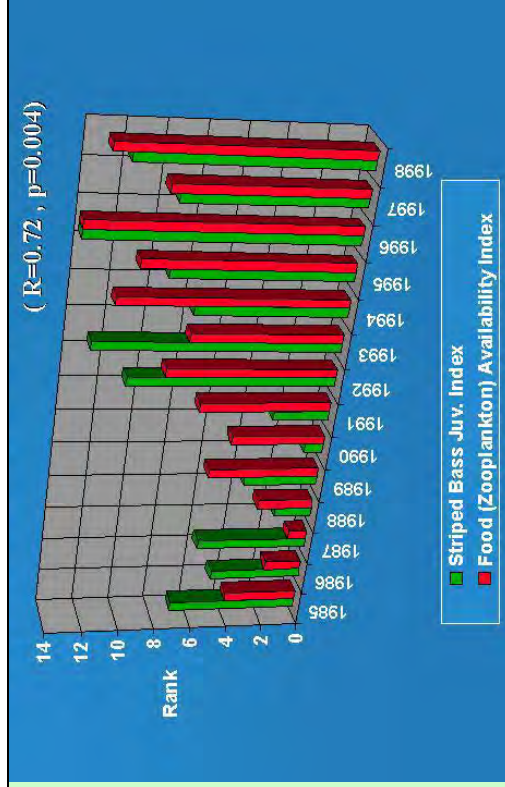
## Potential Applications:

The FAI was conceived as a measure to describe the status of mesozooplankton abundance relative to larval anadromous fish species. This measure can be used individually with some validity or could be part of a more dynamic index which assesses zooplankton or ecosystem health. Zooplankton indexes of biotic integrity (IBI) have been developed for the mesohaline and polyhaline portions of the estuary during the summer and the FAI could be one for the metrics in a spring tidal fresh IBI. Furthermore an ecosystem index is currently being explored which utilizes components from the available phytoplankton, zooplankton and benthic indexes of biotic integrity for Chesapeake Bay. The incorporation of the FAI to this ecosystem index would help bridge the gap between the lower trophic levels and important fish stocks in Chesapeake Bay. A similar index could be calculated in conjunction with gelatinous zooplankton feeding to assess food availability to other important estuarine species such as bay anchovy.

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Versar, Inc. 1999. Mesozooplankton component of the Chesapeake Bay Water Quality Monitoring Program Level I Report to Maryland Department of Natural Resources, Annapolis, MD.

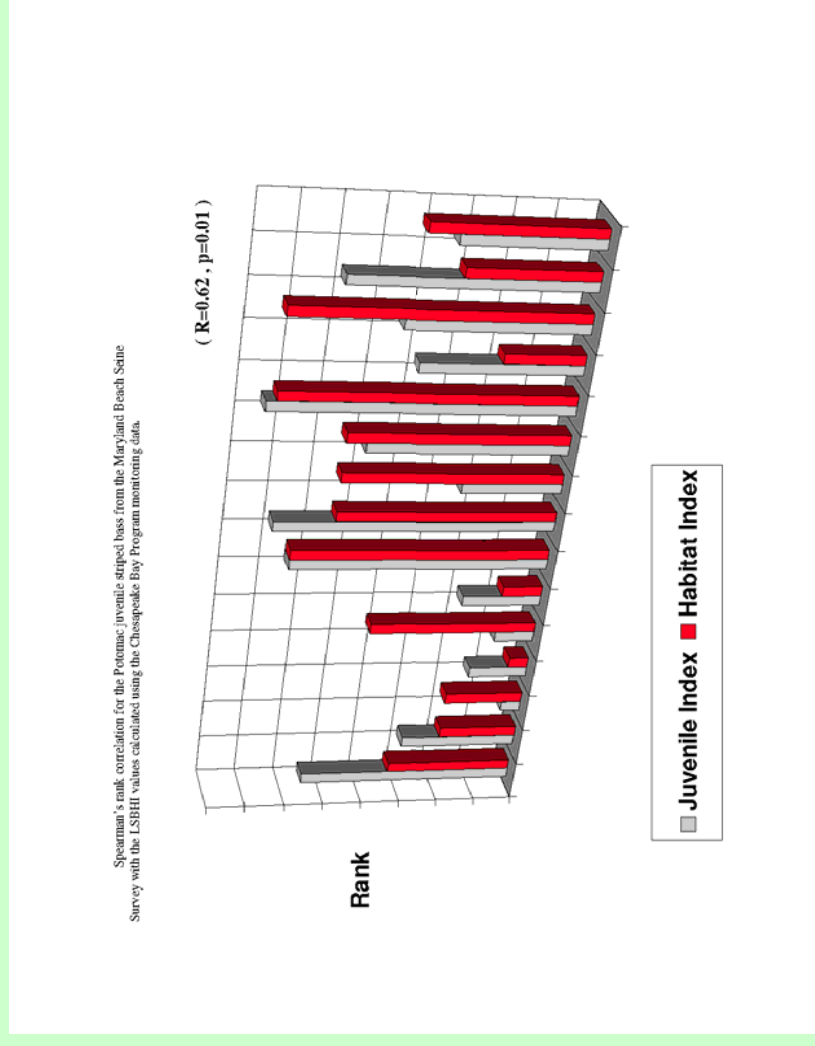# Larval Striped Bass Habitat Index for Chesapeake Bay

## Background:

The strength of a given year-class of striped bass is determined by the end of the first year of life (Houde et al. 1990; Uphoff 1989). Further evidence has indicated that a successful year-class is established in the larval stage of development (Cowan et al. 1993; Rutherford et al. 1997). A variety of laboratory and field studies have been conducted in an effort to determine the variables which are essential for success during these larval stages. Some of the parameters other than food supply which have been identified include temperature, rainfall and/or flow (Boreman 1983; Dey 1981; Kimmerer et al. 2002; Rose et al. 1986; Secor and Houde 1995; Uphoff 1989), egg supply (Olney et al. 1991) and a combination of different factors (Cowan et al. 1993).

## Larval Striped Bass Habitat Index:

The Larval Striped Bass Habitat Index (LSBHI) uses the individual based model of Rose and Cowan (1993) as a template (Heimbuch et al. 2004). This model examined the effects of various environmental conditions on individual larva to predict the impacts of those conditions at the population level. This approach is used in this context in an attempt to assess the overall suitability

Figure 1. Larval Striped Bass Habitat Index comparison to juvenile striped bass beach seine data



Spearman's rank correlation for the Potomac juvenile striped bass from the Maryland Beach Seine Survey with the LSBHI values calculated using the Chesapeake Bay Program monitoring data.

( R=0.62 , p=0.01 )

Rank

Juvenile Index  Habitat Index

of annual conditions for the successful recruitment of various tributaries' year-class of striped bass and white perch. Three sub-indices make up the LSBHI – 1) a spawning sub-index, 2) an early survival sub-index and 3) a zooplankton or food availability index. The spawning sub-index analyzes water temperature and salinity bi-weekly in order to assess spawning conditions (each bi-weekly period and specific region is assumed to represent a potential

# Larval Striped Bass Habitat Index for Chesapeake Bay

striped bass cohort). The early survival sub-index uses water temperature to estimate the survival rates of eggs and yolk-sac larvae. The zooplankton availability index uses micro- and mesozooplankton abundance and biomass in order to assess food conditions. The average bi-weekly measurements and subsequent calculations using the aforementioned parameters as well as secchi depth are subsequently used to score each sub-index. The score is arranged on a scale of 0 – 4 and the final score for the LSBHI for each bi-weekly region (cohort) reflects the minimum value of the three sub-indices. This minimum value is assumed to indicate a limiting condition. The final scores of the LSBHI were compared to the catch/haul values of the juvenile striped bass beach seine data (MDDNR). The correlation was quantified by the Spearman's rank correlation method. For the Potomac and Patuxent Rivers the correlation of the LSBHI with the beach seine values was significant R=0.62, p<0.01; R=0.55, p=0.03, respectively) (ie. Figure 1). By examining the individual sub-index scores, insight was gained into which conditions were driving the specific correlation for a given year-class and tributary. There was no significant correlation for the Choptank River data (R=0.14, p=0.61). This seems to indicate that other factors may be important for the survival of early life stages of striped bass in this tributary.

## Potential Applications:

The LSBHI was designed as a "stand-alone" model to estimate habitat suitability for striped bass and white perch. Comparisons between the LSBHI and the juvenile stripe bass surveys in the Choptank River indicate the need for refinements to the model for different tributaries. Hypothetical refinements have been suggested by Heimbuch et.al. (in review) The application of the model in the Potomac and Patuxent Rivers allowed for the assessment of biotic and abiotic conditions limiting larval survival. This understanding of the importance of various habitat conditions may assist managers in implementing new measures aimed at improving the abiotic (water clarity) and biotic (nutrients) parameters associated with healthy habitats. In addition, this type of modeling effort which utilizes micro and mesozooplankton data could be applied to other important forage fish species in Chesapeake Bay.



Image 1. One Day Old Larval Striped Bass

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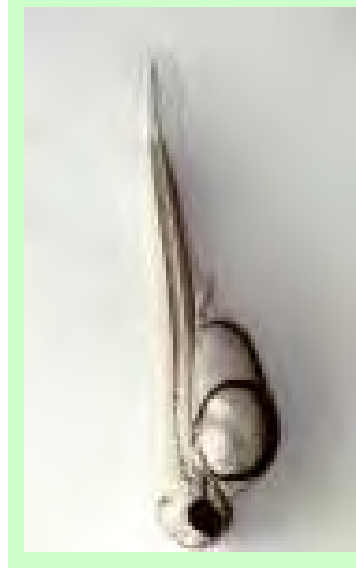
# Summer Mesohaline Zooplankton Index of Biotic Integrity for Chesapeake Bay

## Background:

A zooplankton Index of Biotic Integrity (IBI) that responds to eutrophication parameters has been developed from existing long-term monitoring data for summer (July-September) mesohaline conditions (>5 – 18 ppt) in Chesapeake Bay. Desirable levels of key physical, chemical, and phytoplankton parameters were used to delineate impaired and least-impaired (reference) habitat conditions. The IBI is composed of six metrics and correctly classifies 80% of the least-impaired sampling events and 75% of the impaired sampling events. Higher abundances of total mesozooplankton, the dominant calanoid copepod *Acartia tonsa*, and the cyclopoid copepods are associated with "least-impaired" or reference habitat conditions. Higher abundances of rotifers and balanid larvae, and higher ctenophore biovolume are associated with "impaired" or degraded habitat conditions. The index suggests that nutrient and sediment load reductions may have a positive impact on the summer mesohaline zooplankton community, an important food source for upper trophic levels.

## Index Development Process:

Samples used in the index came from 19 different stations in Chesapeake Bay (Figure 1). The possible effects of variable freshwater flow entering the Bay were controlled for by using data from stations that were mesohaline at the time of sampling, as opposed to stations whose monthly or yearly averages for salinity. Multiple criteria for identifying impaired and least-impaired habitat conditions were examined. A total of 25 least-impaired (reference), 206 marginal, and 144 impaired samples were identified when these thresholds were applied to the 375 records in the calibration data set.

Twenty-two candidate metrics were evaluated for inclusion in the IBI. Candidate metrics measured various aspects of zooplankton species abundance, species diversity, and trophic composition. Only metrics with statistically different median values (Mann Whitney U test, $p < 0.05$) were considered for the IBI.



**Figure 1**. Sampling locations and station designations of summer mesohaline stations used to develop the summer mesohaline zooplankton IBI.

# Summer Mesohaline Zooplankton Index of Biotic Integrity for Chesapeake Bay

• The distribution of each metric's values in the 25 reference samples was used to establish two criteria, or thresholds, for scoring the metric. Metric values in all of the samples were subsequently scored as a 5, 3, or 1, depending on whether they approximated, deviated slightly from, or deviated greatly from values in the reference conditions, respectively. For metrics characterized by high values in reference conditions, values below the lower threshold were scored 1. Values between the lower and upper thresholds were scored 3. Values above the upper threshold were scored 5. Scoring was reversed for metrics characterized by low values in the reference conditions

• The summer mesohaline zooplankton index for Chesapeake Bay consists of six metrics (Table 1). The multi-metric index correctly classifies 80% of the least-impaired habitat conditions and 75% of the impaired habitat conditions in the calibration data set, for an average classification efficiency of 77.5%. Box plots of the total IBI scores are shown in Figure 2. Note that the 25th percentile of the reference conditions exceeds the 75th percentile of the impaired habitats demonstrating the discriminatory power of the composite index.

• It was not possible to withhold data for an independent validation of the index due to the limited number of reference samples (*n* = 25) in the calibration data set. Therefore, a jackknife re-sampling with replacement technique was used to obtain estimates of error for the IBI metrics. In this approach, scoring percentiles for all the IBI metrics were re-computed after a single sample was temporarily removed from the calibration data set. The resulting simulated metric cutoffs were then used to re-score the original dataset and simulated validation classification efficiencies were calculated.

## Potential Applications:

The zooplankton IBI is sensitive to changes in habitat conditions and can provide beneficial information to managers for assessing ecosystem integrity of the Bay. The intermediate trophic position of zooplankton in the Chesapeake Bay food web makes this group a critical intermediary linking bottom-up and top-down ecosystem processes, and potentially useful as biological criteria for water quality standards.

Table 1. IBI component metrics and thresholds used for scoring summer mesohaline zooplankton community conditions in the Bay.

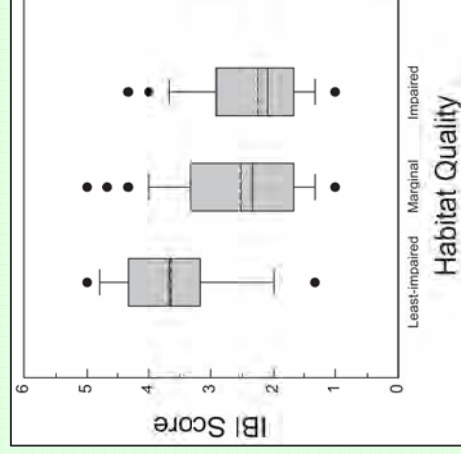| Metric | Index Scoring | | |
|---|---|---|---|
| | 1 | 3 | 5 |
| *Acartia* abundance (#/m$^3$) | < 7,837 | 7,837 – 13,861 | > 13,861 |
| Larval Barnacle abundance (#/m$^3$) | > 49.1 | 15.9 - 49.1 | < 15.9 |
| Ctenophore biovolume (ml/m$^3$) | > 6.7 | 0.68 - 6.7 | < 0.68 |
| Cyclopoid abundance (#/m$^3$) | <10.8 | 10.8 – 24.0 | > 24.0 |
| Rotifer abundance (#/L) | > 94.7 | 26.6 - 94.7 | < 26.6 |
| Total abundance (# /m$^3$) | < 8,435 | 8,435 – 14,141 | > 14,141 |



Figure 2. Box plots of overall IBI scores for Least-impaired (n=25), Marginal (n=206), and Impaired (n=144) habitat quality. Dashed line = mean; solid = median. Box boundaries = 25% & 75%. Whiskers = 10% & 90%. Dots = 5% & 95%. Median scores for Good, Mixed and Poor habitat quality = 3.67, 2.33, and 2.10, respectively.

