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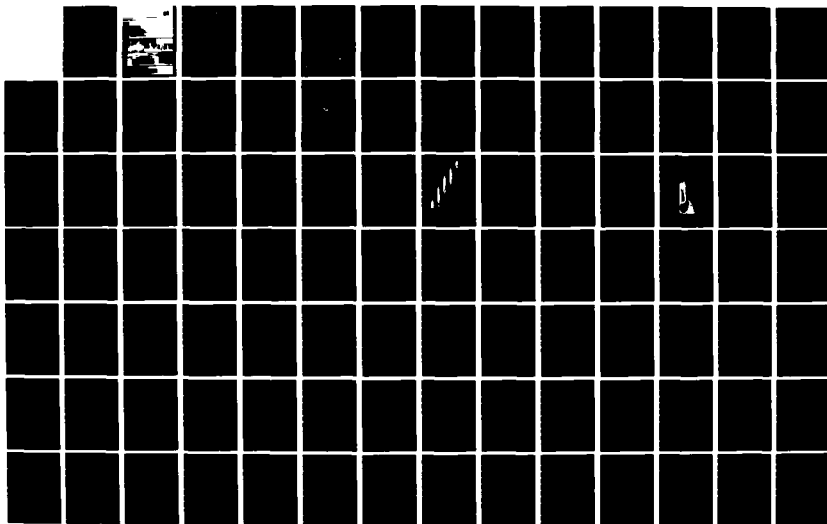
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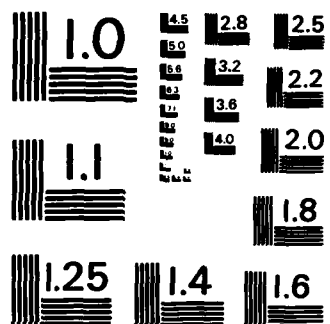
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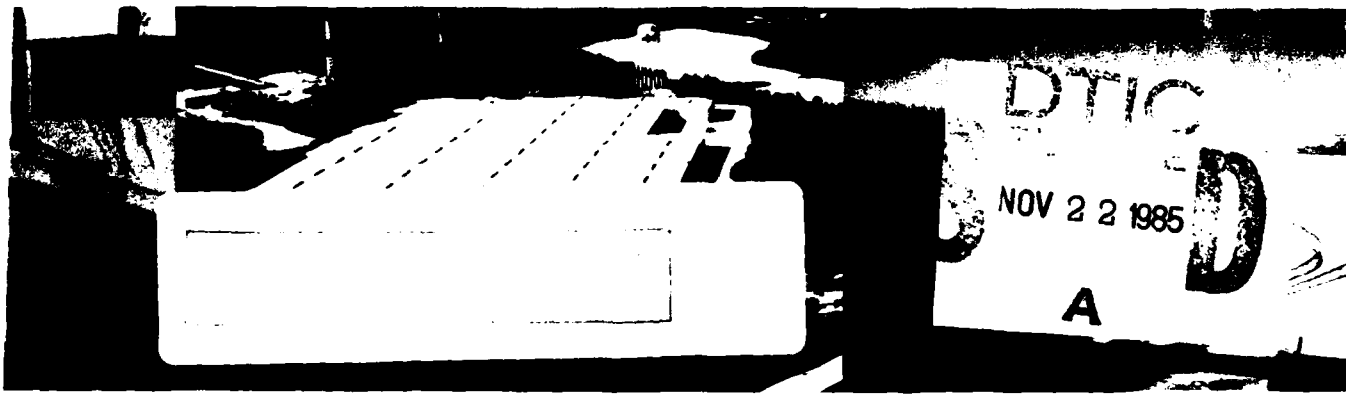
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# Chesapeake Bay Low-Freshwater Inflow Study

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CHB-84-L	2. GOVT ACCESSION NO. <i>AD A161483</i>	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Chesapeake Bay Low Freshwater Inflow Study <del>Main Report, Appendices A through F</del> <i>Appendix E</i>		5. TYPE OF REPORT & PERIOD COVERED
7. AUTHOR(s)		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Baltimore District US Army Corps of Engineers, ATTN: NABPL P.O. Box 1715, Baltimore, MD 21203-1715		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS Baltimore District US Army Corps of Engineers, ATTN: NABPL P.O. Box 1715, Baltimore, MD 21203-1715		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE September 1984
		13. NUMBER OF PAGES 1130 pages, 108 plates
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release, distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Chesapeake Bay, low freshwater inflow, low flow, hydraulic model, estuary, water supply, water demand, water withdrawal, consumptive loss, biota, habitat, nutrients, salinity, drought, drought management, ecosystem, plankton, tributary, water conservation		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Chesapeake Bay is a complex estuarine system that is dependent on the freshwater inflow from its tributaries to maintain the salinity regime that characterizes its ecosystem.  Increasing population and economic growth in the Bay drainage area is predicted to result in increased water supply demands and attendant increases in the amount of water used consumptively. This will cause a marked reduction in freshwater inflow to the Bay and result in higher salinities throughout the Bay		

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20. ABSTRACT

system. In the long term, salinities would be expected to increase by as much as 2 to 4 ppt.

The Low Freshwater Inflow Study methodology involved selecting representative species for study, mapping potential habitat under various conditions, using expert scientists to interpret the significance of habitat change, and assessing socio-economic and environmental impacts of the changes.

While no specific plan was developed to solve the problems caused by reduced freshwater inflows, several alternatives were identified as "most promising". These include reservoir storage, conservation, growth restriction, oyster bed restoration, and fisheries management.

The final report recommends that a comprehensive water supply and drought management study be conducted that will identify those measures required to optimize the use of existing water supplies in the Bay drainage basin and minimize reductions in freshwater inflow to the Bay.

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# Chesapeake Bay Low Freshwater Inflow Study

## APPENDIX E-BIOTA

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CHESAPEAKE BAY  
LOW FRESHWATER INFLOW STUDY

APPENDIX E

BIOTA

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Baltimore District, Corps of Engineers  
Baltimore, Maryland  
September 1984

## FOREWORD

This is one of the volumes comprising the final report on the Corps of Engineers' Chesapeake Bay Study. The report represents the culmination of many years of study of the Bay and its associated social, economic, and environmental processes and resources. The overall study was done in three distinct developmental phases. A description is provided below of each study phase, followed by a description of the organization of the report.

The initial phase of the overall program involved the inventory and assessment of the existing physical, economic, social, biological, and environmental conditions of the Bay. The results of this effort were published in a seven volume document titled Chesapeake Bay Existing Conditions Report, released in 1973. This was the first publication to present a comprehensive survey of the tidal Chesapeake and its resources as a single entity.

The second phase of the program focused on projection of water resource requirements in the Bay Region for the year 2020. Completed in 1977, the Chesapeake Bay Future Conditions Report documents the results of that work. The 12-volume report contains projections for resource categories such as navigation, recreation, water supply, water quality, and land use. Also presented are assessments of the capacities of the Bay system to meet the identified future requirements, and an identification of problems and conflicts that may occur with unrestrained growth in the future.

In the third and final study phase, two resource problems of particular concern in Chesapeake Bay were addressed in detail: low freshwater inflow and tidal flooding. In the Low Freshwater Inflow Study, results of testing on the Chesapeake Bay Hydraulic Model were used to assess the effects on the Bay of projected future depressed freshwater inflows. Physical and biological changes were quantified and used in assessments of potential social, economic, and environmental impacts. The Tidal Flooding Study included development of preliminary stage-damage relationships and identification of Bay communities in which structural and nonstructural measures could be beneficial.

The final report of the Chesapeake Bay Study is composed of three major elements: (1) Summary, (2) Low Freshwater Inflow Study, and (3) Tidal Flooding Study. The Chesapeake Bay Study Summary Report includes a description of the results, findings, and recommendations of all the above described phases of the Chesapeake Bay Study. It is incorporated in four parts:

- Summary Report
- Supplement A — Problem Identification
- Supplement B — Public Involvement
- Supplement C — Hydraulic Model

The Low Freshwater Inflow Study consists of a Main Report and six supporting appendices. The report includes:

- Main Report
- Appendix A — Problem Identification
- Appendix B — Plan Formulation
- Appendix C — Hydrology
- Appendix D — Hydraulic Model Test

Appendix E -- Biota  
Appendix F -- Map Folio

The Tidal Flooding Study consists similarly of a Main Report and six appendices. The report includes:

Main Report  
Appendix A -- Problem Identification  
Appendix B -- Plan Formulation, Assessment, and Evaluation  
Appendix C -- Recreation and Natural Resources  
Appendix D -- Social and Cultural Resources  
Appendix E -- Engineering, Design, and Cost Estimates  
Appendix F -- Economics

CHESAPEAKE BAY  
LOW FRESHWATER INFLOW STUDY

APPENDIX E  
BIOTA

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## CHAPTER I

### INTRODUCTION

This Appendix provides a detailed discussion of the biota-related matters presented in the Problem Identification Appendix, including background information about the ecology of the Chesapeake Bay, and detailed life history information on 57 study species. This information was used to define the impacts of reduced freshwater inflow on the biological, environmental, social and economic conditions in the Bay. It should be noted that this Appendix contains information on existing conditions, as opposed to future conditions. Future conditions scenarios are described in Appendix A, Problem Identification.