# Summer Polyhaline Zooplankton Index of Biotic Integrity for Chesapeake Bay

## Background:

Zooplankton monitoring data associated with least-impaired water quality conditions in summer (July - September) polyhaline (>18 - 32 ppt.) waters were used to characterize a "reference community" and develop a zooplankton index of biotic integrity (Carpenter et al. Submitted). Least-impaired conditions in the summer polyhaline Chesapeake Bay were defined as waters with <0.07 mg liter$^{-1}$ dissolved inorganic nitrogen (DIN), <0.007 mg liter$^{-1}$ dissolved ortho-phosphate (PO$_4$), and Secchi depth >1.85 meters. These conditions are desirable because nitrogen and phosphorus concentrations are both low enough to limit the formation of algal blooms (Fisher and Gustafson 2003) and water column transparency is adequate for unstressed, healthy phytoplankton and submerged aquatic vegetation growth (Buchanan et al. 2005). Phytoplankton samples from the same least-impaired waters were successfully used to characterize phytoplankton reference communities (Buchanan et al. 2005) and develop seasonal phytoplankton IBIs (Lacouture et al. In prep.). The zooplankton IBI classification efficiency is 88%, which indicates the IBI is responsive to water quality conditions. The results suggest that nutrient and sediment load reductions to the Chesapeake estuary may ultimately increase the abundance of summer polyhaline mesozooplankton, an important food source for upper trophic levels.
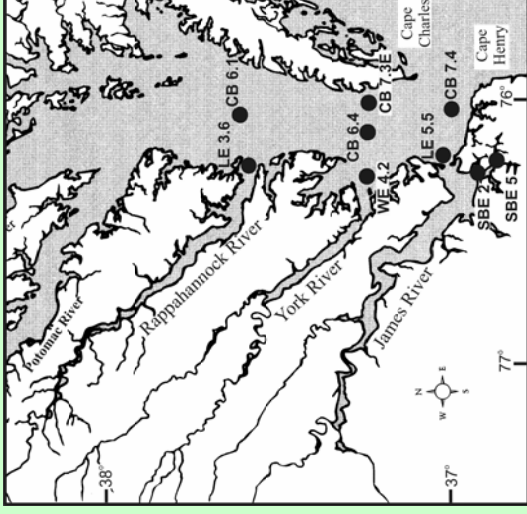
## Index Development Process:

Samples for the zooplankton calibration data set came from nine different stations in the lower Chesapeake Bay (Figure 1), and from sampling events associated with >18 ppt salinity during summer period of July - September. Only Virginia data collected between 1993 and 1997 and between 2000 and 2002 were used in order to avoid method-related problems in the data. The 1993 - 1997 samples were adjusted on the basis of a split sample study to make them fully comparable to both the 2000 - 2002 Virginia data and the Maryland data (Carpenter et al. Submitted). From a calibration data set of 158 samples, a total of 11 least-impaired (reference) were identified based on the DIN, PO$_4$, and Secchi depth criteria above. Samples failing all of the criteria (31) were identified as impaired.

Seven of the zooplankton metrics that discriminated between impaired and least-impaired water quality conditions were chosen for the IBI (Mann-Whitney U test, p < 0.05). Two of the metrics - barnacle nauplii and rotifer - had significantly higher abundances in impaired conditions. The remaining metrics - Simpson diversity and the abundances of cladocerans, copepods, predatory mesozooplankton, and total mesozooplankton - were significantly higher in least-impaired conditions. The distribution of each metric's values in the reference samples was used to establish



Figure 1. Zooplankton monitoring stations that experience polyhaline salinities (>18 ppt).

# Summary Polyhaline Zooplankton Index of Biotic Integrity for Chesapeake Bay

two criteria, or thresholds, for scoring the metric (Gibson et al. 2000). Metric values were scored as 5, 3, or 1 depending on whether they approximated, deviated slightly from, or deviated greatly from values in the reference conditions, respectively (Table 1). The scores of all seven metrics in each individual record of the calibration data set were then averaged to obtain an IBI score for that record.

The summer polyhaline zooplankton IBI scores in the calibration data set correctly classified 29 of the 31 (94%) records associated with impaired water quality and 9 of the 11 records (82%) associated with least-impaired conditions. The average classification efficiency was therefore 88%. The limited number of samples precluded withholding a subset of samples to validate the IBI. Therefore, a jackknife with replacement protocol was used to establish error estimates (Snedecor and Cochran 1989). The average error rate of the IBI score in the validation trials was 11.5%. Box plots of the total IBI scores for are shown in Figure 2. Note that the 25th percentile of the reference conditions exceeds the 75th percentile of the impaired habitats demonstrating the discriminatory power of the composite index.

## Potential Applications:

The summer polyhaline zooplankton IBI provides a sensitive measure of eutrophication impacts on the Chesapeake Bay food web, and can be used in

assessments of Chesapeake Bay ecosystem integrity.

## Literature Cited:

Buchanan, C., R. V. Lacouture, H. G. Marshall, M. Olson, and J. Johnson. 2005. Phytoplankton Reference Communities for Chesapeake Bay and its Tidal Tributaries. Estuaries 28(1). In press.

Carpenter, K., C. Buchanan, and J. M. Johnson. (Submitted.) An Index of Biotic Integrity Based on the Summer Polyhaline Zooplankton Community of the Chesapeake Bay.

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Lacouture, R.V., J. Johnson, C. Buchanan, and H. G. Marshall. (In Prep.) Phytoplankton Index of Biotic Integrity for Chesapeake Bay.

Snedecor, G. W., and W. Cochran. 1989. Statistical Methods. Ames: Iowa State University Press.

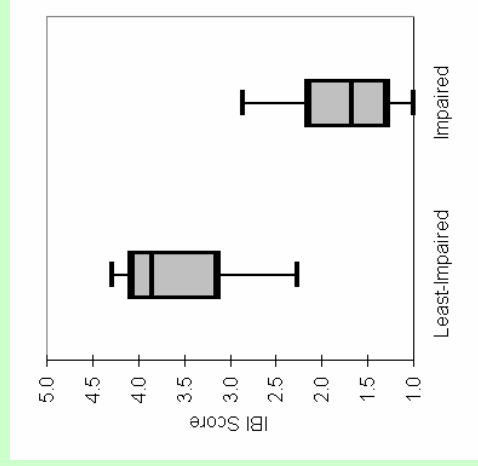| Metric | Index Scores | | |
|---|---|---|---|
| | 1 | 3 | 5 |
| Barnacle abundance (#/m$^3$) | > 45.6 | 0-45.6 | = 0 |
| Cladoceran abundance (#/m$^3$) | < 50.3 | 50.3-1034.29 | $\geq$ 1034.3 |
| Copepod abundance (#/m$^3$) | <4795.9 | 4795.9-10193.9 | $\geq$ 10194.0 |
| Predator abundance(#/m$^3$) | < 134.1 | 134.1-1706.69 | $\geq$ 1706.7 |
| Rotifer abundance (#/L) | > 14.0 | 0.9-14.0 | $\leq$ 1.0 |
| Simpson diversity | < 0.4166 | 0.4166-0.72339 | $\geq$0.7234 |
| Total Mesozooplankon abundance (#/m$^3$) | < 8265.1 | 8265.1-13993.49 | $\geq$ 13993.5 |



Figure 2 Boxplots of overall IBI scores for least impaired (n=11) and impaired (n=31) habitat quality. The 5th, 25th, 50th, 75th and 95th percentiles are shown. Median score is 3.86 in least impaired and 1.67 in impaired.

# Summer Polyhaline Zooplankton Index of Biotic Integrity for Chesapeake Bay

## Background:

Zooplankton monitoring data associated with least-impaired water quality conditions in summer (July - September) polyhaline (>18 - 32 ppt.) waters were used to characterize a "reference community" and develop a zooplankton index of biotic integrity (Carpenter et al. Submitted). Least-impaired conditions in the summer polyhaline Chesapeake Bay were defined as waters with <0.07 mg liter$^{-1}$ dissolved inorganic nitrogen (DIN), <0.007 mg liter$^{-1}$ dissolved ortho-phosphate (PO$_4$), and Secchi depth >1.85 meters. These conditions are desirable because nitrogen and phosphorus concentrations are both low enough to limit the formation of algal blooms (Fisher and Gustafson 2003) and water column transparency is adequate for unstressed, healthy phytoplankton and submerged aquatic vegetation growth (Buchanan et al. 2005). Phytoplankton samples from the same least-impaired waters were successfully used to characterize phytoplankton reference communities (Buchanan et al. 2005) and develop seasonal phytoplankton IBIs (Lacouture et al. In prep.). The zooplankton IBI classification efficiency is 88%, which indicates the IBI is responsive to water quality conditions. The results suggest that nutrient and sediment load reductions to the Chesapeake estuary may ultimately increase the abundance of summer polyhaline mesozooplankton, an important food source for upper trophic levels.

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**Figure 1. Zooplankton monitoring stations that experience polyhaline salinities (>18 ppt).**

# Summer Polyhaline Zooplankton Index of Biotic Integrity for Chesapeake Bay

two criteria, or thresholds, for scoring the metric (Gibson et al. 2000). Metric values were scored as 5, 3, or 1 depending on whether they approximated, deviated slightly from, or deviated greatly from values in the reference conditions, respectively (Table 1). The scores of all seven metrics in each individual record of the calibration data set were then averaged to obtain an IBI score for that record.

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## Potential Applications:

The summer polyhaline zooplankton IBI provides a sensitive measure of eutrophication impacts on the Chesapeake Bay food web, and can be used in

assessments of Chesapeake Bay ecosystem integrity.

## Literature Cited:

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Carpenter, K., C. Buchanan, and J. M. Johnson. (Submitted.) An Index of Biotic Integrity Based on the Summer Polyhaline Zooplankton Community of the Chesapeake Bay.

Fisher, T., and A. Gustafson. 2003. Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program Nutrient Bioassay Component. Report to Maryland Department of Natural Resources. 50 p.

Gibson, G. R., M. L. Bowman, J. Gerritsen, and B. D. Snyder. 2000. Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Technical Guidance. EPA 822-B-00-024. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Lacouture, R.V., J. Johnson, C. Buchanan, and H. G. Marshall. (In Prep.) Phytoplankton Index of Biotic Integrity for Chesapeake Bay.

Snedecor, G. W., and W. Cochran. 1989. Statistical Methods. Ames: Iowa State University Press.

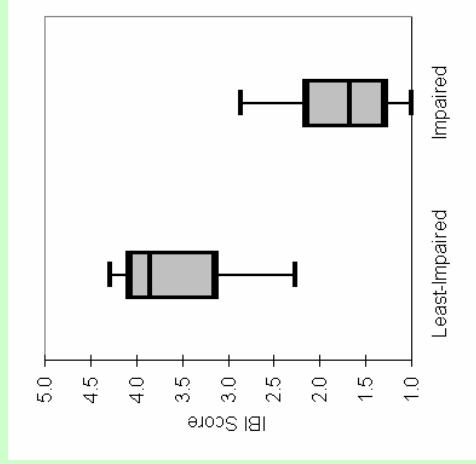| Metric | Index Scores | | |
| --- | --- | --- | --- |
| | 1 | 3 | 5 |
| Barnacle abundance (#/m³) | > 45.6 | 0-45.6 | = 0 |
| Cladoceran abundance (#/m³) | < 50.3 | 50.3-1034.29 | ≥ 1034.3 |
| Copepod abundance (#/m³) | <4795.9 | 4795.9-10193.9 | ≥ 10194.0 |
| Predator abundance(#/m³) | < 134.1 | 134.1-1706.69 | ≥ 1706.7 |
| Rotifer abundance (#/L) | > 14.0 | 0.9-14.0 | ≤ 1.0 |
| Simpson diversity | < 0.4166 | 0.4166-0.72339 | ≥0.7234 |
| Total Mesozooplankon abundance (#/m³) | < 8265.1 | 8265.1-13993.49 | ≥ 13993.5 |



Figure 2 Boxplots of overall IBI scores for least impaired (n=11) and impaired (n=31) habitat quality. The 5th, 25th, 50th, 75th and 95th percentiles are shown. Median score is 3.86 in least impaired and 1.67 in impaired.

**2005 Proposed Food Web Monitoring Stations**
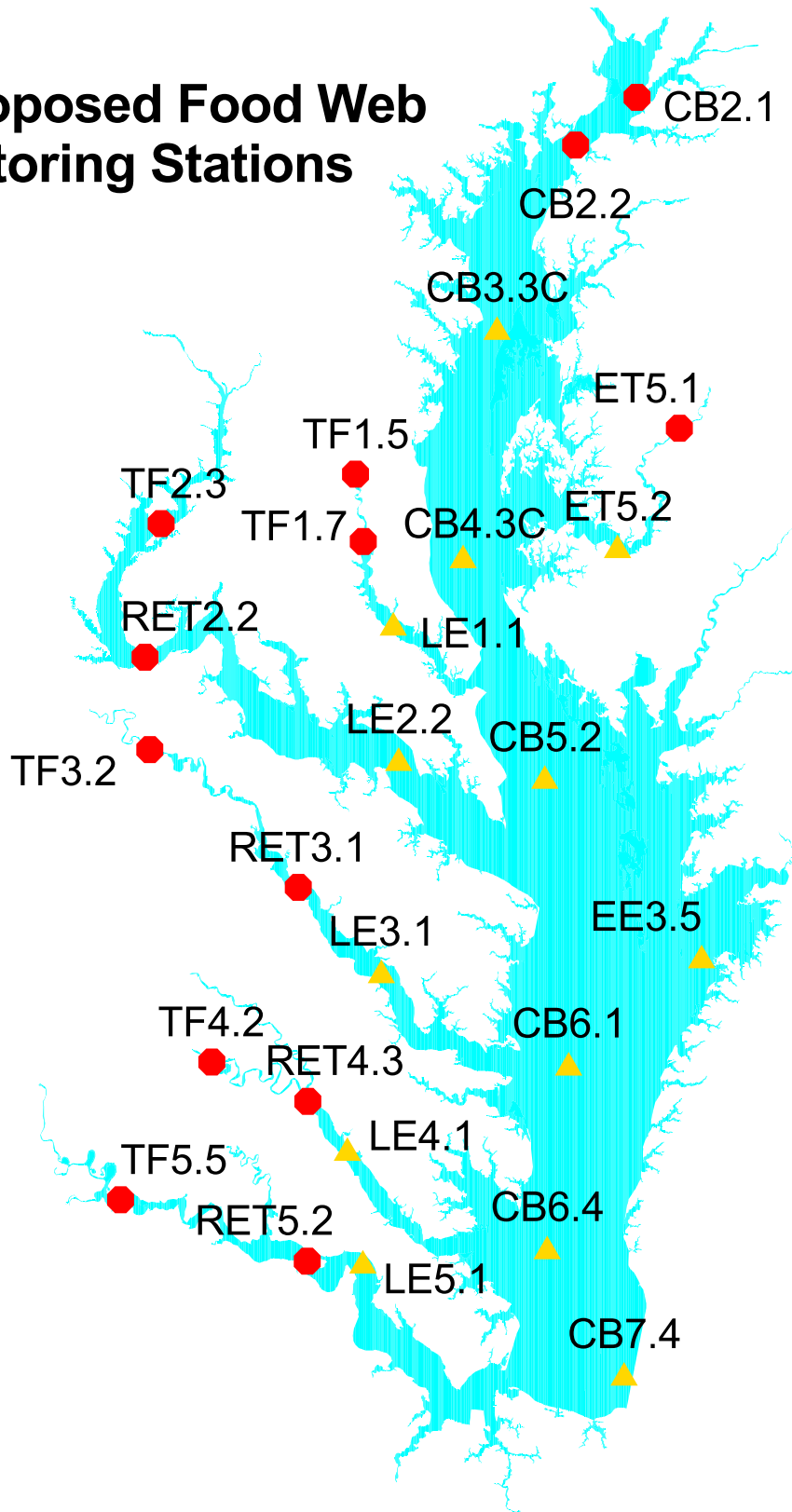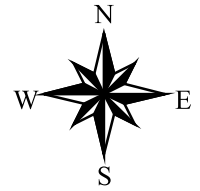
Proposed Food Web Monitoring Stations
- ● SPRING
- ▲ SUMMER
- ▬ Shoreline Med Resolution

# Background Fisheries Information

# Seasonal Distribution of FMP Fish for Chesapeake Bay With Linkages to Zooplankton

| COMMON NAME | LIFE STAGE | ZOOPLANKTON FEEDER | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEPT | OCT | NOV | DEC | NOTES | SPECIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PRIORITY MANAGEMENT SPECIES** | | | | | | | | | | | | | | | | |
| **AMERICAN SHAD** | LARVAL | * | | | | X | X | | | | | | | | Tributary spawning and nursery species. Juveniles present in to Nov in lower tribs. | **Alosa sapidissima** |
| | JUVENILES | * | | | | | X | X | X | X | X | X | | | | |
| | ADULT | | | | X | X | X | | | | | | | | | |
| **BAY ANCHOVY** | LARVAL | * | | | | X | X | X | X | X | X | | | | Resident fish, resides in deepwater in winter, in shallow areas in summer. | **Anchoa mitchilli** |
| | JUVENILES | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| | ADULT | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| **ATLANTIC MENHADEN** | LARVAL | * | X | X | X | | | | | | X | X | X | X | Tributary nursery species. Filter feeders on both phytoplankton and zooplankton. | **Brevoortia tyrannus** |
| | JUVENILES | * | | | | X | X | X | X | X | X | | | | | |
| | ADULT | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| **ATLANTIC CROAKER** | LARVAL | | | | | | | | | | | X | X | X | Bay used as nursery area. Opportunistic bottom feeders who will eat large meso and macro zooplankton. | **Micropogonias undulatus** |
| | JUVENILES | * | X | X | X | X | X | X | X | X | X | X | X | | | |
| | ADULT | * | | | | | X | X | X | X | X | X | X | | | |
| **STRIPED BASS** | LARVAL | * | | | X | X | X | | | | | | | | Juveniles present in mainstem Apr-Oct, but in tributaries year round. Anadromous spawner. | **Morone saxatilis** |
| | JUVENILES | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| | ADULT | | X | X | X | X | X | X | X | X | X | X | X | X | | |
| **OTHER MANAGED SPECIES** | | | | | | | | | | | | | | | | |
| **BLUEBACK HERRING** | LARVAL | * | | | | X | X | | | | | | | | Anadromous spawned. Juveniles present in main stem of bay from Feb-Nov. True mesozooplankton feeders. | **Alosa aestivalis** |
| | JUVENILES | * | | | | | X | X | X | X | X | X | X | | | |
| | ADULT | | | | X | X | X | X | | | | | | | | |
| **HICKORY SHAD** | LARVAL | * | | | | X | X | | | | | | | | Anadromous spawned. Prefer large macro zooplankton. | **Alosa mediocris** |
| | JUVENILES | * | | | | | X | X | X | X | X | | | | | |
| | ADULT | | | | | X | X | | | | | | | | | |
| **ALEWIFE** | LARVAL | * | | | X | X | | | | | | | | | Anadromous spawned. Juveniles present in main stem of bay from Feb-Nov. True mesozooplankton feeders. | **Alosa pseudoharengus** |
| | JUVENILES | * | | | | | X | X | X | X | X | | | | | |
| | ADULT | | | X | X | X | X | | | | | | | | | |
| **STRIPED ANCHOVY** | LARVAL | * | | | | | | | | | | | | | Bay used as nursery area, spawns off shore. Zooplankton feeder. | **Anchoa hepsetus** |
| | JUVENILES | * | | | X | X | X | X | X | X | X | | | | | |
| | ADULT | * | | | X | X | X | X | X | X | X | | | | | |
| **ATLANTIC HERRING** | LARVAL | | | | | | | | | | | | | | Adults present in main stem and infrequently in lower tribs. Filter feeders on phytoplankton and zooplankton. | **Clupea harengus** |
| | JUVENILES | | | | | | | | | | | | | | | |
| | ADULT | * | X | X | X | X | X | | | | | | | X | | |
| **WEAKFISH** | LARVAL | * | | | | X | X | X | X | X | | | | | Bay used as nursery area. Eat Macro zooplankton, eventually becoming piscivorous. | **Cynoscion regalis** |
| | JUVENILES | * | | | | X | X | X | X | X | X | X | X | | | |
| | ADULT | | | | | X | X | X | X | X | X | X | X | | | |
| **SPOT** | LARVAL | | X | X | X | | | | | | | | | X | Use Bay as nursery area. Juveniles feed on zooplankton eventually becoming piscivorous. | **Leiostomus xanthurus** |
| | JUVENILES | * | | | | X | X | X | X | X | X | X | X | | | |
| | ADULT | | | | | X | X | X | X | X | X | X | X | | | |
| **ATLANTIC SILVERSIDE** | LARVAL | * | | | | X | X | X | X | X | | | | | Valuable forage fish for piscivores. Prefers copepods and mysids. | **Menidia menidia** |
| | JUVENILES | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| | ADULT | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| **WHITE PERCH** | LARVAL | * | | | | X | X | X | X | | | | | | Resident fish, resides in deepwater in winter, in shallow areas in summer. | **Morone americana** |
| | JUVENILES | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| | ADULT | | X | X | X | X | X | X | X | X | X | X | X | X | | |
| **STRIPED BASS** | LARVAL | * | | | | X | X | X | | | | | | | Juveniles present in mainstem Apr-Oct, but in tributaries year round. Anadromous spawner. | **Morone saxatilis** |
| | JUVENILES | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| | ADULT | | X | X | X | X | X | X | X | X | X | X | X | X | | |
| **YELLOW PERCH** | LARVAL | * | | | X | X | | | | | | | | | Resident fish eat macro zooplankton. | **Perca flavescens** |
| | JUVENILES | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| | ADULT | * | X | X | X | X | X | X | X | X | X | X | X | X | | |
| **BLACK DRUM** | LARVAL | * | | | | X | X | X | | | | | | | Larvae noted to suffer heavy predation by gelatinous zooplankton. | **Pogonius cromis** |
| | JUVENILES | | | | | X | X | X | X | X | X | X | X | | | |
| | ADULT | | | | | X | X | X | X | X | X | X | X | | | |
| **RED DRUM** | LARVAL | | | | | | | | | | | | | | Spawn off shore in fall. Eats small to moderate sized crustaceans. | **Sciaenops ocellatus** |
| | JUVENILES | * | | | | X | X | X | X | X | X | X | X | | | |
| | ADULT | * | | | X | X | X | X | X | X | X | X | | | | |

Data compiled from
1) Distribution and Abundances of Fishes and Invertebrates in Mid-Atlantic Estuaries, NOAA, March 1994
2) Fishes of Chesapeake Bay, Murdy, Birdsong and Musick, 1997

## NOTES ON PRESENTATION OF FISH HABITAT INFORMATION

Information presented in these maps originally appeared in the document Habitat Requirements for Chesapeake Living Resources, 1991. This document included information on the life histories, ecological roles, habitat requirements, and special concerns for 31 "target species" compiled and interpreted from extensive literature by recognized experts.  Please see the source document for details on the derivation of map materials.

## NOTES ON PRESENTATION OF FISH SEINE SURVEY DATA

All data from the various beach seine surveys in the Chesapeake Bay region presented in the following maps has been converted into percent of time a species was found to be present during sampling events.  If a site was sampled 100 times during the period of record and a species was found in 50 of the 100 sampling events then the percent presence value would be 50 percent.  Data from the two MDDNR Seine surveys were taken from the 1970-2003-time period with stations visited on 50 or more occasions being used for comparison. Data from the VIMS Seine Survey was taken from the 1970-1999-time period with stations visited on 45 or more occasions being used for comparison.

## MARYLAND JUVENILE STRIPED BASS SURVEY

Juvenile indices are derived annually from sampling at 22 fixed stations within Maryland's portion of the Chesapeake Bay. Stations have been sampled continuously since 1954, with changes in some station locations. Sites are divided among four the major spawning and nursery areas in the state of Maryland: the Potomac River, the Nanticoke River and the Choptank River. A 30.5-m x 1.24-m bag-less beach seine of untreated 6.4-mm bar mesh was set by hand.  One end was held on shore.  The other was fully stretched perpendicular from the beach and swept with the current.  When depths of 1.6-m or greater were encountered, the offshore end was deployed along this depth contour.  An estimate of distance from the beach to this depth was recorded.  Replicate seine hauls, a minimum of thirty minutes apart, were taken at each site on each sample round.  Sampling is monthly, with rounds (sampling excursions) occurring during July (Round I), August (Round II), and September (Round III).

Striped bass and selected other species were separated into 0 and 1+ age groupings.  Ages were assigned from length-frequencies and verified through scale examination.  Age 0 fish were measured from a random sample of up to 30 individuals per site and round.  All other finfish were identified to species and counted. Additional data were collected at each site and sample round. These included: time of first haul, maximum distance from shore, weather, maximum depth, surface water temperature ($^{0}$C), tide stage, surface salinity (ppt), primary and secondary bottom substrates, and submerged aquatic vegetation within the sample area (ranked by quartiles).  DO, pH, conductivity, and turbidity (Secchi disk) were added in 1997.

## MARYLAND SMALL TRIBUTARY SEINE SURVEY

Each site was sampled monthly during the summer index period (July, August, and September).  This summer index period reflects the time of greatest fish species diversity and abundance in the Chesapeake Bay due to the function of the estuary as spawning and nursery habitat for anadromous, marine, and estuarine resident species. The summer period also represents the time when adverse environmental effects are most evident (i.e. hypoxic events).

Sites were sampled inshore using a 30.5m X 1.2m beach seine with 6.4mm mesh. The seine was pulled with the tide employing the quarter sweep method where one end of the seine is held on shore while the other end is extended fully perpendicular to shore and then pulled in an arc to the beach. Two seine hauls were conducted at each site with a half hour interval between to allow for repopulation of the seine area. Fish from the first seine haul were held and released after completion of the second seine haul.  Fish collected on the second pass were also released after processing. In the channel adjacent to

the seine area, fish were sampled using a 3.1m otter or box trawl with 12.8-mm stretch mesh and 50.8cm by 25.4cm doors. A single trawl was towed with the tide at two knots for five minutes.

All fish captured in the seines and trawls were identified to species, counted, and minimum and maximum lengths were recorded for each species. Age was recorded for game species and species of commercial importance. Scales were collected for these species when age determinations could not be made in the field. When field identification was not possible, specimens were retained for later laboratory evaluation. Additional data were collected at each site and sample round. These included: water temperature, pH, dissolved oxygen, conductivity, and salinity were measured with a Hydrolab Surveyor III at each site. Measurements were taken in the channel near each trawl site at bottom, mid-water and surface depths. Water clarity was measured with a Secchi disc at each site.

## VIMS SEINE SURVEY
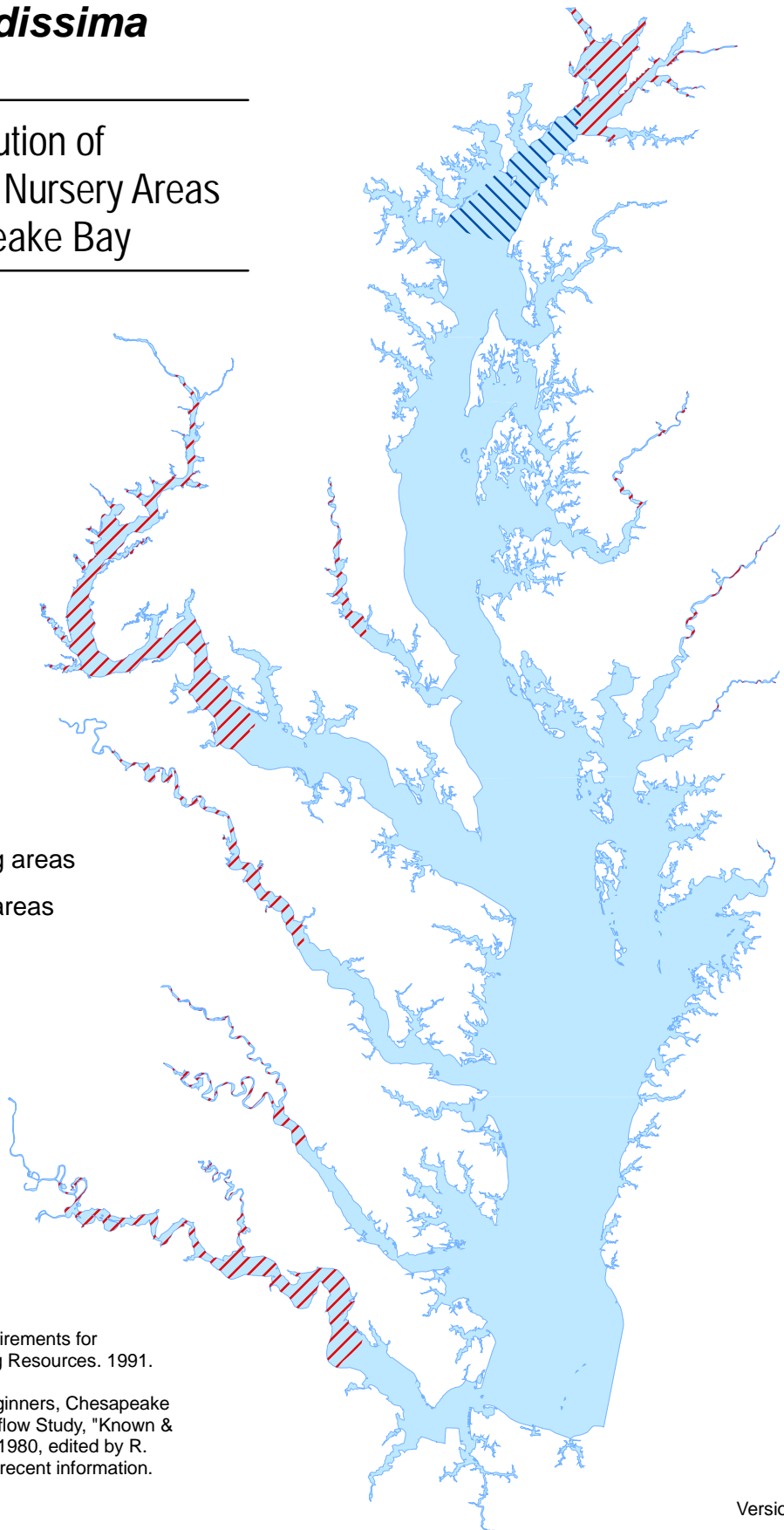
This estimation of juvenile striped bass in Virginia waters is part of a coast-wide sampling program of striped bass recruitment conducted from New England to North Carolina under the coordination of the ASMFC. Virginia's efforts started in 1967 and continued until 1973 when the program was terminated due to loss of funding. It was re-instituted in 1980. Currently, this survey samples waters from eighteen historically sampled sites (index stations) and twenty-two auxiliary sites along the shores of the James, York and Rappahannock river systems. After 1980, additional auxiliary sites were added to provide better geographic coverage and create larger within-river-system sample sizes so that trends in juvenile abundance can be meaningfully monitored on a system-by-system basis.

Field sampling is conducted during five approximately biweekly sampling periods from July through mid-September. At each station, collections are made by deploying a 100 ft. (30.5 m.) long, 4 ft. (1.22 m.) deep, 1/4 in. (0.64 cm.) bar mesh minnow seine perpendicular to the shoreline (either until the net is fully extended or a depth of approximately four feet is encountered) and then leaving the onshore brail in a fixed position while pulling the offshore end down current and back to the shore, resulting in the sweeping of a quarter circle quadrant. In the case of index stations, all fish taken during the first tow are removed from the net and held in water-filled buckets until after the second tow. All fish collected are identified and counted, and all striped bass and all individuals or a sub sample of at least 25 individuals of other species are measured to the nearest millimeter fork length (or total length if appropriate). Originally, this program used a 6 ft. x 100 ft. (2 m. x 30.5 m.) x 0.25 in. (6.4 mm.) mesh bag seine, but after comparison tows with Maryland gear, 4 ft. x 100 ft. x 0.25 in. mesh (1.2 m. x 30.5 m. x 6.4 mm.) showed virtually no statistical differences in catch, Virginia adopted the "Maryland seine". Atmospheric and station data are also recorded and include: salinity, water temperature, pH, dissolved oxygen, sampling time, tidal stage and weather conditions. All fishes captured, except those preserved for life history studies, are returned to the water at the conclusion of sampling.