The purposes of this Appendix are as follows:

- Present a summary characterization of the Chesapeake Bay ecosystem.
- Describe the process for selection of the study species used in the Low Freshwater Inflow Study.
- Present detailed species life history information, habitat requirements and salinity tolerances for the selected study species.

This Appendix is designed to provide detailed technical support to the report, as well as to serve as a useful source for those interested in a general discussion of the ecology of the Bay and its organisms. Thus, it may be read in concert with other portions of the report or it may stand alone as a source book. References to other sections of this report will be made frequently in order to guide the reader who is interested in the complete study.

### APPENDIX ORGANIZATION

Chapter 2 is entitled "The Chesapeake Bay Ecosystem." This chapter characterizes the productivity and complexity of the Bay system. It describes the major groups of flora and fauna in the Bay, including phytoplankton, submerged aquatic vegetation, emergent aquatic vegetation, zooplankton, benthos, fish and wildlife. The intricateness of the Bay's biological components are illustrated with the use of food web diagrams.

Chapter 3 is entitled "Selection of Study Species." This chapter describes the rationale for selection of study species and traces the development of the criteria used in the selection process.

Chapter 4 is entitled "Life History Summaries of Study Species." This chapter contains species descriptions for each of the 57 selected study species. Each account discusses aspects of range, salinity tolerance, tolerance to other factors, trophic importance and sources of information.

Also included is a glossary of terms used in this volume. Numerous scientific terms relating to species are used throughout this Appendix. For unfamiliar terms which are not included in the glossary, the reader is referred to the Dictionary of Scientific and Technical Terms. 1978. Daniel L. Lapedes (ed.). McGraw - Hill Company. New York.

## SOURCES

This Appendix relies heavily upon information provided in earlier phases of the Corps of Engineer's Chesapeake Bay Study. Specifically, the following four reports were utilized to a large extent in the preparation of this Appendix.

### Chesapeake Bay Existing Conditions Report

Published in 1973, this report provides a detailed inventory of the Chesapeake Bay and its water resources. Divided into a summary and four appendices, the report presents an overview of the Bay Area and the economy; a survey of the Bay's land resources and its use; and a description of the Bay's life forms and hydrodynamics. The biota portion of the report was funded by the Corps of Engineers and prepared by the Smithsonian Institution, the University of Maryland, and the Virginia Institute of Marine Science. Their charge was to summarize the existing knowledge of the biota of Chesapeake Bay. Given the immense volume of information available and short time frame for the product, the chosen approach was to ask competent and experienced workers to summarize their view of the state of knowledge within their area of interest.

### Chesapeake Bay Future Conditions Report

Released in 1977, this report describes the present use of the resource, estimates future demands to be placed on the resources, assesses the ability of the resource to meet future demands, and identifies general means to satisfy projected resource needs. The primary focus of this report was the projection of water resources needs to the year 2020 and the identification of the problems and conflicts which would result from unrestrained growth and use of the Bay's resources. The report consists of a summary document and 16 supporting appendices. The Biota Appendix (Appendix 11) was prepared and coordinated by the Baltimore District Corps of Engineers; however, all technical segments were prepared by the Chesapeake Research Consortium, Inc. under contract. The Chesapeake Research Consortium is composed of the Virginia Institute of Marine Service, the Smithsonian Institution, the Chesapeake Biological Laboratory of the University of Maryland and the Chesapeake Bay Institute of the Johns Hopkins University.

### Chesapeake Bay Low Freshwater Study: Biota Assessment, Phase I

The Low Freshwater Inflow Study, Biota Assessment, Phase I, was completed in 1980 by Western Eco-Systems Technology (WESTECH), of Bothell, Washington. The study's purpose was to develop a methodology for assessing the impacts of reduced freshwater inflows on the biota of the Bay. The selection of study species was also a key element in the Phase I effort. (NOTE: The second phase of the Biota Assessment, completed by WESTECH in 1982, involved primarily the application of the methodology to quantify changes in habitat based on results of the hydraulic model test. This latter effort is discussed in detail in Appendix A, Problem Identification).

Biological Effects of Potential Reductions of Freshwater Flow into the Chesapeake Bay -  
Report of the Biota Evaluation Panel

This report was prepared by a panel of expert Bay scientists under contract to the U.S. Fish and Wildlife Service. The purpose of the panel was to identify the consequences of reduced freshwater inflows on the biota of the Chesapeake, based on the habitat work done by WESTECH.

Where major pieces of this Appendix are based substantially upon one of these sources, the source will not be made. Citations of individual papers which may be contained within the source will be credited. Further, it is not considered practicable to provide comprehensive credit in this appendix to all the individuals who most graciously provided input to this study. The reader is referred to the acknowledgements section of the Main Report for a list of those individuals contributing to this effort.

## CHAPTER II

### THE CHESAPEAKE BAY ECOSYSTEM

The focus of this chapter is the ecology of the Chesapeake Bay with the emphasis on the biota. An overview of the functioning of the Bay's ecosystem is provided together with a description of the seven major groups of fauna and flora of the Bay. The major groups include phytoplankton, submerged aquatic vegetation, emergent aquatic vegetation, zooplankton, benthic organisms, fish and wildlife. A discussion of each component, its importance to the Bay, physical description and factors which control abundance and distribution are included. The interactions between these groups are discussed with the help of trophic diagrams and species interaction matrices.

#### ECOSYSTEM FUNCTIONING

The flow of the energy in Chesapeake Bay originates with the sun and moves through the plants and animals of the ecosystem. Nutrients and non-living particulate matter also fuel the system. The energetics of the Bay are illustrated in Figures E-II-1 and E-II-2, as derived from the WESTECH report. As illustrated, radiant energy is used by four primary producers compartments (net phytoplankton, nannoplankton, submerged aquatic vegetation, and emergent aquatic vegetation) to produce plant tissue. Two of these plant compartments, net phytoplankton and nannoplankton, produce material which primarily enters a grazing food web. Zooplankton, both macro- and micro-(copepods, rotifers), feed on these plants, as do ichthyoplankton, invertebrate meroplankton (oyster, barnacle larvae, etc.), forage fish and menhaden. Benthic suspension feeders also graze the phytoplankton.

The other two primary producer compartments, emergent aquatic vegetation and submerged aquatic vegetation (which includes a smaller epiphytic community) contribute the major portion of their production to the detrital food chain (although a substantial amount is eaten by waterfowl). The detritus produced is utilized by benthic detritivores (crabs, etc.) and benthic suspension feeders (oysters, clams, etc.). Macrozooplankters, forage fish, and menhaden also utilize detritus to a certain extent.

The plankton species mentioned above (macro- and micro-zooplankton, ichthyoplankton, and invertebrate meroplankton) are fed upon by ctenophores and cnidarians (comb-jellies and sea-nettles), fish such as menhaden and forage fish (silversides, etc.), and benthic suspension feeders (such as barnacles). At this point in the conceptual model, energy flows to the predator layers of the system. Pelagic fish (bluefish, etc.), demersal fish (flounder, etc.), and waterfowl (canvasbacks) are top predators, and the energy equivalent of the food they eat is exported from the system or expended in feedback controls in the system.

#### MAJOR GROUPS OF FLORA AND FAUNA IN THE BAY

The living components of the Chesapeake Bay ecosystem can be grouped many different ways (classifications), depending upon the purpose. The following classification method is used to give an overview of the types of organisms within the Bay. The seven categories reflect both function and habitat. They are ordered from lower to higher trophic level: phytoplankton, submerged aquatic vegetation, emergent aquatic vegetation, zooplankton, benthos, fish and wildlife.