# American Shad

## *Alosa sapidissima*

Habitat Distribution of
Spawning and Nursery Areas
in the Chesapeake Bay

Spawning areas
Nursery areas

Version Date 2 November 2004

# American Shad

## *Alosa sapidissima*

Percent of Time Target
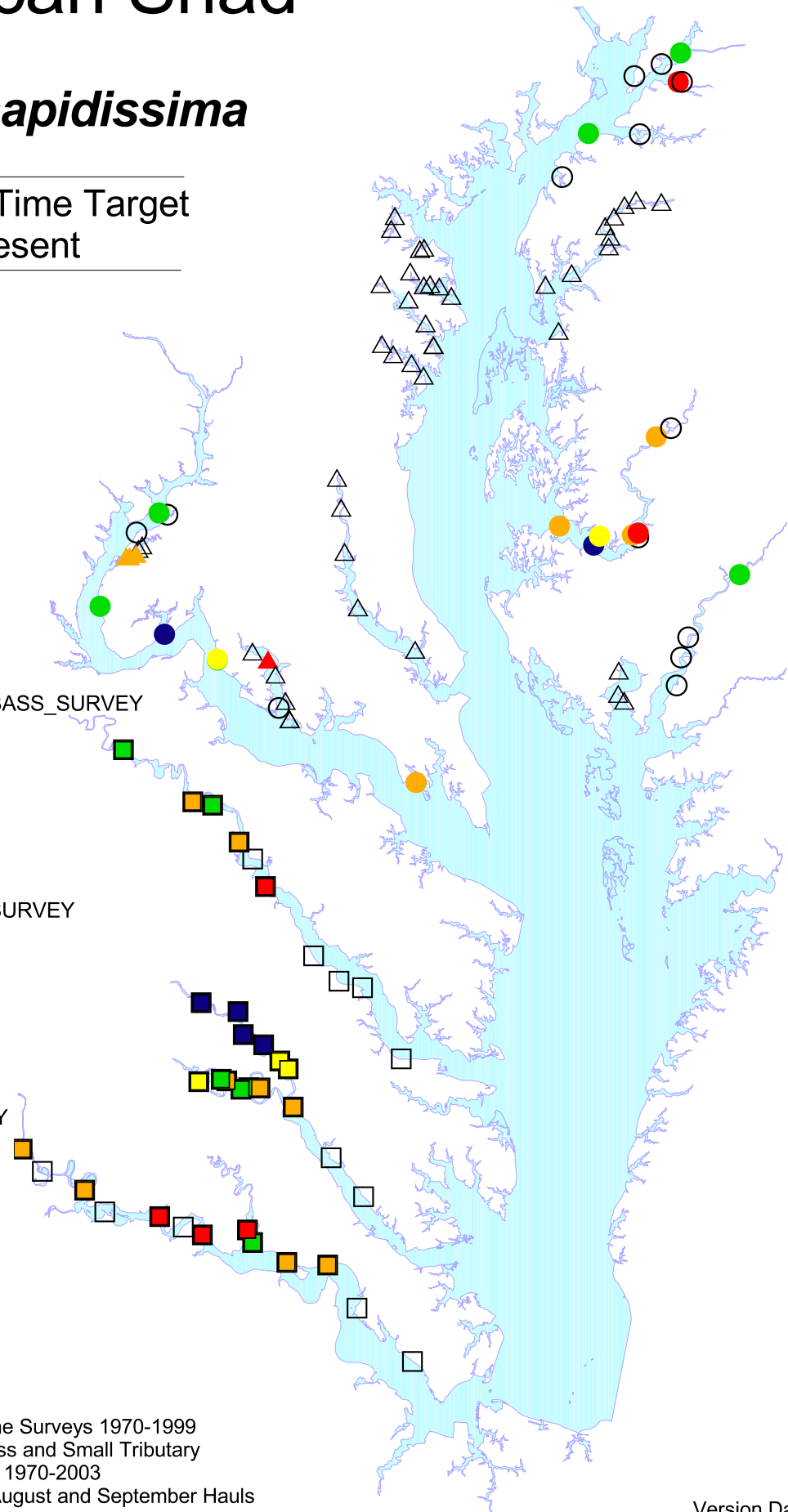Species Present

**MD_DNR_STRIPED_BASS_SURVEY**
- ○ 0
- ● 0.1 - 2
- ● 2 - 10
- ● 10.1 - 20
- ● 20.1 - 40
- ● 40.1 - 100

**MD_DNR_SM_TRIB_SURVEY**
- △ 0
- ▲ 0.1 - 2
- ▲ 2.1 - 10
- ▲ 10.1 - 20
- ▲ 20.1 - 40
- ▲ 40.1 - 100

**VIMS_SEINE_SURVEY**
- □ 0
- ■ 0.1 - 2
- ■ 2.1 - 10
- ■ 10.1 - 20
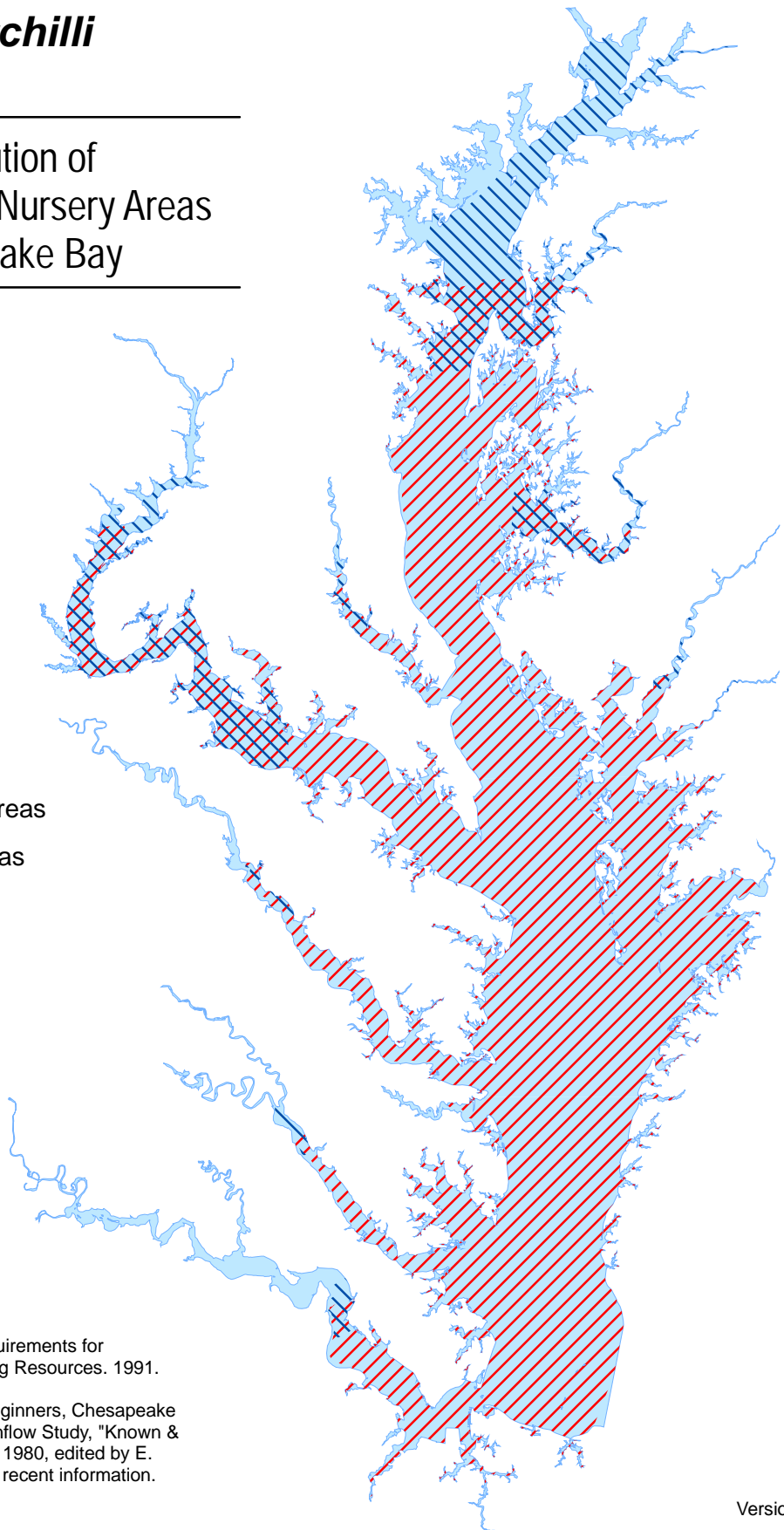- ■ 20.1 - 40
- ■ 40.1 - 100

Sources: VIMS Seine Surveys 1970-1999
MDDNR Striped Bass and Small Tributary
Seine Surveys from 1970-2003
All data from July, August and September Hauls

Version Date 27 September 2004

# Atlantic Menhaden

## *Brevoortia tyrannus*

Habitat Distribution of
Juveniles and Nursery Areas
in the Chesapeake Bay

Nursery areas

General distribution
(juveniles)

Sources: Habitat Requirements for
Chesapeake Bay Living Resources. 1991.
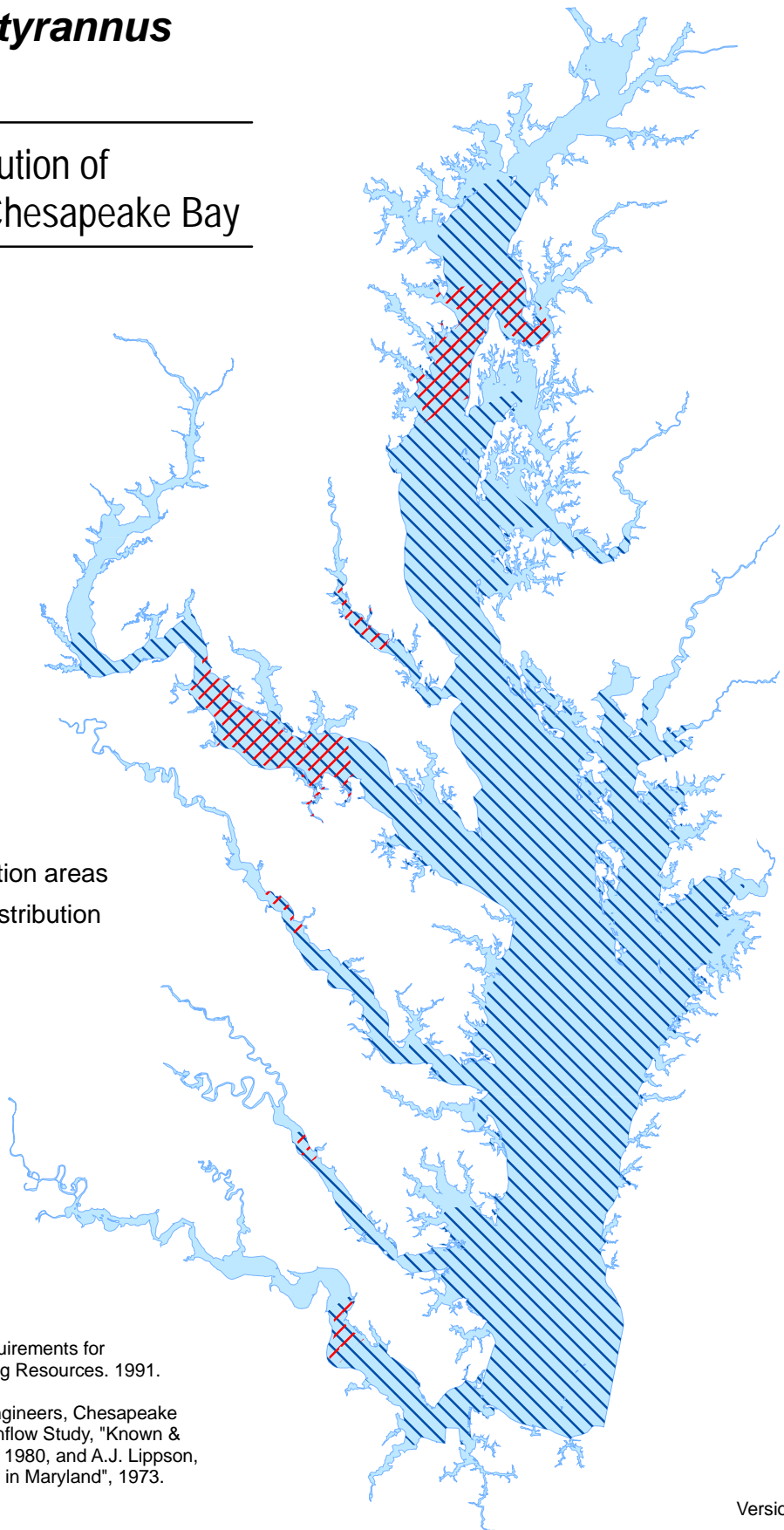
U.S. Army Corps of Engineers, Chesapeake
Bay Low Freshwater Inflow Study, "Known &
potential habitat" map, 1980, and A.J. Lippson,
"The Chesapeake Bay in Maryland", 1973.

Version Date 2 November 2004

# Atlantic Menhaden

## *Brevoortia tyrannus*

Habitat Distribution of
Adults in the Chesapeake Bay



Concentration areas
General distribution

Sources:  Habitat Requirements for
Chesapeake Bay Living Resources. 1991.

U.S. Army Corps of Engineers, Chesapeake
Bay Low Freshwater Inflow Study, "Known &
potential habitat" map, 1980, and A.J. Lippson,
"The Chesapeake Bay in Maryland", 1973.