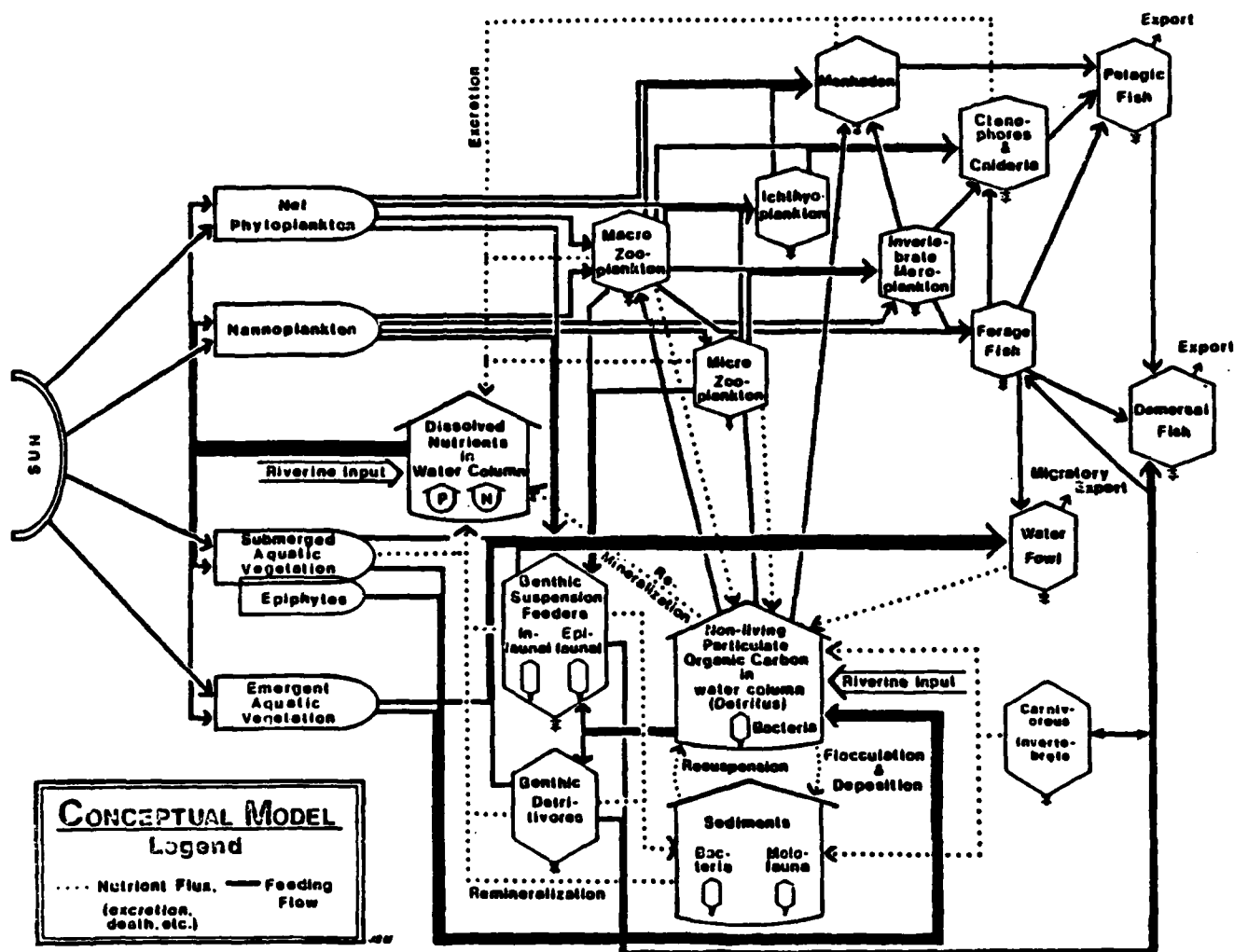


FIGURE E-II-1 CONCEPTUAL MODEL OF BAY ENERGETICS

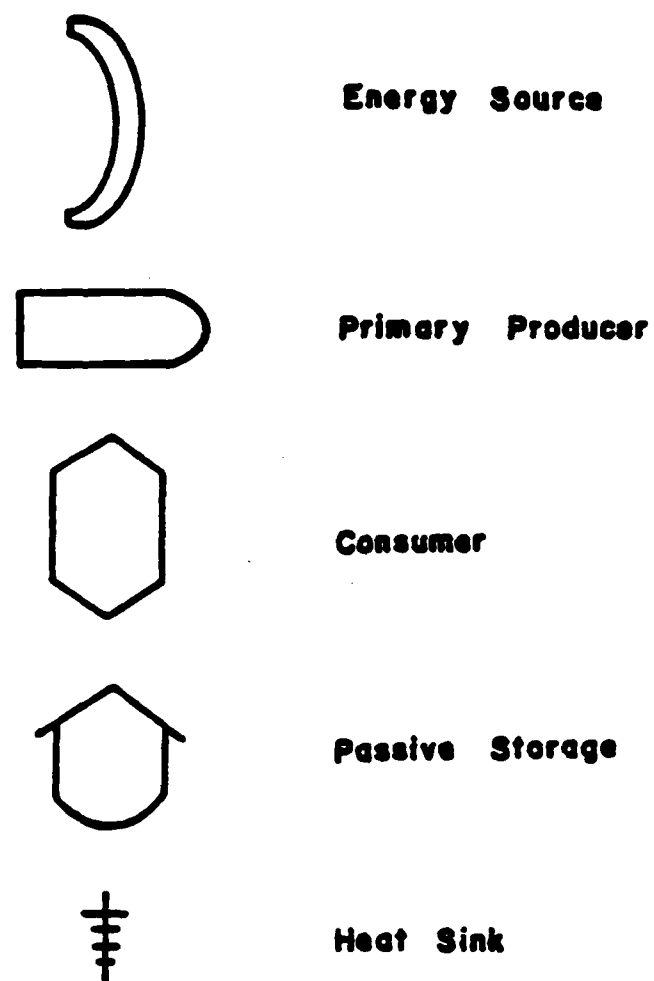


FIGURE E-II-2 KEY TO SYMBOLS USED IN THE CONCEPTUAL MODEL

## Phytoplankton

Importance to the Bay. Phytoplankton perform a vital function in the Chesapeake Bay ecosystem. They are the major primary producers in most of the Bay's tidal waters, thereby providing organic material to the food web and ultimately sustaining the fisheries. Their relative importance has increased with the decline of the Bay's submerged aquatic vegetation.

Many organisms depend on phytoplankton for part or all of their food supply. Copepods utilize algae down to 8  $\mu$ m in size, and microzooplankters such as rotifers and tintinnids can ingest even smaller forms. Larger species of phytoplankton can be used by zooplankton and juveniles of planktivorous fish. Benthic suspension feeders also graze phytoplankton heavily. Oysters feed upon smaller species.

Not all species of phytoplankton are equally good as food, and some (such as toxic dinoflagellates) are detrimental. "Nuisance blooms" of algae are primarily a summer phenomena in Chesapeake Bay, but blooms of cold water dinoflagellates such as Katodinium rotundatum have also been observed.

Physical description. Phytoplankton are microscopic, usually single-celled plants which represent several divisions of algae. Functionally, the group comprises both net-and nanno-plankton, the latter being species less than 10  $\mu$ m diameter. Some workers further identify ultra-plankton, which are species less than 2 to 3  $\mu$ m. This category would include most planktonic bacteria, which are heterotrophs and, as a group, not well-known in the Bay.

Phytoplankton are pelagic, and are moved about by actions of currents and tides in a manner not totally understood. They are found throughout the Bay although particular species are limited to certain areas. Phytoplankton are not uniformly distributed throughout the water column but are limited to the top of the water column in the euphotic zone.

Net phytoplankton in the Bay are grouped by salinity range. Within each salinity range a certain set of phytoplankton species is expected. Generally salinity ranges for the four associations are:

Tidal Freshwater	0-5 ppt
Oligohaline/Low Mesohaline	3-10 ppt
Mesohaline	8-15 ppt
Polyhaline	13 ppt-Bay mouth

From area to area, and year to year, the exact composition of the various associations changes as different species dominate. Typical associations within each of the above groups are discussed in Chapter IV. As is illustrated by the overlap in salinities, there is considerable overlap in the distributions of the various phytoplankton assemblages relative to salinity. The overall effect is a continuous gradation from one association to another with few abrupt changes.

The importance of nannoplankton was not appreciated until relatively recently. It has been found that nannoplankton contribute 80 percent of total phytoplankton productivity (biomass). The existence of nannoplankton was hidden due to the selectivity of sampling gear. The mesh of traditional plankton nets allow nannoplankton to pass through. When

productivity studies were done it was found that part of the primary productivity was unaccounted for; thus, researchers went searching for this missing component and found nanoplankton. Due to the relatively recent discovery and the difficulty of sampling, less is known about nanoplankton than net plankton.

Controlling factors. Knowledge concerning phytoplankton species in the Bay has increased but much uncertainty still persists. Taxonomic identification is tedious for the many algal groups represented in the Bay's phytoplankton. Their taxonomic diversity is large and presumably reflects differences in ecological and physiological requirements. Thus, it is difficult to generalize about phytoplankton as a group.

The distribution and abundance of phytoplankton is controlled by many factors including light (penetration in the water column and length of day), salinity, temperature, nutrients, predation, competition between species, circulation patterns, tides, winds, salt wedge, and dissolved oxygen.

Live phytoplankton are limited by light penetration to the upper layers of the estuary. Depth of the euphotic zone varies from area to area within the Bay. As a generality it is shallowest at the fresh water estuarine transition zone, and deepest in the lower Bay. In winter, the euphotic zone is deeper than in summer months.

Temperature affects the Bay phytoplankton at both the community and the species level: first, by determining what species are present, and second, by affecting their rate of nutrient uptake, photosynthesis, and cell division.

Nutrient input from runoff is reduced during winter. However, elimination of thermal stratification and overturn by wind action mixes the water column and moves nutrients into the euphotic zone. Increasing insulations, rising temperatures, and initiation of spring runoff triggers increased phytoplankton growth in spring. The spring phytoplankton bloom is most pronounced in the polyhaline areas of Chesapeake Bay and is dominated by diatom species.

The location and abundance of any particular species in the phytoplankton group is cyclical in time and location. For example, see the diagram of annual transport of red-tide dinoflagellate Prorocentrum mariaelebourae from its wintering area near the Bay mouth to its bloom area in the Upper Bay (Figure E-II-3).

Studies of phytoplankton ecology, systematics, and productivity are common in the Chesapeake Bay literature. In general, such investigations fall into two categories: (1) those dealing with species composition, distribution and seasonality, and the factors influencing them; and (2) those studies dealing with seasonal and spatial variations in primary productivity, nutrients and nutrient/phytoplankton inter-relationships.

As a group net phytoplankton biomass (as measured by chlorophyll a concentration) and productivity have been surveyed in Chesapeake Bay for over 30 years. In general, biomass is highest in the spring months, moderate through the summer and has a brief peak in early fall. The spring bloom is most obvious in the lower Bay.