Version Date 2 November 2004

# Menhaden

## *Brevoortia tyrannus*

Percent of Time Target
Species Present

MD_DNR_STRIPED_BASS_SURVEY
- ○ 0
- ● 0.1 - 5
- ● 5.1 - 20
- ● 20.1 - 35
- ● 35 - 50
- ● 50.1 - 100

VIMS_SEINE_SURVEY
- ☐ 0
- ■ 0.1 - 5
- ■ 5.1 - 20
- ■ 20.1 - 35
- ■ 35.1 - 50
- ■ 50.1 - 100

Sources: VIMS Seine Surveys 1970-1999
MDDNR Striped Bass Seine Surveys
from 1970-2003
All data from July, August and September Hauls

Version Date 27 September 2004

# Bay Anchovy
## *Anchoa mitchilli*

Habitat Distribution of
Spawning and Nursery Areas
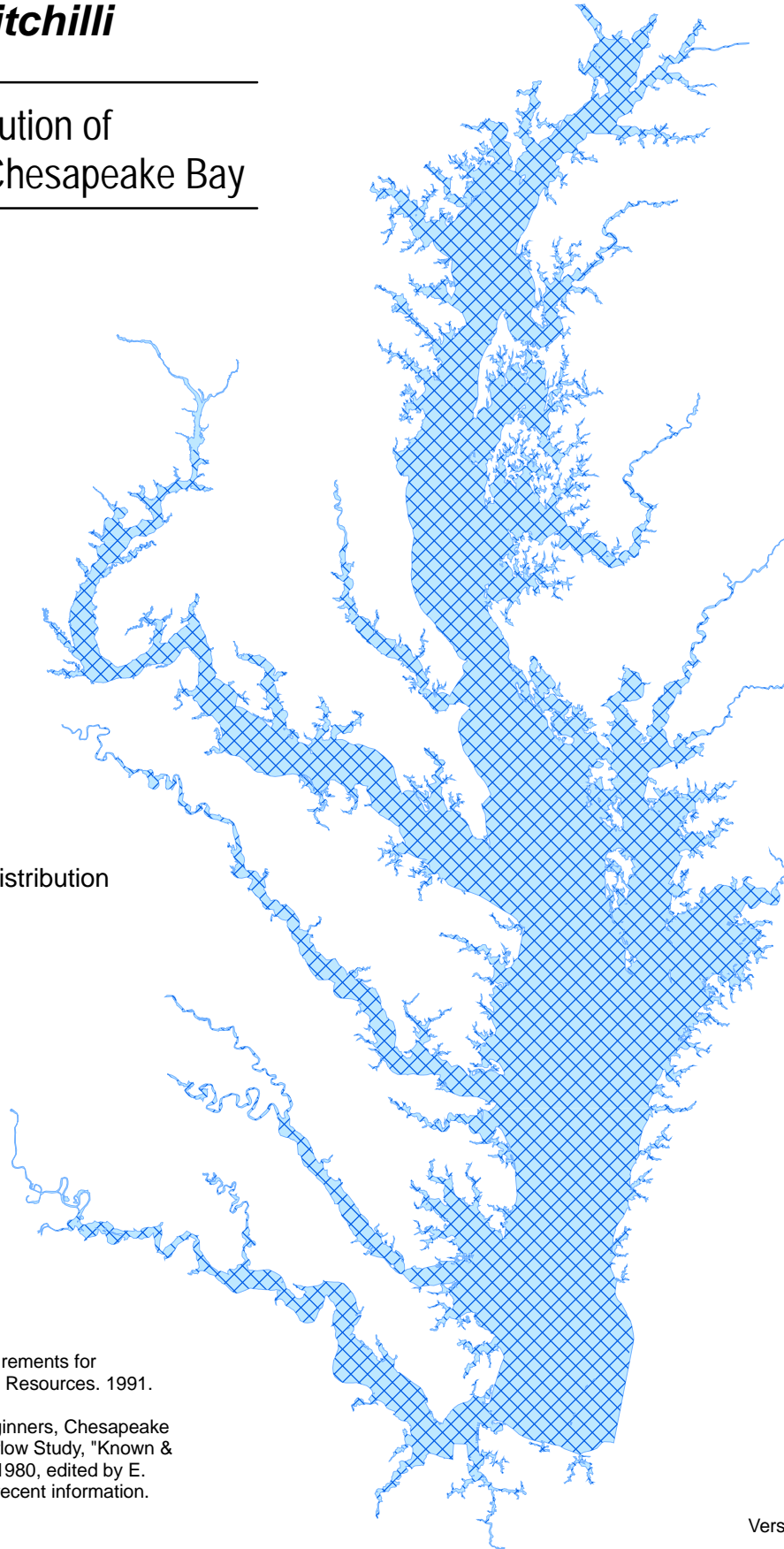in the Chesapeake Bay

Spawning areas

Nursery areas

Version Date 2 November 2004

# Bay Anchovy

## *Anchoa mitchilli*

Habitat Distribution of
Adults in the Chesapeake Bay

Potential distribution

Sources:  Habitat Requirements for
Chesapeake Bay Living Resources. 1991.

U.S. Army Corps of Enginners, Chesapeake
Bay Low Freshwater Inflow Study, "Known &
potential habitat" map, 1980, edited by E.
Houde based on more recent information.

Version Date 2 November 2004

# Bay Anchovy

## *Anchoa mitchilli*

### Percent of Time Target Species Present

MD_DNR_STRIPE_BASS_SURVEY
- ○ 0
- 🔴 0.1 - 10
- 🟠 10.1 - 20
- 🟢 20.1 - 40
- 🟡 40.1 - 60
- 🔵 60.1 - 100

VIMS_SEINE_SURVEY
- ☐ 0
- 🟥 0.1 - 10
- 🟧 10.1 - 20
- 🟩 20.1 - 40
- 🟨 40.1 - 60
- 🟦 60.1 - 100

Sources: VIMS Seine Surveys 1970-1999
MDDNR Striped Bass Seine Surveys
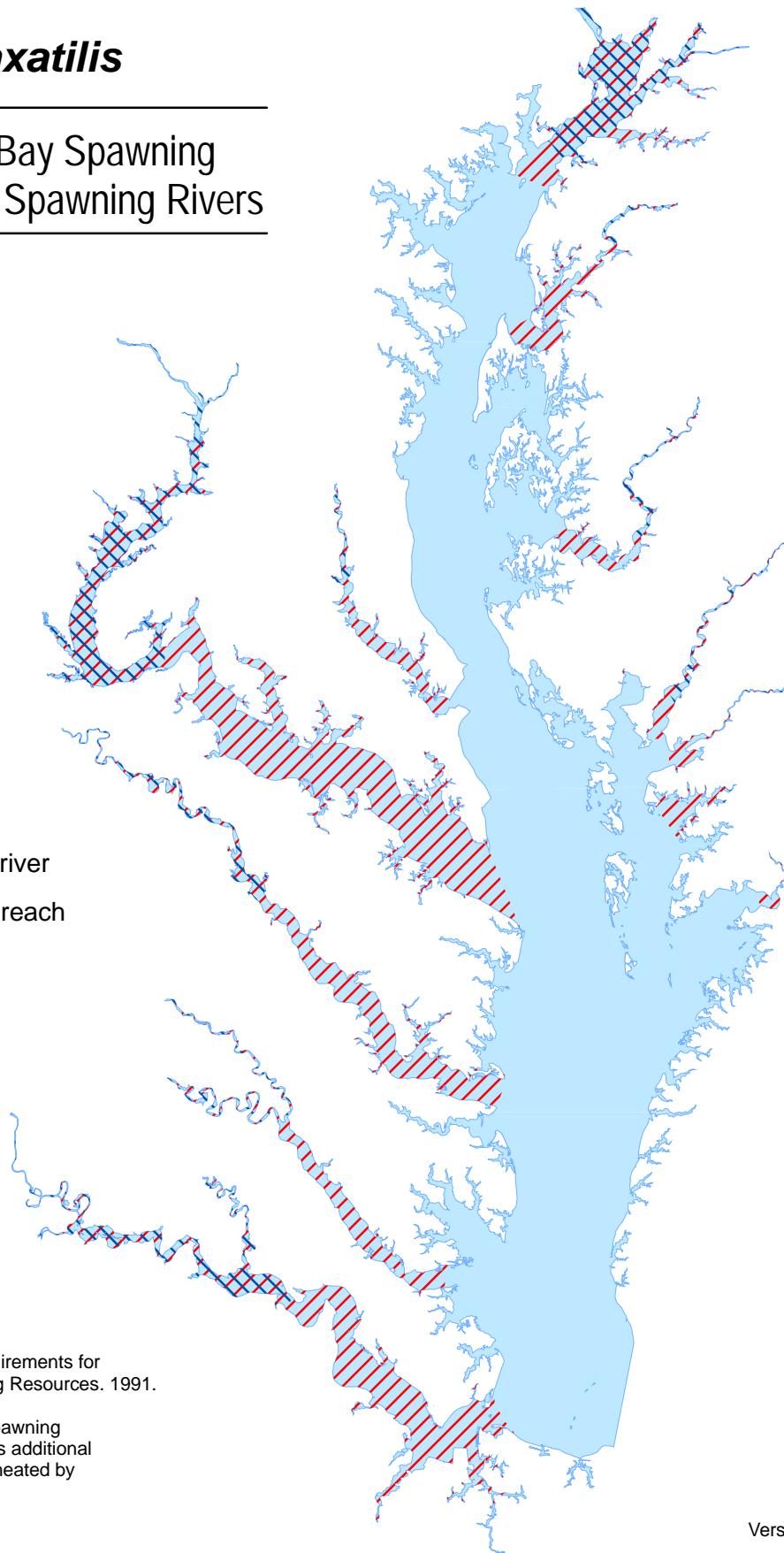from 1970-2003
All data from July, August and September Hauls

Version Date 27 September 2004

# Striped Bass

## *Morone saxatilis*

Chesapeake Bay Spawning
Reaches and Spawning Rivers

Spawning river

Spawning reach

Sources: Habitat Requirements for
Chesapeake Bay Living Resources. 1991.

Legislatively defined spawning
reaches and rivers, plus additional
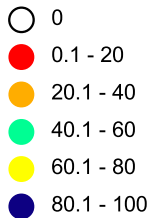spawning reaches delineated by
E. Setzler-Hamilton.
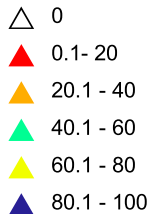
Version Date 2 November 2004

# Striped Bass

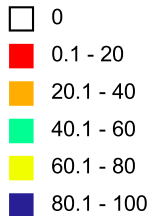## *Morone saxatilis*

Percent of Time Target
Species Present

MD_DNR_STRIPED_BASS_SURVEY
- ○ 0
- 🔴 0.1 - 20
- 🟠 20.1 - 40
- 🟢 40.1 - 60
- 🟡 60.1 - 80
- 🔵 80.1 - 100

MD_DNR_SM_TRIB_SURVEY
- △ 0
- 🔺 0.1- 20
- 🔺 20.1 - 40
- 🔺 40.1 - 60
- 🔺 60.1 - 80
- 🔺 80.1 - 100

VIMS_Seine_Survey
- ☐ 0
- 🟥 0.1 - 20
- 🟧 20.1 - 40
- 🟩 40.1 - 60
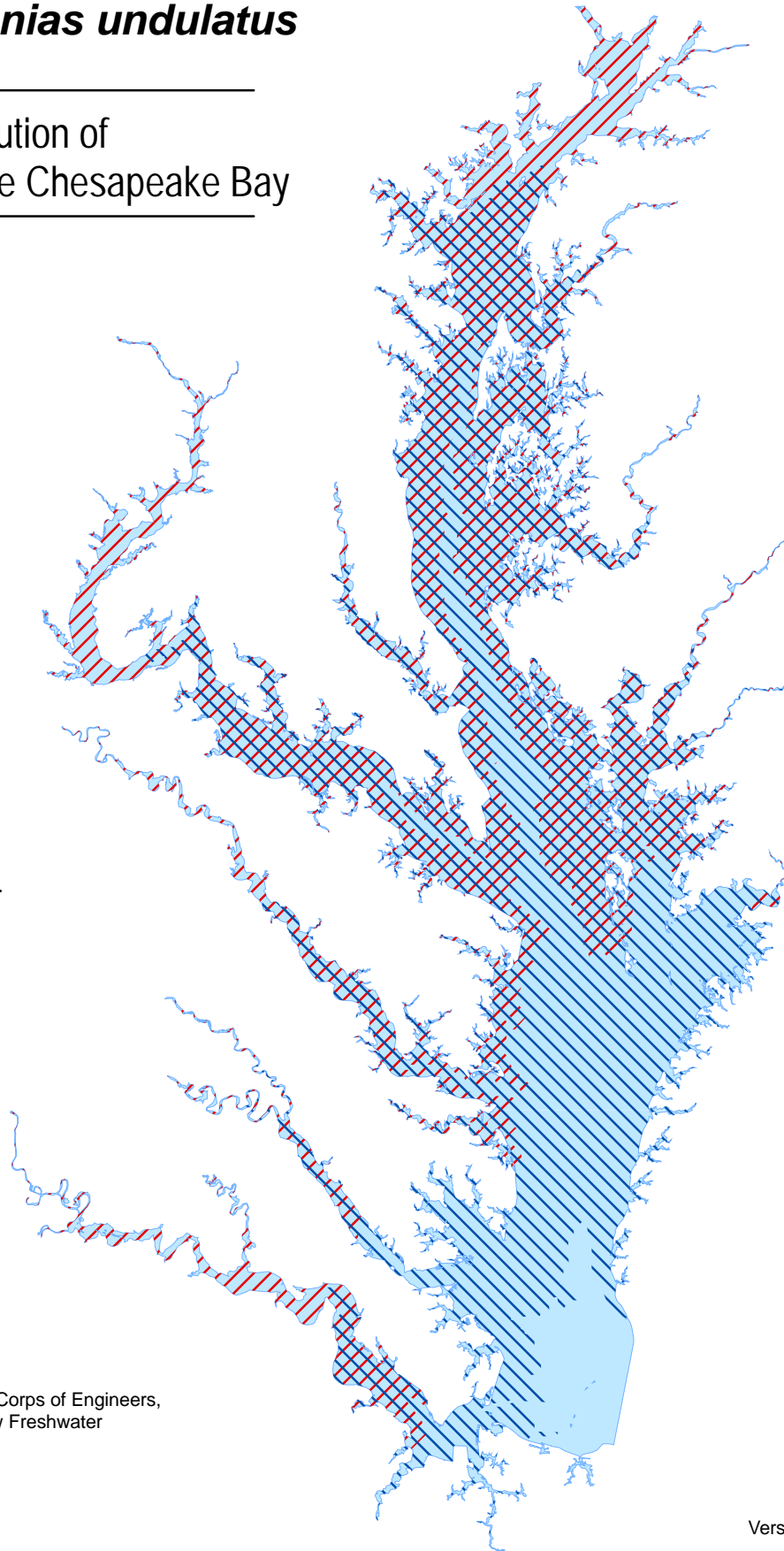- 🟨 60.1 - 80
- 🟦 80.1 - 100

Sources: VIMS Seine Surveys 1970-1999
MDDNR Striped Bass and Small Tributary
Seine Surveys from 1970-2003
All data from July, August and September Hauls

Version Date 27 September 2004

# Atlantic Croaker

## *Micropogonias undulatus*

Habitat Distribution of
Juveniles in the Chesapeake Bay

Spring

Summer



Sources:  U.S. Army Corps of Engineers,
Chesapeake Bay Low Freshwater
Inflow Study.