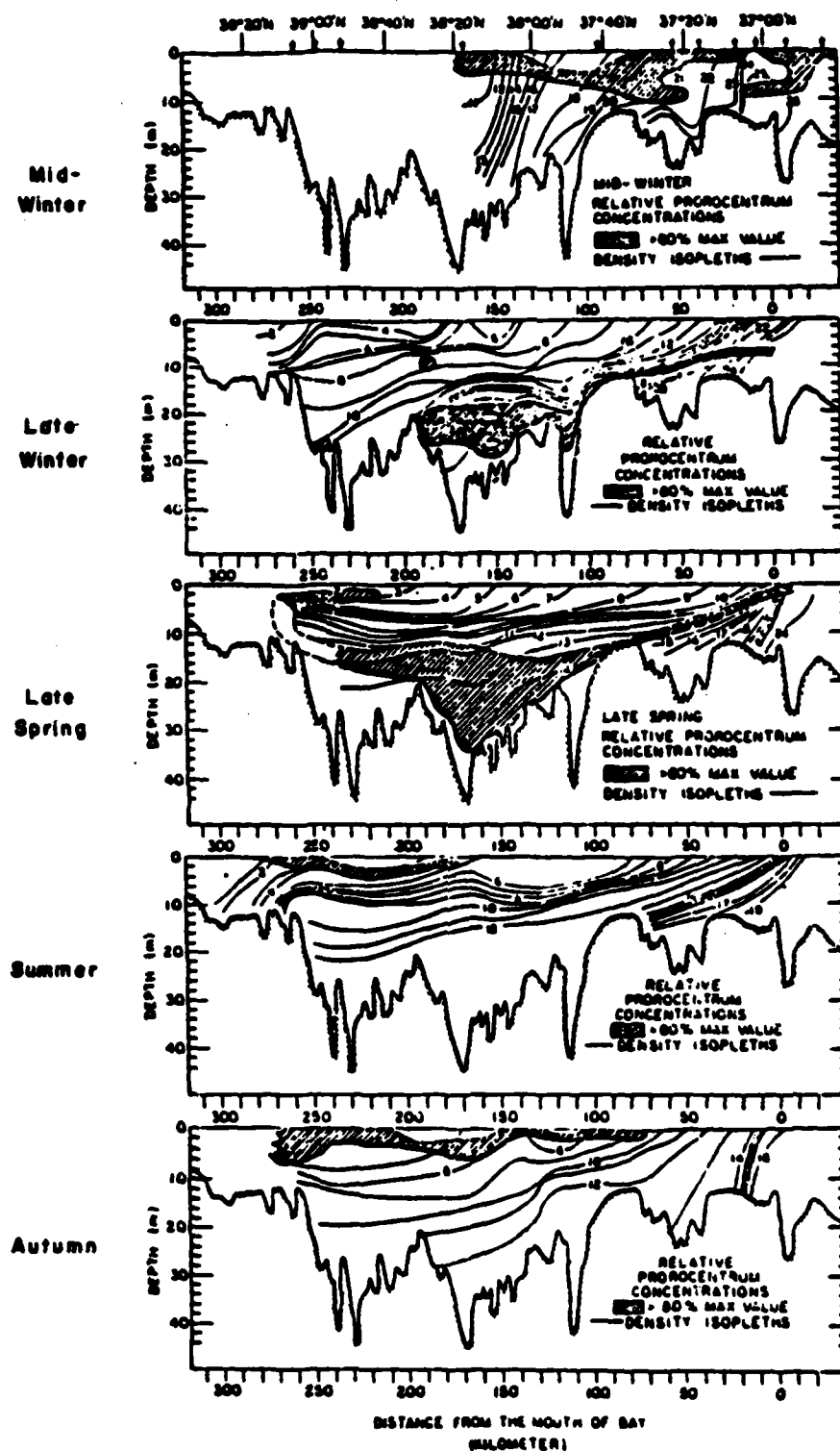


FIGURE E-II-3 SUBSURFACE TRANSPORT OF *Prorocentrum* OVER AN ANNUAL CYCLE, 1975

Along Longitudinal Sections of Chesapeake Bay

(From: Tyler & Setiger, 1978)

Primary productivity and standing crop observations in the northern half of the Bay show that both parameters are maximum during the warmer seasons, particularly in the oligohaline zone. Values are lower in the mid Bay stations and less variable seasonally. Another difference observed is that upper stations tend to have a single warm season peak rather than the spring/fall peaks observed in more saline portions of the Bay.

Nannoplankton which represent a significant fraction of phytoplankton biomass, also accounts for much of the Bay's primary production. It has been found that these small forms constitute 80 percent of the measured biomass (approximated by measuring chlorophyll a) and over 85 percent of the productivity. There appears to be no particular seasonal trend in the importance of the smaller forms.

#### Submerged Aquatic Vegetation

Importance to the Bay. Submerged aquatic vegetation is important in the Chesapeake Bay for a number of reasons, including habitat, substrate, food source and source of detritus. Habitat is probably the most important because aquatic vegetation serves as a habitat for many species. These species include benthic invertebrates, fish, and even other plant organisms (epiphytes). As an example, Table E-II-1 lists the dominant infaunal species found by one investigator in Zostera marina beds in the Chesapeake Bay area. A maximum of 62 species comprised by 32,913 individuals were found in these beds. It has also been shown that significantly more species and infauna inhabit the Zostera beds than in surrounding substrate (Figure E-II-4).

TABLE E-II-1  
RANK ANALYSIS FOR DOMINANT SPECIES BASED ON 110 SAMPLES

<u>Species</u>	<u>Mean Total Biological Index Per Sample</u>	<u>Frequency of Occurrence in 110 Samples</u>
1. <u>Heteromastus filiformis</u> (P)	1.83	107
2. <u>Spiochaetopterus oculatus</u> (P)	1.72	92
3. <u>Streblospio benedicti</u> (P)	1.43	63
4. <u>Nereis succinea</u> (P)	1.36	82
5. <u>Polydora ligni</u> (P)	1.20	61
6. <u>Ampelisca vadorum</u> (A)	1.11	74
7. <u>Oligochaetes</u>	0.99	76
8. <u>Ampelisca abdita</u> (A)	0.95	69
9. <u>Prionospio heterobranchia</u> (P)	0.74	52
10. <u>Edotea triloba</u> (I)	0.62	64
11. <u>Exogone dispar</u> (P)	0.50	43
12. <u>Macoma balthica</u> (B)	0.45	19
13. <u>Scoloplos robustus</u> (P)	0.33	75
14. <u>Lumbrineris tenuis</u> (P)	0.25	20

P = Polychaete, A = Amphipod, I = Isopod, B = Bivalve.

From: Orth, 1973 (Ches. Sci. 14).

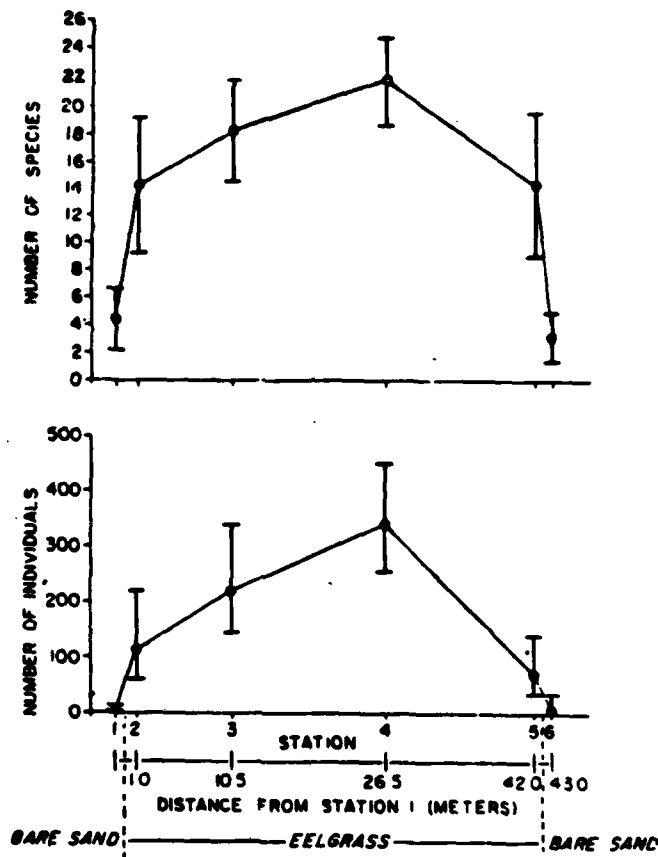


FIGURE E-II-4

RELATIONSHIP BETWEEN BENTHIC INFAUNA AND EELGRASS  
ALONG AN SAV TRANSECT

Source: Orth, 1977

Submerged aquatic vegetation can also serve as a substrate for organisms. Studies of the epifauna of Zostera in the York River estuary found 167,000 individuals of 100 species in 48 samples of Zostera plants (Figure E-II-5). A study of Ruppia found more than 5,000 individuals per gram of grass.

SAV beds are also important to more motile organisms in the Chesapeake Bay. In particular, fish utilize submerged aquatic vegetation in several ways. These can be divided into the following categories: 1) fish eggs, larvae, post larvae and pelagic juveniles, 2) resident fishes, and 3) migratory predators. The use of SAVs by resident fishes is illustrated in Figure E-II-6. Figure E-II-6 also shows the larger number of fish found in Zostera and Ruppia beds compared with unvegetated sand. Of the fish considered residents, spot (Leiostomus xanthurus), was the most abundant in this study.

A number of SAV species, such as Zostera marina, Ruppia maritima, and Potamogeton perfoliatus are the preferred food of certain waterfowl. Besides waterfowl, muskrats and fish are also reported to feed on SAV.

As primary producers, SAV also contribute to the organic detrital load of the Bay. The detrital based food web is discussed in more detail under emergent aquatic vegetation and in a later section on biological interactions.

Physical Description. Submerged Aquatic Vegetation are plants - usually rooted - which live submerged below the water's surface. Submerged aquatics in Chesapeake Bay are chiefly angiosperms (seed plants), although some species (e.g., Nitella) are macroalgae.

Submerged aquatic vegetation (SAV) are found in the fresh, oligohaline, mesohaline and polyhaline waters of the Chesapeake Bay. Maximum depth of SAV in the Bay is approximately 3 meters, although in clearer water SAV species occur at greater depths.

Substrate does not seem to be a critical factor for any species in the Bay although certain SAV species are commonly found on particular substrates. Approximately 20 species of SAV are found in the Chesapeake Bay, although the frequency of occurrence is species dependent, with about 12 of the species forming dominant associates in at least one area of the Bay (Table E-II-2).

Three associations of SAV were defined in a Virginia study. These associations were characteristic of waters that are (1) fresh, (2) brackish water (less than 15 ppt salinity), and (3) marine waters (greater than 15 ppt salinity). These associations are dominated by a variety of genera including (1) Najas, Ceratophyllum, Elodea and Potamogeton in fresh water; (2) Potamogeton, Zannichellia, Vallisneria, Callitriche and Myriophyllum in brackish water; and (3) Zannichellia and Ruppia in marine waters.

Submerged aquatic vegetation was apparently more common in the past than it is today. Although a catastrophic decline in one species, Zostera marina, during the 1930's has been documented for the Atlantic Coastal region, most of the records of SAV distribution and abundance in the Chesapeake Bay date from the 1950's.



**FIGURE E-11-5**

E-13

FIGURE E-II-6

Number of Resident Fish Associated With an SAV Community  
(#/100 m<sup>2</sup>)

	March			April			May			June			July			August		
	Z	R	S	Z	R	S	Z	R	S	Z	R	S	Z	R	S	Z	R	S
<i>Anguilla rostrata</i>				3.15	0.44	1.90	1.97										0.22	
<i>Alopias americanus</i>																		
<i>A. pseudoharengus</i>																		
<i>Brevoortia tyrannus</i>				1.40	2.75	70.08	69.26	34.45					0.58					
<i>Anchoa mitchilli</i>	0.56	0.97	1.30	10.63	22.93	27.46	27.17	33.24	52.15	94.49	57.22	50.0	31.60	21.78	42.68	49.73	49.20	14.47
<i>Urolocheilichthys</i>				0.79	1.23		0.39	0.39					0.26	0.26				
<i>Menidia menidia</i>							0.79	0.66										
<i>Menidia martinica</i>							8.27	1.05	0	0.95								
<i>Gasterosteus aculeatus</i>	9.02	0.65	0.43	2.36	0.26	0.33											0.22	
<i>Symphodus fuscus</i>	0.43			1.18	0.96	3.28	1.97	1.71	2.08	5.51	1.54	0.35	4.72	1.57	2.53	3.31	1.95	
<i>Centropomus striata</i>																		
<i>Orthopristis chrysoptera</i>																		
<i>Bairdiella chrysoura</i>							3.15	1.57		1.74	0.71		3.60	4.46	1.13	3.94	2.60	0.22
<i>Cynoscion nebulosus</i>								0.39										
<i>C. regalis</i>																		
<i>Leiostomus xanthurus</i>																	2.01	1.30
<i>Menicirrhus americanus</i>																	1.34	1.10
<i>Gobiosoma kinsburgi</i>										5.00	0.39	3.51	1.74				1.08	0.65
<i>Peprilus sp.</i>				0.39			0.39										1.95	0.66
<i>Paralichthys dentatus</i>								0.39		0.29	0.24	0.35				0.22		
<i>Scophthalmus aquosus</i>								0.66										
<i>Pseudopleuronectes americanus</i>	0.56																	
<i>Tricentrus maculatus</i>										0.29								
<i>Sphaeroides maculatus</i>																	0.22	0.22

Z: *Zostera* bed; R: *Ruppia* bed; S: sand bed

Source: Merriner and Boelherth 1979

TABLE E-II-2

SUBMERGED AQUATIC VEGETATION FOUND IN MARYLAND AND VIRGINIA  
WATERS OF THE CHESAPEAKE BAY

- Callitriche verna  
 \* Ceratophyllum demersum  
Chara sp.  
 \* Elodea canadensis  
Elodea nuttallii  
 \* Myriophyllum spicatum  
 \* Najas spp.  
 \* Nitella sp.  
Potamogeton crispis  
Potamogeton filiformis  
Potamogeton foliosus  
Potamogeton nodosus  
 \* Potamogeton pectinatus  
 \* Potamogeton perfoliatus  
 \* Ruppia maritima  
 \* Vallisneria americana  
 \* Zannichellia palustris  
 \* Zostera marina

\* Dominant in the Chesapeake Bay (Orth et al. 1979, Stevenson and Confer 1978).

The historical data show a general decline in SAV distribution and abundance since the 1950's. Out of 21 river systems where SAV was reported in 1971, 19 showed a decline in the percentage of sample sites with vegetation in 1977 (Figure E-II-7). The occurrence of dominant SAV species in the Susquehanna flats has been documented from 1958 - 1975. Three of the species almost completely disappeared from this area after 1972. Besides showing the decline of SAV on the Susquehanna flats, data also document the increase and subsequent decline of Eurasian watermilfoil (Myriophyllum spicatum) at that site, a phenomenon which occurred throughout the Chesapeake Bay. Studies of Zostera in Virginia show a distinct decline in acreage between 1937 and 1978.

Controlling factors of distribution and abundance. The density of the submerged aquatic beds varies considerably. Maximum standing crop of Myriophyllum spicatum was calculated in June to be 108.16 g/m<sup>2</sup> in the fresh oligohaline zone; Ruppia marina biomass was calculated at 69.5 g/m<sup>2</sup> in July from an area in Eastern Bay; Zostera and Ruppia mean standing crop were calculated at 78.2 g/m<sup>2</sup> and 43.2 g/m<sup>2</sup> in August in the meso-polyhaline areas of the Bay.

Controlling factors of the abundance and distribution of submerged aquatic vegetation includes salinity, light, water quality parameters such as herbicides, turbidity and nutrient enrichment, presence and density of epiphytes, water velocity, critical bed size, proximity to seed beds, and grazing by animals such as waterfowl and rays.

FIGURE E-II-7

Frequency of Occurrence of Vegetated Samples and Indicated Change  
by River Systems. Migratory Bird and Habitat Research Laboratory  
Survey, 1971-1976<sup>a</sup>

Area code	River system	1971	1972	1973	1974	1975	1976	1977 <sup>b</sup>	Number of stations							
		% Veg.	% Veg.	% Veg.	% Veg.	% Veg.	% Veg.	% Veg.	71	72	73	74	75	76	77	
1	Elk & Bohemia Rivers	6.67	0	0	0	0	0	0	15	16	16	16	16	16	16	
2	Sassafras River	30.00	0	0	0	0	0	0	10	10	10	10	10	10	10	
3	Howell & Swan Points	16.67	0	0	0	0	0	0	12	6	12	12	12	12	12	
4	Eastern Bay	34.04	46.51	34.04	36.17	21.74	42.22	28	47	43	47	47	46	45	47	
5	Choptank River	35.00	39.66	19.30	27.69	1.72	41.07	25	60	58	57	58	58	56	60	
6	Little Choptank River	21.05	21.05	0	0	0	15.79	5	19	19	19	19	19	19	19	
7	James Island & Honga River	44.12	35.29	2.94	5.88	5.88	8.82	3	34	34	34	34	34	34	34	
8	Honga River	50.00	40.00	13.33	16.66	10.35	17.84	3	30	30	30	30	29	29	30	
9	Bloodsworth Is.	37.50	22.73	10.87	11.63	6.98	2.22	4	40	44	46	43	43	45	46	
10	Susquehanna Flats	44.44	2.70	0	13.51	11.11	8.57	11	27	37	37	37	36	35	37	
11	Fishing Bay	8.00	4.00	0	0	0	0	0	25	25	25	25	24	25	25	
12	Nanticoke & Wicomico Rivers	0	0	0	0	0	0	0	30	30	30	31	30	30	31	
13	Manokin River	40.00	46.67	13.33	20.00	7.14	6.67	20	15	15	15	15	14	15	15	
14	Patapsco River	0	5.00	4.76	9.52		9.52	14	21	20	21	21	0	21	21	
15	Big & Little Annessex Rivers	70.00	60.00	30.00	57.89	33.33	30.00	30	20	20	20	19	18	20	20	
16	Gunpowder & Bush River Headwaters	11.11	0	0	0		0	11	9	8	7	9	0	9	9	
17	Pocomoke Sound (Maryland)	18.18	10.00	4.76		15.00	9.09	10	22	20	21	0	20	22	22	
18	Magothy River	33.33	0	16.67	16.66	-	16.67	25	12	12	12	12	0	12	12	
19	Severn River	40.00	20.00	26.67	26.67	-	46.15	20	15	15	15	15	0	13	15	
20	Patuxent River	2.00	4.26	0	4.00	0	2.04	2	50	47	50	50	47	49	50	
21	Back, Middle & Gunpowder Rivers	13.64	4.55	4.55	1.55	9.09	4.55	9	22	22	22	22	22	22	22	
22	Curtis & Cove Points	0	0	0	0	0	0	0	20	19	19	19	6	21	21	
23	South, West & Rhode Rivers	0	0	0	0	0	12.50	0	8	10	10	8	8	8	10	
24	Chester River	61.11	36.11	26.47	23.52	25.00	25.71	38	36	36	34	34	36	35	36	
25	Love & Kent Points	0	0	0	12.50	0	0	0	8	8	8	8	8	8	8	
26	Smith Island (Maryland)	64.71	45.46	25.00	36.29	22.22	35.29	24	17	11	12	17	17	17	17	
Total		28.53	20.98	10.49	14.85	8.70	14.97	12	624	615	629	611	552	628	645	