Version Date 2 November 2004

# Atlantic Croaker

## *Micropogonias undulatus*

Percent of Time Target
Species Present

**MD_DNR_STRIPE_BASS_SURVEY**
- ○ 0
- 🔴 0.1 - 10
- 🟠 10.1 - 20
- 🟢 20.1 - 40
- 🟡 40.1 - 50
- 🔵 50.1 - 100

**VIMS_SEINE_SURVEY**
- ☐ 0
- 🟥 0.1 - 10
- 🟧 10.1 - 20
- 🟩 20.1 - 40
- 🟨 40.1 - 50
- 🟦 50.1 - 100
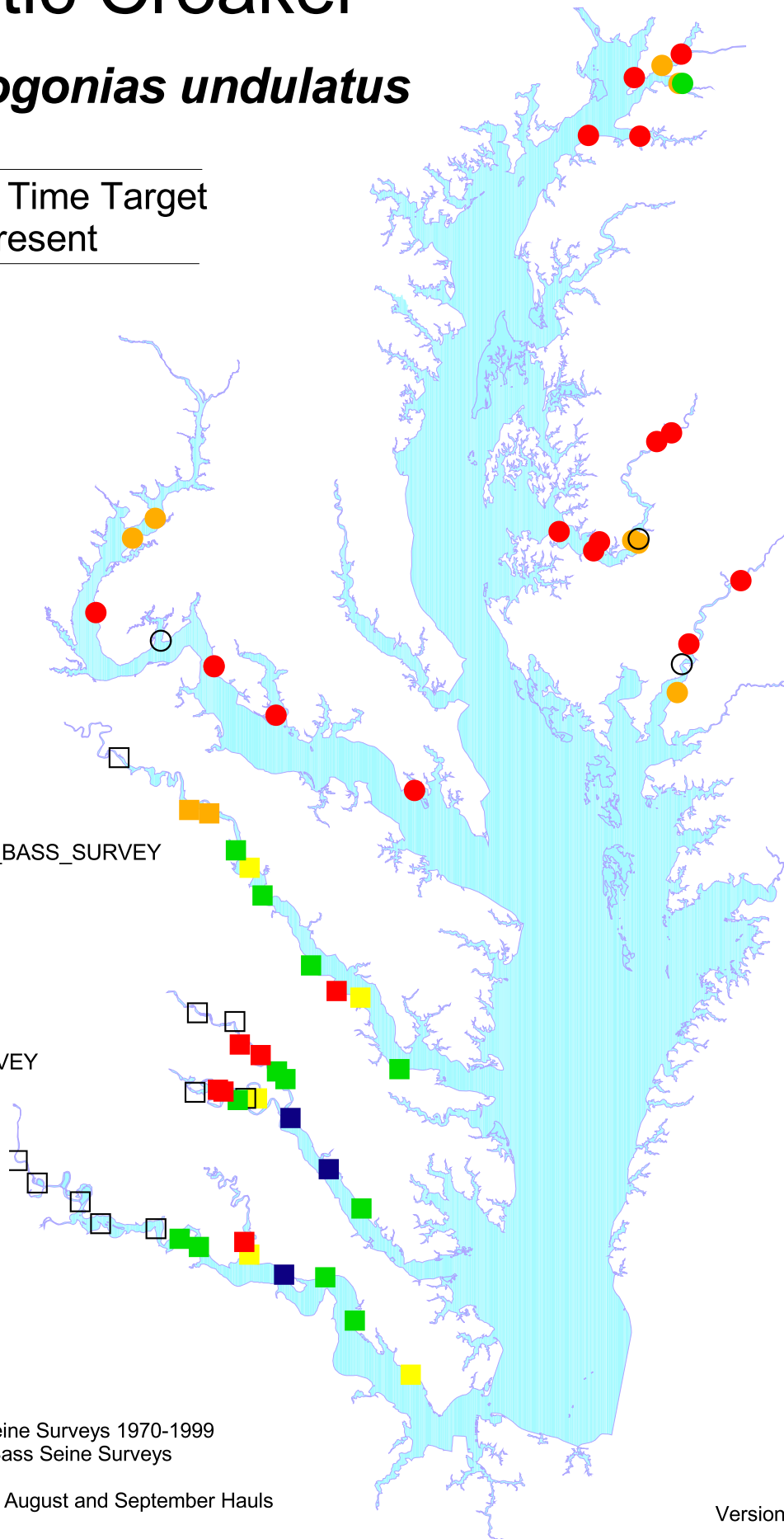
Sources: VIMS Seine Surveys 1970-1999
MDDNR Striped Bass Seine Surveys
from 1970-2003
All data from July, August and September Hauls

Version Date 27 September 2004

# Background Water Quality Information
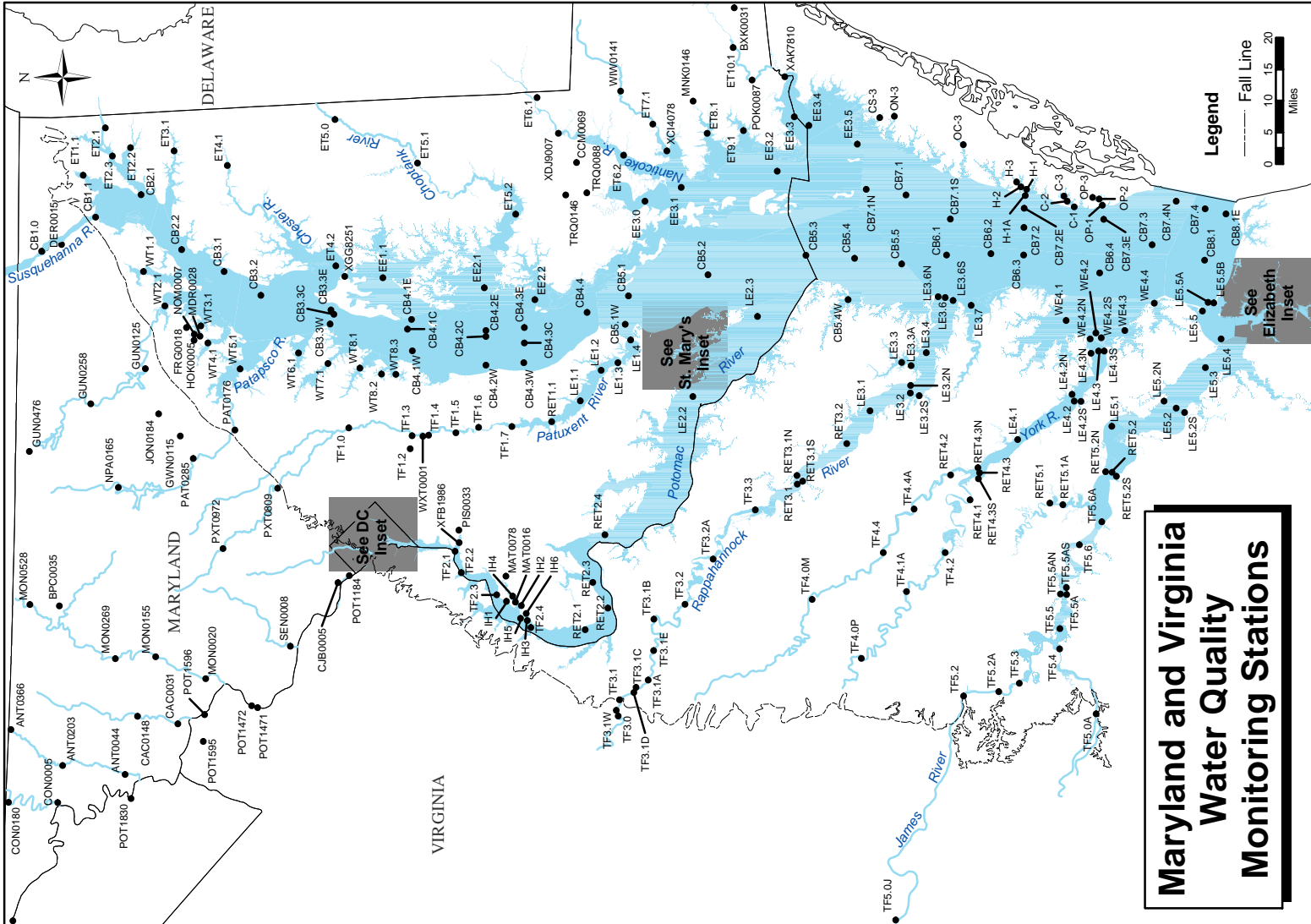
# Maryland and Virginia Water Quality Monitoring Stations
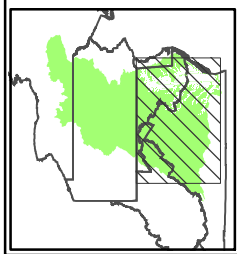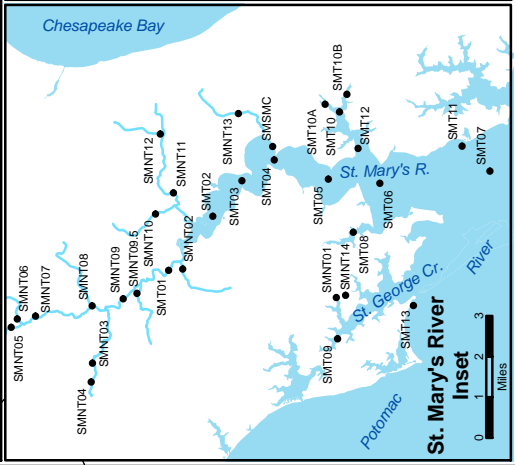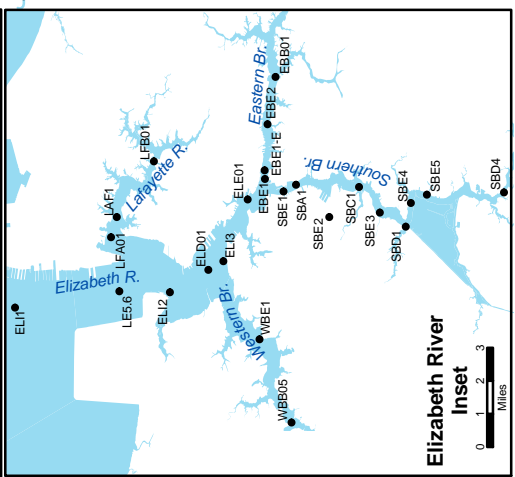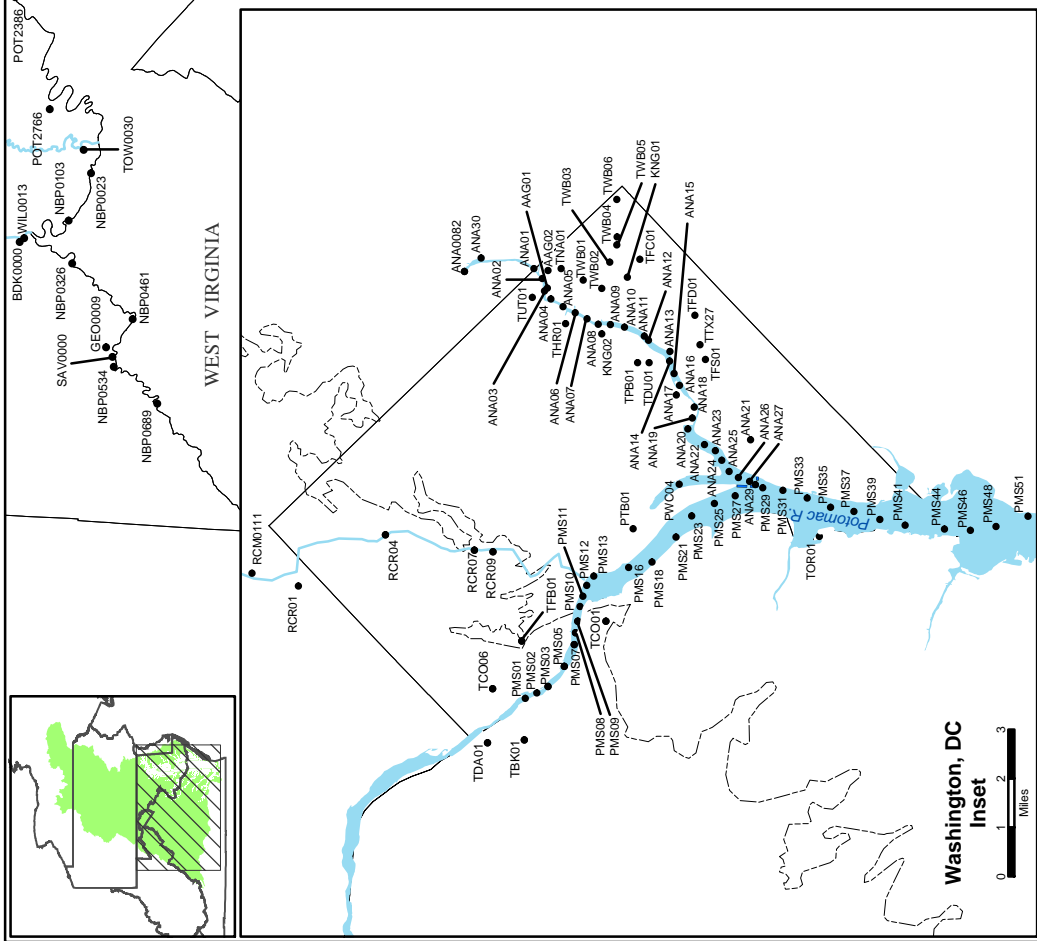
**Legend**