<sup>a</sup> U.S. Fish and Wildlife Service Migratory Bird and Habitat Research Laboratory files 1977  
<sup>b</sup> Preliminary results (Stotts, personal communication)

Source: Stevenson and Confer (1978).

## Emergent Aquatic Vegetation

Importance to the Bay. Wetlands are valued as habitat and food sources for a large number of aquatic and terrestrial organisms, as a source of detritus and nutrients, and in erosion control.

Fish utilize the marsh for spawning, as a nursery, and/or as an adult feeding area, depending on the species. For an example of the diversity of use, the 44 fish species which utilize the marsh in Dorchester County are listed in Figure E-II-8 along with the type of usage, season of usage, and abundance.

Waterfowl and animals such as muskrats and nutria utilize the leaves, stalks, rhizomes, and seeds of the vegetation for food. Muskrats and nutria live year round in the marsh; both migratory and resident waterfowl depend on the wetlands for cover and nesting habitat, as do some song birds. Many birds such as herons and egrets feed on the fish and invertebrates which live in the marsh.

Most of the primary production of tidal marshes enters the vast coastal detrital food web, and nutrients are released upon decomposition. Many estuarine organisms at the lower end of the food chain (e.g. copepod Eurytemora affinis) utilize detritus and/or the microorganisms it supports as a food source. These organisms in turn serve as food for other organisms.

Fresh water marshes tend to be a more important direct food source to waterfowl and animals such as muskrats than brackish water marshes. Both fresh and salt water marshes contribute detritus to the estuary.

There is evidence that freshwater marshes function differently than salt marshes in terms of export from the marsh. Export from freshwater marshes may contain more dissolved organics and salt marshes may export a higher percent of particulate organic material, since freshwater species (e.g. Peltandra virginica) have been shown to decompose more rapidly than Spartina alterniflora a major salt marsh species. Both the dissolved and particulate organic materials contribute to the productivity of the Bay.

Marshes are effective in preventing erosion. Most notable in this role is Juncus roemerianus which has a dense rhizome structure.

Physical description. Emergent Aquatic Vegetation are plants which grow in partially submerged, regularly or occasionally flooded, or in wet soils. They make up the bulk of vegetation in marshes and other wetlands. Wetlands compose the ecotone between the aquatic and terrestrial ecosystems.

The Chesapeake Bay tidal wetlands system comprises one of the great tidal wetlands systems in the United States. In Maryland, tidal wetlands have a total area of about 210,000 acres, while in Virginia there are more than 90,000 acres of tidal wetlands.

There are many classification systems which have been developed for wetlands. Wetlands are generally classified according to the type of emergent aquatic vegetation present. The dominant species depend upon the level of salinity and frequency and duration of flooding.

FIGURE E-II-8

Fish Species Present and the Type of Utilization in a Dorchester County, Maryland Salt Marsh.

Fish species present	Common name	Usage			Season of Usage				Abundance		
		Spawning	Nursery	Adult Feeding	Spring	Summer	Fall	Winter	High	Moderate	Low
<i>Petromyzon marinus</i>	sea lamprey	x									
<i>Carcharhinus leucas</i>	bull shark			x		x					
<i>Carcharhinus milberti</i>	sandbar shark			x		x					
<i>Sphyrna zygaena</i>	hammerhead shark			x		x					
<i>Raja eglanteria</i>	clearnose skate			x		x					
<i>Rhinoptera bonasus</i>	cownose ray			x		x					
<i>Acipenser oxyrinchus</i>	Atlantic sturgeon	x			x				x		
<i>Alosa aestivalis</i>	blueback herring	x			x				x		
<i>Alosa mediocris</i>	hickory shad	x			x				x		
<i>Alosa pseudoharengus</i>	alewife	x			x				x		
<i>Alosa sapidissima</i>	American (white) shad	x			x				x		
<i>Bravoortia tyrannus</i>	Atlantic menhaden		x	x	x	x	x		x		
<i>Dorosoma cepedianum</i>	gizzard shad		x	x		x	x				x
<i>Anchoa mitchilli</i>	bay anchovy	x	x	x	x	x	x	x	x		
<i>Cyprinus carpio</i>	Carp			x			x	x			x
<i>Notropis hudsonius</i>	spottail shiner			x			x	x			x
<i>Ictalurus catus</i>	white catfish		x		x						x
<i>Anguilla rostrata</i>	American eel		x	x	x	x	x	x	x		
<i>Strongylura marina</i>	Atlantic needlefish	x	x	x	x	x	x	x	x		
<i>Hyporhamphus unifasciatus</i>	halfbeak		x	x		x	x		x		
<i>Cyprinodon variegatus</i>	sheepshead minnow	x	x	x	x	x	x	x	x		
<i>Fundulus heteroclitus</i>	mummichog	x	x	x	x	x	x	x	x		
<i>Fundulus majalis</i>	striped killifish	x	x	x	x	x	x	x	x		
<i>Lucania parva</i>	rainwater killifish	x	x	x	x	x	x	x	x		
<i>Syngnathus fuscus</i>	northern pipefish	x	x	x	x	x	x	x	x		
<i>Roccus americanus</i>	white perch	x	x	x	x	x	x	x	x		
<i>Roccus saxatilis</i>	striped bass	x	x	x	x	x	x	x	x		
<i>Bairdiella chrysura</i>	mademoiselle		x	x		x	x			x	
<i>Cynoscion regalis</i>	greytrout (weakfish)		x	x		x	x				x
<i>Cynoscion nebulosus</i>	spotted seatrout		x	x		x	x				x
<i>Pomatomus saltatrix</i>	bluefish		x	x		x	x		x		
<i>Leiostomus xanthurus</i>	spot		x	x		x	x		x		
<i>Micropogon undulatus</i>	Atlantic croaker		x	x		x	x				x
<i>Pogonias cromis</i>	black drum		x	x		x	x			x	
<i>Sciaenops ocellatus</i>	channel bass (red drum)		x	x		x	x				x
<i>Chasmodes bosquianus</i>	striped blenny	x	x	x	x	x	x	x			x
<i>Parpilus astepidatus</i>	butterfish (Southern harvestfish)		x		x	x	x				x
<i>Menidia menidia</i>	Atlantic silverside	x	x	x	x	x	x	x	x		
<i>Paralichthys dentatus</i>	summer flounder		x			x					x
<i>Pseudopleuronectes americanus</i>	winter flounder		x		x			x		x	
<i>Trinectes maculatus</i>	hog choker	x	x	x	x	x	x	x	x		
<i>Gobiosoma strumosus</i>	clingfish (skittletfish)	x	x	x	x	x	x	x			x
<i>Opsanus tau</i>	oyster toadfish	x	x	x	x	x	x	x		x	
<i>Sphaeroides maculatus</i>	northern puffer		x			x					
Total		20	31	32	24	34	30	18	21	4	12

\* Adults present during spawning migration, but not used as a spawning ground per se.

One classification scheme divides the wetlands into three categories: coastal freshwater, coastal brackish water and brackish irregularly flooded marsh. The coastal freshwater marsh is confined to freshwater. The coastal brackish water marsh occurs from low mesohaline to polyhaline regions and is flooded regularly. The brackish irregularly flooded marsh is found in low mesohaline to euhaline regions in areas subject to less tidal inundation than coastal brackish.

Coastal fresh marshes typically have a high diversity of species and a mixture of abundant species. The following emergent plant species are very common in coastal fresh marshes although other species are also found:

Acorus calamus  
Hibiscus palustris  
Leersia spp.  
Nuphar leiteum  
Peltandra virginica  
Phragmites australis

Polygonum spp.  
Pontederia cordata  
Sagittaria latifolia  
Typha angustifolia  
Typha latifolia  
Zizania aquatica

Coastal brackish marshes generally have a lower diversity than fresh water marshes with species often occurring in large monospecific stands. Emergent plant species which are common in coastal brackish marshes include the following:

Baccharis halimifolia  
Distichlis spicata  
Iva frutescens  
Limonium carolinianum

Salicornia spp.  
Scirpus spp.  
Spartina alterniflora  
Typha spp.