Fall Line

0 5 10 15 20 Miles

**Washington, DC Inset**

0 1 2 3 Miles

**Elizabeth River Inset**

0 1 2 3 Miles

**St. Mary's River Inset**

0 1 2 3 Miles

See St. Mary's Inset

See DC Inset

See Elizabeth Inset

Chesapeake Bay

MARYLAND

DELAWARE

VIRGINIA

WEST VIRGINIA

**CURRENT CHESAPEAKE BAY PROGRAM WATER QUALITY MONITORING STATIONS**

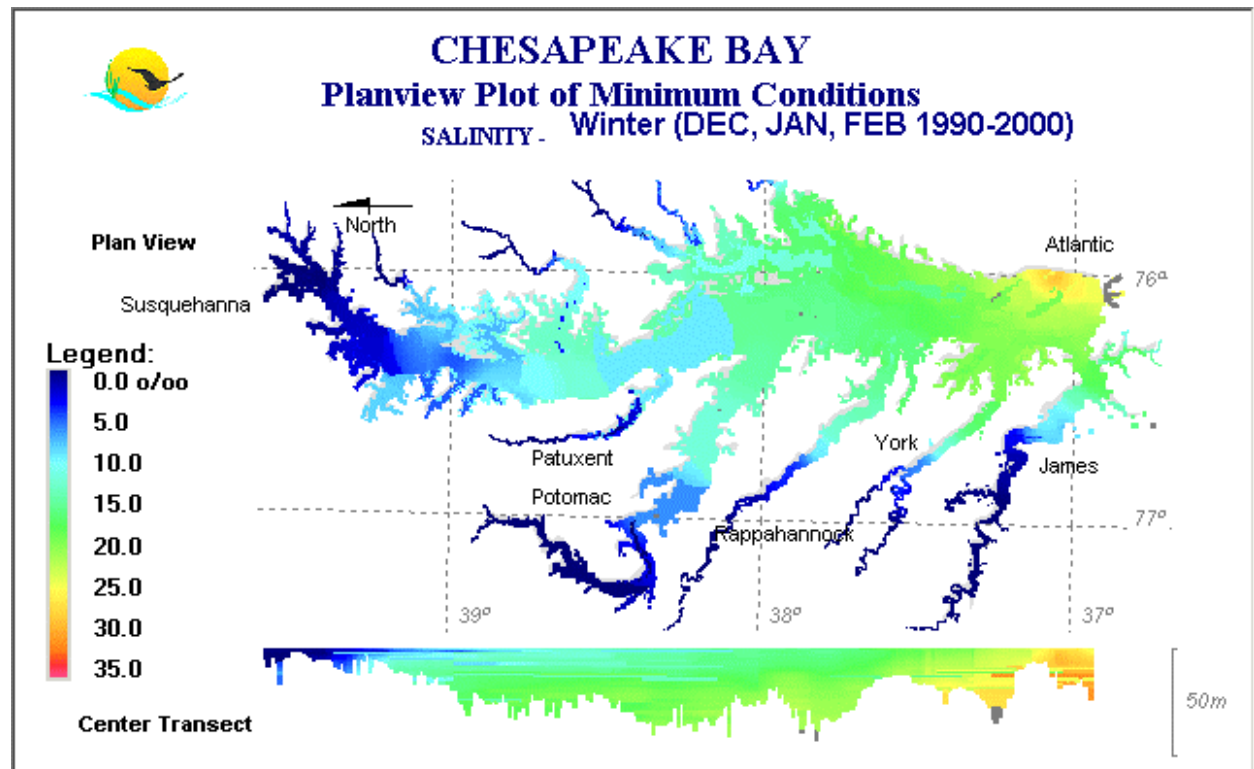| STATION | DESCRIPTION | WATER_BODY |
|---|---|---|
| CB1.1 | MOUTH OF SUSQUEHANNA RIVER; HEAD OF BAY; MID-CHANNEL | CHESAPEAKE BAY |
| CB2.1 | SOUTHWEST OF TURKEY POINT; UPPER LIMIT OF TRANSITION ZONE; MID-CHANNEL | CHESAPEAKE BAY |
| CB2.2 | WEST OF STILL POND NEAR BUOY R-34; MIDDLE OF TRANSITION ZONE; MID-CHANNEL | CHESAPEAKE BAY |
| CB3.1 | SOUTHEAST OF GUNPOWDER NECK BETWEEN BUOY 24A AND 24B; LOWER LIMIT OF TRANSITION ZONE; MID-CHANNEL | CHESAPEAKE BAY |
| CB3.2 | NORTHWEST OF SWAN POINT NEAR BUOY R-10; LOWER ESTUARINE REACH; MID-CHANNEL | CHESAPEAKE BAY |
| CB3.3C | NORTH OF BAY BRIDGE; CHARACTERIZES MID-CHANNEL | CHESAPEAKE BAY |
| CB3.3E | NORTHEAST OF BAY BRIDGE; CHARACTERIZES EASTERN SHORE | CHESAPEAKE BAY |
| CB3.3W | NORTHWEST OF BAY BRIDGE; CHARACTERIZES WESTERN SHORE | CHESAPEAKE BAY |
| CB4.1C | SOUTHWEST OF KENT POINT; CHARACTERIZES MID-CHANNEL | CHESAPEAKE BAY |
| CB4.1E | SOUTH OF KENT POINT; BOUNDARY BETWEEN CB4 AND EE1; RIVER CHANNEL | EASTERN BAY |
| CB4.1W | SOUTHEAST OF HORSESHOE POINT; CHARACTERIZES WESTERN SHORE | CHESAPEAKE BAY |
| CB4.2C | SOUTHWEST OF TILGHMAN ISLAND NEAR BUOY CR; CHARACTERIZES MID-CHANNEL | CHESAPEAKE BAY |
| CB4.2E | SOUTHWEST OF TILGHMAN ISLAND; CHARACTERIZES EASTERN SHORE | CHESAPEAKE BAY |
| CB4.2W | NORTHWEST OF PLUM POINT; CHARACTERIZES WESTERN SHORE | CHESAPEAKE BAY |
| CB4.3C | EAST OF DARES BEACH NEAR BUOY R-64; CHARACTERIZES MID-CHANNEL | CHESAPEAKE BAY |
| CB4.3E | MOUTH OF CHOPTANK RIVER; BOUNDARY BETWEEN CB4 AND EE2 | CHESAPEAKE BAY |
| CB4.3W | EAST OF DARES BEACH; CHARACTERIZES WESTERN SHORE | CHESAPEAKE BAY |
| CB4.4 | NORTHEAST OF COVE POINT; MID-CHANNEL | CHESAPEAKE BAY |
| CB5.1 | EAST OF CEDAR POINT AND PR BUOY; MID-CHANNEL | CHESAPEAKE BAY |
| CB5.1W | MID-CHANNEL BETWEEN CEDAR POINT AND COVE POINT; CHARACTERIZES LOWER ESTUARINE | CHESAPEAKE BAY |
| CB5.2 | EAST OF POINT NO POINT; MID-CHANNEL | CHESAPEAKE BAY |
| CB5.3 | NORTHEAST OF SMITH POINT AT VIRGINIA STATE LINE; MID-CHANNEL; OVERLAP STATION WITH VIRGINIA | CHESAPEAKE BAY |
| CB5.4 | CENTRAL CHESAPEAKE BAY (DEEP MAIN CHANNEL) | CHESAPEAKE BAY |
| CB5.4W | CENTRAL CHESAPEAKE BAY AT THE MOUTH OF THE GREAT WICOMICO RIVER | CHESAPEAKE BAY |
| CB5.5 | CENTRAL CHESAPEAKE BAY (MAIN CHANNEL) | CHESAPEAKE BAY |
| CB6.1 | LOWER WEST CENTRAL CHESAPEAKE BAY (MAIN CHANNEL OFF LOWER END OF THE RAPPAHANNOCK RIVER) | CHESAPEAKE BAY |
| CB6.2 | LOWER WEST CENTRAL CHESAPEAKE BAY | CHESAPEAKE BAY |
| CB6.3 | LOWER WEST CENTRAL CHESAPEAKE BAY (WOLFTRAP) | CHESAPEAKE BAY |
| CB6.4 | CENTRAL CHESAPEAKE BAY OFFSHORE FROM MOUTH OF YORK RIVER | CHESAPEAKE BAY |
| CB7.1 | LOWER EAST CENTRAL CHESAPEAKE BAY (EASTERN SHORE CHANNEL) | CHESAPEAKE BAY |
| CB7.1N | LOWER EAST CENTRAL CHESAPEAKE BAY (TANGIER SOUND CHANNEL) | CHESAPEAKE BAY |
| CB7.1S | LOWER EAST CENTRAL CHESAPEAKE BAY (EASTERN SHORE CHANNEL) | CHESAPEAKE BAY |
| CB7.2 | LOWER EAST CENTRAL CHESAPEAKE BAY (EASTERN SHORE CHANNEL) | CHESAPEAKE BAY |
| CB7.2E | LOWER EAST CENTRAL CHESAPEAKE BAY (EASTERN SHORE, SIDE CHANNEL) | CHESAPEAKE BAY |
| CB7.3 | MAINSTEM YORK SPIT CHANNEL | CHESAPEAKE BAY |
| CB7.3E | LOWER EASTERN SHORE CHANNEL AREA | CHESAPEAKE BAY |
| CB7.4 | BALTIMORE CHANNEL AT THE BAY BRIDGE/TUNNEL | CHESAPEAKE BAY |
| CB7.4N | NORTH CHANNEL AT THE BAY BRIDGE/TUNNEL | CHESAPEAKE BAY |
| CB8.1 | BETWEEN JAMES RIVER MOUTH AND THIMBLE SHOALS CHANNEL | CHESAPEAKE BAY |
| CB8.1E | THIMBLE SHOALS CHANNEL AT BAY BRIDGE/TUNNEL | CHESAPEAKE BAY |
| EE1.1 | EASTERN BAY BETWEEN TILGHMAN POINT AND PARSONS ISLAND, NORTH OF BUOY R-4; CHARACTERIZES EMBAYMENT | EASTERN BAY |
| EE2.1 | CHOPTANK EMBAYMENT BETWEEN TODDS POINT AND NELSON POINT; MIDWAY BETWEEN BUOY BWN63B AND R-12 | CHOPTANK RIVER |
| EE2.2 | LITTLE CHOPTANK RIVER MID-CHANNEL WEST OF RAGGED POINT, WEST OF BUOY FIG-"3"; CHARACTERIZES EMBAYMENT | LITTLE CHOPTANK RIVER |
| EE3.0 | FISHING BAY AT DAYMARK 3, WEST OF ROASTING EAR POINT; CHARACTERIZES EMBAYMENT | FISHING BAY |
| EE3.1 | NORTH TANGIER SOUND, NORTHWEST OF HAINES POINT, 100 YARDS NORTH OF BUOY R-16; CHARACTERIZES EMBAYMENT | TANGIER SOUND |
| EE3.2 | SOUTH TANGIER SOUND, MID-CHANNEL; EAST OF SMITH ISLAND, 500 YARDS NNW OF BUOY R-8; CHARACTERIZES EMBAYMENT | TANGIER SOUND |
| EE3.3 | POCOMOKE SOUND, MID-CHANNEL NEAR BUOY W-"A" PLACE; STATE LINE; CHARACTERIZES EMBAYMENT | POCOMOKE SOUND |
| EE3.4 | POCOMOKE SOUND NORTHWEST OF LONG POINT | POCOMOKE SOUND |
| EE3.5 | CHESAPEAKE BAY SOUTHEAST OF TANGIER ISLAND | CHESAPEAKE BAY |
| ET1.1 | NORTHEAST RIVER AT BUOY F1R-12 OFF HANCE POINT; MID-CHANNEL; TIDAL FRESH WATER STATION | NORTHEAST RIVER |
| ET10.1 | UPPER POCOMAKE RIVER NEAR ALTERNATE ROUTE 13 BRIDGE AT POCOMAKE CITY; TIDAL FRESH WATER STATION | POCOMOKE RIVER |
| ET2.1 | BACK CREEK NEAR ROUTE 213 BRIDGE AT CHESAPEAKE BAY; TIDAL FRESH WATER STATION | BACK CREEK |
| ET2.2 | BOHEMIA RIVER OFF OLD HACK POINT AT BUOY F1R-4; MID-CHANNEL; TIDAL FRESH WATER STATION | BOHEMIA RIVER |

# CURRENT CHESAPEAKE BAY PROGRAM WATER QUALITY MONITORING STATIONS

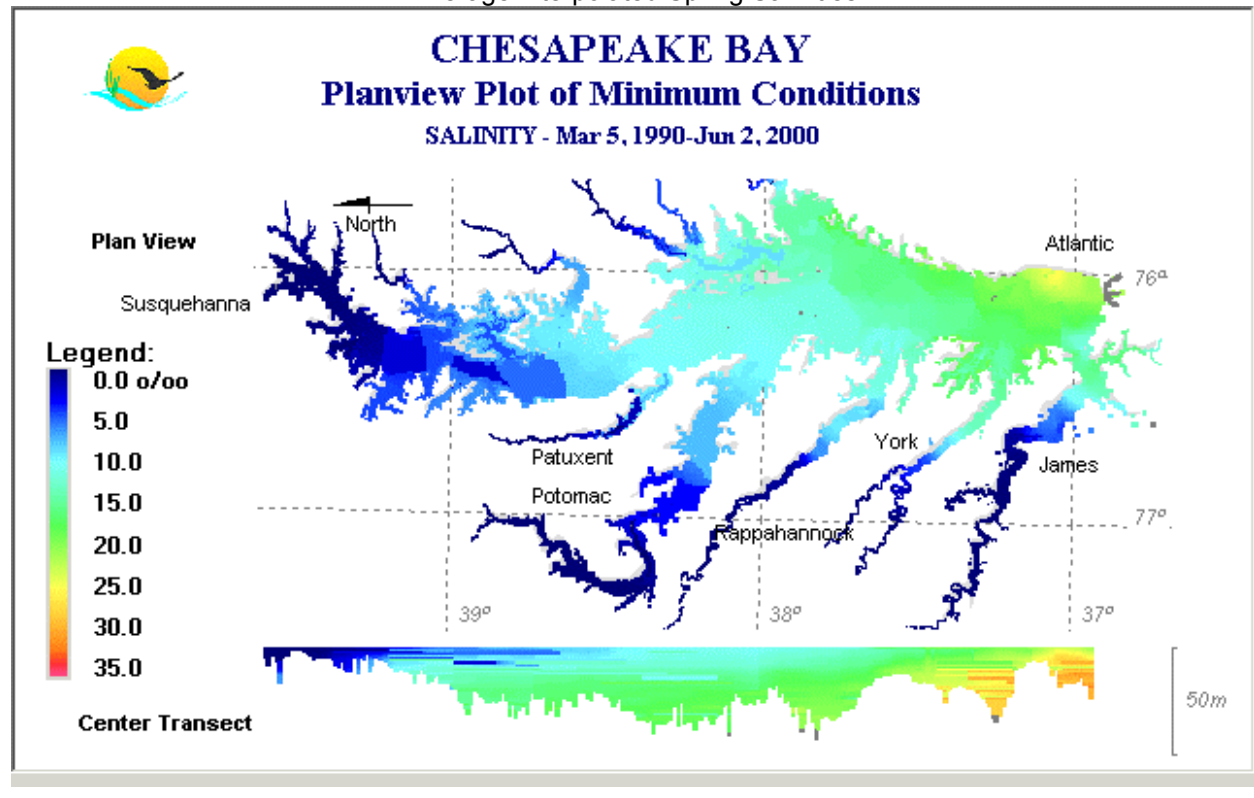| STATION | DESCRIPTION | WATER_BODY |
|---|---|---|
| ET2.3 | ELK RIVER, SOUTHEAST OF OLDFIELD POINT AT B-15; MID-CHANNEL; TIDAL FRESH WATER STATION | ELK RIVER |
| ET3.1 | SASSAFRAS RIVER NEAR ROUTE 213 BRIDGE; TIDAL FRESH WATER STATION | SASSAFRAS RIVER |
| ET4.1 | CHESTER RIVER AT CRUMPTON NEAR ROUTE 290 BRIDGE; TIDAL FRESH WATER STATION | CHESTER RIVER |
| ET4.2 | LOWER CHESTER RIVER, SOUTH OF EASTERN NECK ISLAND AT BUOY FIG-9; CHARACTERIZES LOWER ESTUARINE | CHESTER RIVER |
| ET5.1 | UPPER CHOPTANK RIVER AT GANEY WHARF, DOWNSTREAM OF CONFLUENCE; TUCKAHOE CIRCLE; TIDAL FRESH WATER STATION | CHOPTANK RIVER |
| ET5.2 | LOWER CHOPTANK RIVER NEAR ROUTE 50 BRIDGE AT CAMBRIDGE; CHARACTERIZES LOWER ESTUARINE | CHOPTANK RIVER |
| ET6.1 | UPPER NANTICOKE RIVER NEAR ROUTE 313 BRIDGE AT SHARPTOWN; MID-CHANNEL; TIDAL FRESH WATER STATION | NANTICOKE RIVER |
| ET6.2 | LOWER NANTICOKE RIVER; MID-CHANNEL NEAR BUOY FIG-11; CHARACTERIZES LOWER ESTUARINE | NANTICOKE RIVER |
| ET7.1 | LOWER WICOMICO RIVER AT WHITEHEAVEN OFF OF FERRY ROAD; CHARACTERIZES LOWER ESTUARINE | WICOMICO RIVER |
| ET8.1 | MANOKIN RIVER AT UPPER EXTENT OF CHANNEL NEAR BUOY R-8; CHARACTERIZES LOWER ESTUARINE | MANOKIN RIVER |
| ET9.1 | BIG ANNEMESSEX RIVER, NORTHWEST OF LONG POINT; 250 YARDS EAST OF DAY BEACON G-5; CHARACTERIZES LOWER ESTUARINE | BIG ANNEMESSEX RIVER |
| LE1.1 | MID-CHANNEL; SSW OF JACK BAY SANDSPIT AND NORTHEAST OF SANDGATES; CHARACTERIZES LOWER ESTUARINE | PATUXENT RIVER |
| LE1.2 | MID-CHANNEL 1600 METERS; SOUTHWEST OF PATERSONS POINT; CHARACTERIZES LOWER ESTUARINE | PATUXENT RIVER |
| LE1.3 | MID-CHANNEL 1200 METERS DUE NORTH OF POINT PATIENCE; ENE OF HALF PONE POINT; CHARACTERIZES LOWER ESTUARINE | PATUXENT RIVER |
| LE1.4 | MID-CHANNEL BETWEEN DRUM POINT AND FISHING POINT; CHARACTERIZES LOWER ESTUARINE | PATUXENT RIVER |
| LE2.2 | POTOMAC RIVER OFF RAGGED POINT AT BUOY 51B; LOWER ESTUARINE ZONE | POTOMAC RIVER |
| LE2.3 | MOUTH OF POTOMAC RIVER; BOUNDARY BETWEEN CB5 AND LE2; RIVER CHANNEL | POTOMAC RIVER |
| LE3.1 | VIMS SLACK WATER, BUOY #11 | RAPPAHANNOCK RIVER |
| LE3.2 | LONG POINT UPSTREAM OF BUOY #R8 | RAPPAHANNOCK RIVER |
| LE3.3 | CORROTOMAN RIVER, BUOY #R6 | CORROTOMAN RIVER |
| LE3.4 | ORCHARD PT, VIMS SLACK WATER | RAPPAHANNOCK RIVER |
| LE3.6 | MOUTH OF THE RAPPAHANNOCK RIVER | RAPPAHANNOCK RIVER |
| LE3.7 | MOUTH OF THE PIANKATANK RIVER | PIANKATANK RIVER |
| LE4.1 | VIMS SLACK WATER, #N44 | YORK RIVER |
| LE4.2 | VIMS SLACK WATER, #N34 | YORK RIVER |
| LE4.3 | YORK RIVER BETWEEN AMOCO AND SARAH CREEKS | YORK RIVER |
| LE5.1 | VIMS SLACK WATER, RED BUOY #36 | JAMES RIVER |
| LE5.2 | BUOY #C12-13 | JAMES RIVER |
| LE5.3 | NH-15 JAMES RIVER BRIDGE, VIMS | JAMES RIVER |
| LE5.4 | BUOY #9, HAMPTON ROADS, VIMS | JAMES RIVER |
| LE5.5 | MOUTH OF THE JAMES RIVER | JAMES RIVER |
| LE5.6 | RED BUOY #18 | ELIZABETH RIVER |
| RET1.1 | MID-CHANNEL, 5000 METERS ENE OF LONG POINT; CHARACTERIZES TRANSITION ZONE | PATUXENT RIVER |
| RET2.1 | BUOY 27 SOUTHWEST OF SMITH POINT; CHARACTERIZES TRANSITION ZONE | POTOMAC RIVER |
| RET2.2 | BOUY 19 MID-CHANNEL OFF MARYLAND POINT; CHARACTERIZES TRANSITION ZONE | POTOMAC RIVER |
| RET2.4 | MID-CHANNEL AT MORGANTOWN BRIDGE (U.S. ROUTE 301); CHARACTERIZES LOWER ESTUARINE | POTOMAC RIVER |
| RET3.1 | RAPPAHANNOCK RIVER NORTH OF BUOY R10, VIMS SLACK | RAPPAHANNOCK RIVER |
| RET3.2 | RAPPAHANNOCK RIVER (VIMS SLACK WATER #N16) | RAPPAHANNOCK RIVER |
| RET4.1 | PAMUNKEY RIVER AT SOUTHERN END OF LEE MARSH | PAMUNKEY RIVER |
| RET4.2 | MATTAPONI RIVER AT MUDDY POINT | MATTAPONI RIVER |
| RET4.3 | YORK RIVER (VIMS SLACK WATER #C57) | YORK RIVER |
| RET5.1A | CHICKAHOMINY RIVER ABOVE SHIPYARD LANDING | CHICKAHOMINY RIVER |
| RET5.2 | SWANN'S POINT, JAMES RIVER WQMP STA#19 | JAMES RIVER |
| SBE2 | SOUTHERN BRANCH ELIZABETH RIVER - ADJACENT TO ATLANTIC WOOD | SOUTHERN BRANCH ELIZABETH RIVER |
| SBE5 | SOUTHERN BRANCH ELIZABETH RIVER - ADJACENT TO VIRGINIA POWER | SOUTHERN BRANCH ELIZABETH RIVER |
| TF1.0 | FROM UPSTREAM SIDE OF THE MD ROUTE 50 BRIDGE; USGS GAGE NO. 59440; CHARACTERIZES TIDAL FRESH ZONE | PATUXENT RIVER |
| TF1.2 | MIDSTREAM AT WATER STREET IN UPPER MARLBORO; CHARACTERIZES TIDAL FRESH ZONE | WESTERN BRANCH |
| TF1.3 | MID-CHANNEL FROM MD ROUTE 4 BRIDGE NEAR WAYSONS CORNER; CHARACTERIZES TIDAL FRESH ZONE | PATUXENT RIVER |

# CURRENT CHESAPEAKE BAY PROGRAM WATER QUALITY MONITORING STATIONS

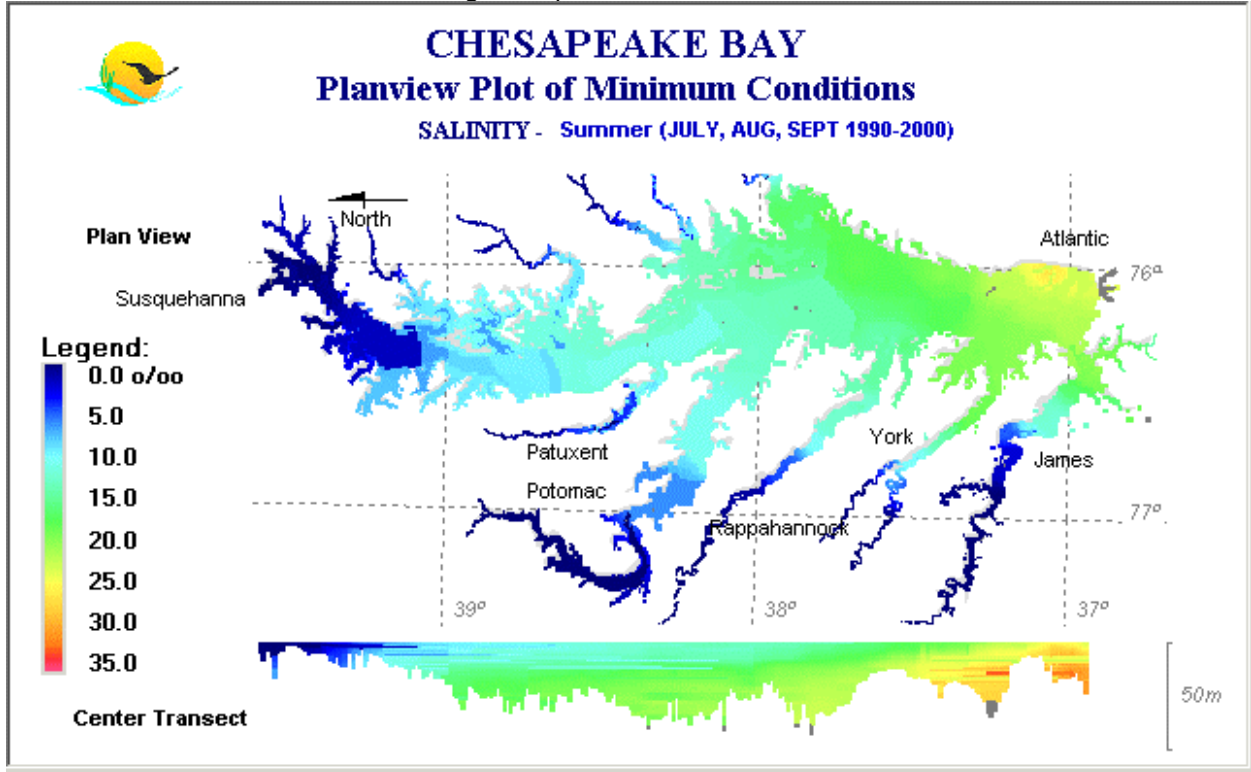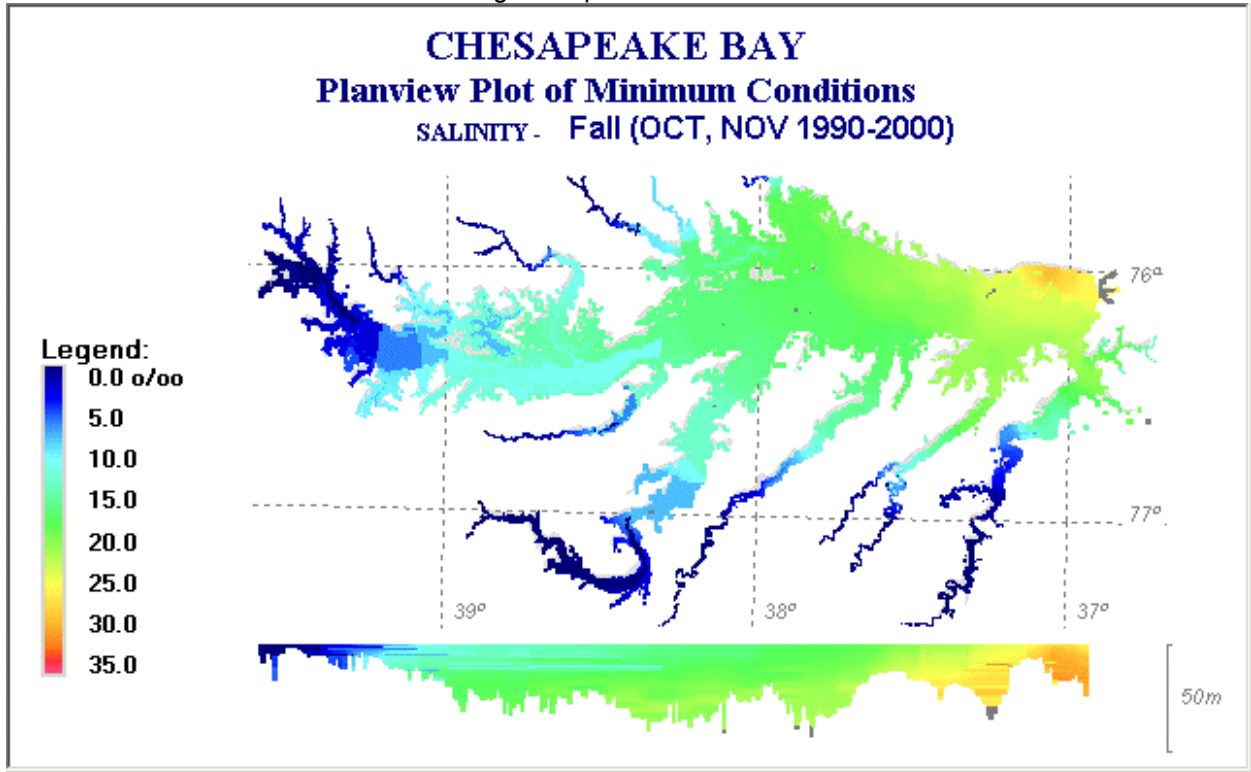| STATION | DESCRIPTION | WATER_BODY |
|---|---|---|
| TF1.4 | WEST SHORE FROM MAIN PIER AT JACKSON LANDING; CHARACTERIZES TIDAL FRESH ZONE | PATUXENT RIVER |
| TF1.5 | MID-CHANNEL AT NOTTINGHAM; CHARACTERIZES TIDAL FRESH ZONE | PATUXENT RIVER |
| TF1.6 | MID-CHANNEL OFF WHARF AT LOWER MARLBORO; CHARACTERIZES TRANSITION ZONE | PATUXENT RIVER |
| TF1.7 | MID-CHANNEL ON A TRANSSECT OF APPROXIMATE 115 DEGREE FROM JACK'S CREEK; CHARACTERIZES TRANSITION ZONE | PATUXENT RIVER |
| TF2.1 | AT FL BOUY 77 OFF MOUTH OF PISCATAWAY CREEK; CHARACTERIZES TIDAL FRESH ZONE | POTOMAC RIVER |
| TF2.2 | BOUY 67 OFF MOUTH OF PISCATAWAY CREEK; CHARACTERIZES TIDAL FRESH ZONE | POTOMAC RIVER |
| TF2.3 | BOUY N 54 MID-CHANNEL OFF INDIANHEAD; CHARACTERIZES TIDAL FRESH ZONE | POTOMAC RIVER |
| TF2.4 | BOUY 44 BETWEEN POSSUM POINT AND MOSS POINT; CHARACTERIZES TIDAL FRESH/TRANSITION ZONE | POTOMAC RIVER |
| TF3.1B | RAPPAHANNOCK RIVER DOWNSTREAM OF FREDERICKSBURG, VA AT BUOY # 89 | RAPPAHANNOCK RIVER |
| TF3.1E | RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA? | RAPPAHANNOCK RIVER |
| TF3.2 | RAPPAHANNOCK RIVER JUST DOWNSTREAM OF THE PORT ROYAL BRIDGE, #N74 | RAPPAHANNOCK RIVER |
| TF3.2A | RAPPAHANNOCK RIVER ONE MILE DOWNSTREAM OF THE PORT ROYAL BRIDGE | RAPPAHANNOCK RIVER |
| TF3.3 | RAPPAHANNOCK RIVER AT JONES CREEK? (VIMS SLACK WATER #N40) | RAPPAHANNOCK RIVER |
| TF4.2 | PAMUNKEY RIVER AT WHITE HOUSE, VA | PAMUNKEY RIVER |
| TF4.4 | MATTAPONI RIVER AT WALKERTON, VA | MATTAPONI RIVER |
| TF5.2 | JAMES RIVER AT MAYO'S BRIDGE (JRWQMP STATION #2) | JAMES RIVER |
| TF5.2A | JAMES RIVER AT BUOY # 166 | JAMES RIVER |
| TF5.3 | JAMES RIVER AT BUOY #157 (JRWQMP STATION #8) | JAMES RIVER |
| TF5.4 | APPOMATTOX RIVER AT BUOY #8 (JRWQMP STATION #20A) | APPOMATTOX RIVER |
| TF5.5 | JAMES RIVER AT RED BUOY #107 (JRWQMP STATION #13) | JAMES RIVER |
| TF5.5A | JAMES RIVER AT BUOY # 91 | JAMES RIVER |
| TF5.6 | JAMES RIVER NORTH OF BUOY #74, JAMES RIVER WQMP STATION #17 | JAMES RIVER |
| WE4.1 | CENTRAL MOBJACK BAY | MOBJACK BAY |
| WE4.2 | MOUTH OF THE YORK RIVER, MID-CHANNEL | YORK RIVER |
| WE4.3 | MOUTH OF THE POQUOSON RIVER EAST OF YORK POINT | POQUOSON RIVER |
| WE4.4 | MOUTH OF THE BACK RIVER OFF NORTHEND POINT | BACK RIVER (VA) |
| WT1.1 | BUSH RIVER, EAST OF GUM POINT AT FL G LT; CHARACTERIZES SALINITY TRANSITION | BUSH RIVER |
| WT2.1 | GUNPOWDER RIVER, 200 YARDS EAST OF OLIVER POINT AT BUOY G-"15"; CHARACTERIZES SALINITY TRANSITION | GUNPOWDER RIVER |
| WT3.1 | MIDDLE RIVER, EAST OF WILSON POINT AT CHANNEL JUNCTION DAY-MARKER; CHARACTERIZES SALINITY TRANSITION | MIDDLE RIVER |
| WT4.1 | BACK RIVER, EAST OF STANSBURY POINT AT DAY BEACON 12; CHARACTERIZES LOWER ESTUARINE | BACK RIVER (MD) |
| WT5.1 | PATAPSCO RIVER, EAST OF HAWKINS POINT AT BUOY 5M; CHARACTERIZES LOWER ESTUARINE | PATAPSCO RIVER |
| WT6.1 | MAGOTHY RIVER, NORTH OF SOUTH FERRY POINT AT BUOY FL R12; CHARACTERIZES LOWER ESTUARINE | MAGOTHY RIVER |
| WT7.1 | SEVERN RIVER, 200 YARDS UPSTREAM OF ROUTE 50-301 BRIDGE; CHARACTERIZES LOWER ESTUARINE | SEVERN RIVER |
| WT8.1 | SOUTH RIVER, SOUTH OF POPLAR POINT AT DAY MARKER R-"16"; CHARACTERIZES LOWER ESTUARINE | SOUTH RIVER |
| WT8.2 | RHODE RIVER BETWEEN FLAT ISLAND AND BIG ISLAND; CHARACTERIZES LOWER ESTUARINE | RHODE RIVER |
| WT8.3 | WEST RIVER JUST UPSTREAM OF DAY MARKER R-"6"; CHARACTERIZES LOWER ESTUARINE | WEST RIVER |
| XGG8251 | KENT ISLAND NARROW AT DRAWSPAN ON ROUTE 50 BRIDGE; CHARACTERIZES FREE-FLOWING FRESHWATER | CHESTER RIVER |

Average Interpolated Winter Salinities



Average Interpolated Spring Salinities

Average Interpolated Summer Salinities



CHESAPEAKE BAY
Planview Plot of Minimum Conditions
SALINITY - Summer (JULY, AUG, SEPT 1990-2000)

Plan View

Susquehanna

Legend:
0.0 o/oo
5.0
10.0
15.0
20.0
25.0
30.0
35.0

Center Transect

North

Atlantic
76º

Patuxent
Potomac
Rappahannock
York
James
77º
39º
38º
37º

50m

Average Interpolated Fall Salinities



CHESAPEAKE BAY
Planview Plot of Minimum Conditions
SALINITY - Fall (OCT, NOV 1990-2000)

Legend:
0.0 o/oo
5.0
10.0
15.0
20.0
25.0
30.0
35.0

76º
77º
39º
38º
37º

50m

CRC