Brackish irregularly flooded marshes are generally dominated by Juncus roemerianus. Species diversity is usually extremely low because Juncus typically occurs in large monospecific stands. Other species such as Spartina alterniflora, S. patens, and Distichlis spicata may be present near the margins of the Juncus marsh.

Tidal wetlands are classified differently by Virginia and Maryland. The acreages of each type by county are given in Figure E-II-9 and Figure E-II-10.

Tidal marshes in the Chesapeake Bay area are productive systems. Researchers have measured standing crop in several locations around the Bay. The standing crops of individual community types ranged from 22 g/m<sup>2</sup> to 2160 g/m<sup>2</sup> with most of the communities between 500 and 1400 g/m<sup>2</sup>.

Controlling factors. The differentiation between fresh water marsh and salt water marsh is determined by two factors: salinity and period of inundation. Fresh water marshes are found at the head of the Bay and at the tidal limits of the major tributaries. Salt water marshes are found downstream of freshwater marshes, where the salinities are 3 percent or greater.

Within fresh and salt water marshes there is a progression of species from those near open water to those of the upland. Fresh and salt marshes give way to uplands as the elevation of the land increases. The transition to uplands species involves two primary

FIGURE E-II-9  
Acreage of Tidal Wetlands and Dominant Species in 17 Virginia Counties.

County	<i>Spartina alterniflora</i>	<i>Juncus roemerianus</i>	<i>Spartina patens</i>	<i>Spartina alterniflora</i>	<i>Iva frutescens</i>	<i>Baccharis halimifolia</i>	<i>Spartina cynosuroides</i>	<i>Typha</i> spp.	<i>Phragmites australis</i>	<i>Peltandra virginica</i>	<i>Pontederia cordata</i>	<i>Sclirpus</i> spp.	Other	Total
Accomack (Bayside)	461	11421	2957	2110	2013	200	-	608	427	23918				
Arlington, Fairfax, Alexandria	-	-	-	-	-	221	10	47	301	934				
Caroline	-	-	-	-	-	9	-	4	431	485				
Essex	15	-	58	32	2819	860	34	698	119	526				5214
Gloucester	257	945	691	435	264	104	-	36	78	269				6329
King George	118	-	10	43	570	291	-	108	57	874				2122
Lancaster	328	328	61	71	231	-	-	-	158	1190				
Mathews	839	1248	552	230	41	-	-	-	4	2937				
New Kent	709	-	-	8	2159	109	-	483	99	1706				5467
Newport News, Fort Eustis	929	1050	314	118	332	13	3	9	15	86				2883
Northampton (Bayside)	836	126	142	218	33	38	1	-	5	9				1404
Northumberland	213	400	309	132	121	-	-	-	-	351				1560
Spotsylvania	-	-	-	-	-	-	-	-	-	7				7
Stafford	-	-	-	13	30	321	-	236	8	728				1337
Westmoreland	413	10	137	285	496	420	-	235	34	527				2590
York, Poquoson	2656	1468	1797	597	218	-	-	-	-	-				6991
TOTAL	11474	16996	7028	4274	9329	2586	48	2153	1074	6404				55368

Data compiled from VIMS Marsh Inventories 1973-1979.



factors. At the lower level of the transition zone, the species composition is determined by the frequency of tidal inundation. At the upper level of the transition zone, competition with upland species limits the species composition.

Salt marshes in the Chesapeake Bay have a lower zone, usually composed of Spartina alterniflora, which receives daily tidal inundation, and an upper zone where the tides do not reach on a daily basis. The upper zone usually consists of a short grass meadow, composed of Spartina patens and Distichlis spicata, frequently interposed with Juncus roemerianus. Other, less abundant species may be present. The transition zone between salt marsh and uplands is often marked by Iva frutescens and Baccharis halimifolia, with Baccharis being the most landward plant.

The freshwater marsh - upland boundary is more difficult to identify. This is probably due to the absence of the salinity factor in freshwater marsh delineation. Patterns of zonation within the marsh are also difficult to identify, which is made even more difficult by the greater species diversity in freshwater marshes. Prevalent zonation and associations are between Nuphar luteum in deeper water and Peltandra virginica/Pontederia cordata above it. Above this zone the species can become quite diverse, and, in the absence of relief, the marsh may merge very gradually into swamp forest or wet upland.

### Zooplankton

Importance to the Bay. As in most estuarine food webs, zooplankton represent the important primary consumers in the Chesapeake Bay. Thus, zooplankton are a key link in the transfer of phytoplankton production to higher trophic levels. Zooplankton regulate phytoplankton abundance and the availability of food for higher organisms.

Zooplankton, particularly copepods, are an important food source for larval and adult fish, including menhaden. High densities of certain copepods, cladocerans and rotifers have been shown to be critical to the survival and development of larval anadromous species such as striped bass.

Ctenophores and cnidarians (combjellies and jellyfish) are an important fraction of the Bays plankton community. They exert significant grazing pressure on other zooplankton, particularly during the summer months. While the primary food of these ctenophores and cnidarians is zooplankton, they also ingest a certain amount of larger phytoplankton, detritus and associated ickthyoplankton and in the case of cnidarians, juvenile and small adult fish. The major consumers of these organisms are (1) larger species of ctenophores and cnidarians and (2) butterfish and harvest fish (Peprilus sp.). Ctenophores and cnidarians are also important to the cycling of the nutrients phosphorus and nitrogen. Zooplankton fecal material enters the detritus/bacteria pathway and may in turn be used as food for other species.

Another function of zooplankton is that in filtering the water for food sources, many zooplankton also remove inert suspended solids from the water column. Ingested inert materials are combined in the fecal pellet, which then sinks due to its density. Copepods in particular have been described in this function. This function may be significant in reducing turbidity in areas since copepods are present in such densities that they filter the equivalent of 25 percent of the water in the entire Chesapeake Bay every day.

Physical description. Zooplankton are usually small/microscopic animals from several phyla. The group is composed of holo-plankton, species which are planktonic through life, and meroplankton, species which spend only part of their life cycle as plankton. The majority of the zooplankton are primary consumers which utilize phytoplankton for a food source. Some components are carnivorous forms such as ctenophores and the planktonic larvae of invertebrates and fish.

Copepods are often the dominant members of the zooplankton community, both in numbers and biomass. Thirty-three families and 73 species of copepods have been reported in the Bay. Of these 73 species, about 5 are abundant. In a study done on the Patuxent River, copepods comprised 98 percent of total zooplankton (excluding ctenophores and cnidaria). Eurytemora affinis dominated upriver in low salinities, while Acartia tonsa was most abundant downstream except during March and April when it was replaced by A. clausii.

Population densities of copepods are commonly 100,000 to 200,000 individuals per  $m^3$  and sometimes exceed 1,000,000 per  $m^3$  during the period from April to October. Annual productivity ranges from 16-28 g. dry weight per  $m^2$  per year depending on location in the estuary.

Controlling factors on distribution and abundance. The distribution of the Bay's zooplankton is determined by salinity, season (light and temperature), availability of food (phytoplankton and detritus) and predators. A relatively sharp distinction in zooplankton species composition has been documented at 5 ppt. A study done on the mainstream of the Bay found species composition in the 20 to 5 ppt salinity zone to be dominated by Acartia tonsa or clausi, Oithona colcava, Podon polyphemoides and the rotifer Synchaeta. Below 5 ppt dominant species include Eurytemora, Bosmina longirostris and Brachionis calyciflorus.

In the upper Bay and upper reaches of the tributaries, the zooplankton composition is greatly influenced by the level of freshwater inflow; while intrusion of typical marine species often occurs in the lower Bay.

The factors controlling the distribution of copepods were documented above in the description section. Some specifics of ctenophores and cnidarians are provided there as well, although knowledge on the functional ecology of these species is lacking.

Relatively little is known about the abundance and seasonality of micro-zooplankton such as rotifers, tintinnids and other protozoans. Since these forms feed typically on nanoplankton, are extremely abundant, and have rapid metabolic rates and fast turnover rates, they probably contribute greatly to energy flux through the ecosystem. What is known, however, reveals rotifers to be an important source of food for some species of larval fish in oligohaline nursery areas. Tintinnids have been documented to be present in numbers greater than 500,000  $m^3$ , but little has been published on their role in the Bay.

#### Benthic Organisms

Importance to the Bay. Benthic organisms represent a major component of the estuarine ecosystem. Many benthic organisms are primary food sources for fish, waterfowl, and

crabs; others are of economic importance. They play major roles in nutrient recycling, sedimentation, sediment chemistry, oxygen dynamics and marine fouling.

Physical description. The benthos is comprised of organisms, mainly invertebrates, which live associated with the substrate. These may be epifauna - species which live attached on or above the bottom - or infauna, species which burrow into the substrate. Some species, such as crabs, are benthic oriented, but are motile or vagile, capable of considerable swimming. Other species are benthic only at some stage of their life cycle, such as the sea nettle (Chrysaora quinquecirrha). The benthos is often divided into macro - (greater than 0.5 mm), meio - (0.5 - 0.1 mm), and micro-benthos (less than 0.1 mm). Of these, only the macro-benthos is well-known in Chesapeake Bay. Because of their importance to the Bay, there is extensive literature on Chesapeake Bay benthic invertebrates. However, many of these have dealt with a few commercially important species such as oysters or clams. Noncommercial species have not fared as well, and groups such as meio- or microfauna are virtually unknown.

Sessile epifauna are generally limited to hard substrates, and are extremely numerous in these environments. Many of these are considered to be "fouling organisms" which have been extensively studied because of the costs to marine industries, and potential damage to oyster beds. Biofouling of oyster beds by a variety of organisms in the mid- and lower Bay, has been investigated. Researchers found wide variability in epifaunal communities depending on season, salinity, temperature, time of recruitment, turbidity and effects of competition for space. The community was dominated by barnacles in autumn, winter, and spring, while ascidians predominated in summer. Both competition for space and sedimentation affected survival of the various organisms.

Infaunal benthic organisms have been extensively studied in the Chesapeake Bay. The earliest surveys were mainly qualitative and directed towards commercially important species such as the oyster or clam. Investigations of benthic assemblages and organism interrelationships have become more common since the 1950's. The abundance, growth, and survival of six bivalves correlated to varying degrees with sediment type. A sample of benthic infauna in the upper Bay oligohaline zone, found that the majority of the 66 species recorded were soft-bottom deposit-feeders well adapted to a turbid environment. Only three species (Cyathura polita, Leptocheirus plumulosus, and Scolecopides viridis) were permanent dominants; other species showed seasonal cycles of abundance mediated by temperature or salinity. Average biomass values ranged between 0.4 and 6.4 g dry wgt m<sup>-2</sup>; population densities and biomass were lowest during the spring months. Another upper Bay study again showed benthic populations to be dominated by a few species: four taxa represented 77 percent of the specimens collected. Sediment type was more important than depth in determining station similarity, although deep stations were the least diverse.

The distribution of macro benthos against the Bay-York River salinity gradient was investigated. In general faunistic changes were gradual and uniform, although certain zones of accelerated change corresponded to particular salinity regime. The 176 species recorded could be divided into five groups based on origin, extent into estuary, life history, and salinity tolerances (Figure E-II-11). These are:

- stenohaline marine,
- euryhaline marine

**SPECIES**

**STENOHALINE  
MARINE**

**EURYHALINE  
MARINE**

**EURYHALINE  
OPPORTUNISTS**

**ESTUARINE  
ENDEMIC**

**FRESH  
WATER**

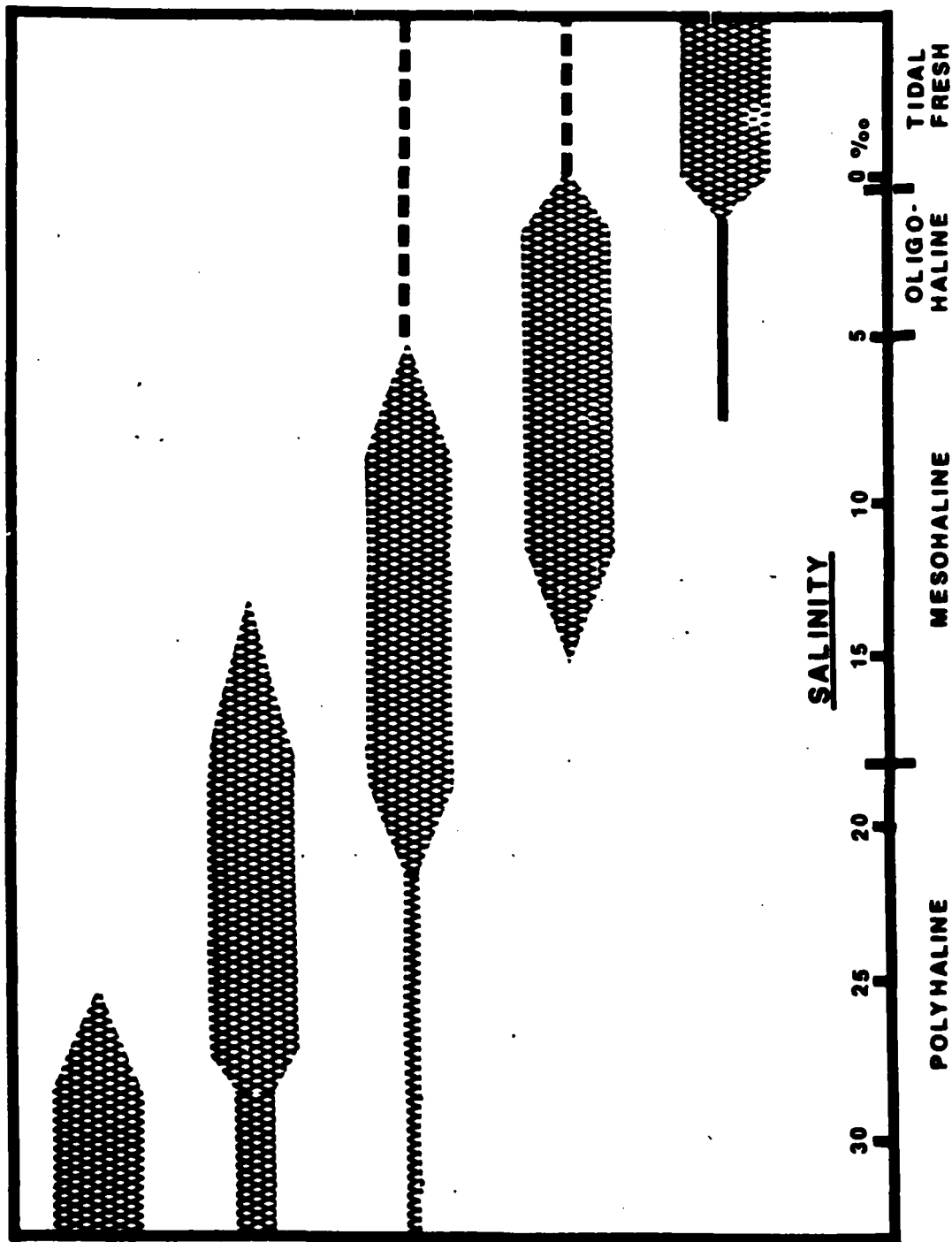


FIGURE E-II-11 ZONATION OF ORGANISMS ALONG THE ESTUARINE SALINITY GRADIENT.

Source: Boesch 1977

- euryhaline opportunistic,
- estuarine endemic, and
- freshwater.

Sampling of the polyhaline macrobenthos of the lower James River found that over 60 percent of the 93 species exhibited marked periodicity in their occurrence, reflecting seasonal spawning and recruitment. Diversity was highest in sand and muddy-sand sites, and during warmer months.

An investigation of the mesohaline, oligohaline, and freshwater areas of the James River showed a gradual decrease in diversity along the salinity gradient, reaching a minimum in the oligohaline and tidal fresh water areas, then increasing again in the nontidal limnetic zone. This apparently reflected both salinity stress and lack of diverse habitats.

Studies in the mesohaline communities near Calvert Cliffs, found depth and sediment type to mediate the structure of these associations. Seasonal depletion of the deepest (9 m) habitat occurred due to summer hypoxia, followed by fall-winter-spring re-colonization.

Benthic organisms may also serve as habitats for other species. The oyster is of particular importance in Chesapeake Bay. Oyster bars shelter densities of organisms an order of magnitude or so greater than the surrounding soft-bottom communities. In addition, productivity can be greatly enhanced. This is similar to the effects of submerged aquatic vegetation beds, and emphasizes the importance of shelter and substrate stability to benthic communities.

Controlling factors on distribution and abundance. The seasonal and spatial distribution of benthos is primarily mediated by physical factors of the environment (chiefly salinity, substrate type, dissolved oxygen, and temperature). In addition, predators exert a controlling effect on the population densities of many Chesapeake Bay benthic organisms.

### Fish

Importance to the Bay. Fish are a very conspicuous component of the Chesapeake Bay fauna. Fish and shellfish are the resources for which Chesapeake Bay is perhaps best known.

Fish inhabit nearly every habitat in the Bay, and, collectively, consume at all trophic levels. Most abundant are the grazers (menhaden), consumers of zooplankton (anchovies, silversides) and bottom invertebrates (hogchoker, white perch). Some are generalized predators (striped bass) while others live mainly on molluscs (drums, cownosed rays), fishes (bluefish), or crustaceans (oyster toadfish).

Both commercial and sport catches are important in the bay. In 1974, an estimated 35 percent of the finfish catch was commercial and 65 percent was sport fishing (not counting menhaden and fish for reduction). Greater than 100,000,000 pounds of fish were harvested in 1974.

Sampling surveys in Maryland in 1974 have shown that for five species of finfish the recreational catch was greater than the commercial catch. These species are striped bass, bluefish, white perch, croaker and spot.

Physical description. There are 287 species of fish which have been reported to occur within the Chesapeake Bay drainage below the fall line or within tidewater. The fish fauna may be divided into four ecological groups based upon salinity and migration patterns: diadromous species, estuarine species, marine species and freshwater species. Eleven species of diadromous fishes occur, including 10 species which are anadromous and 1 catadromous. Only 24 species are resident fauna of the estuary and therefore classified as estuarine. (Actually this number is augmented by three anadromous fishes and two marine species.) Of the 174 marine species, 59 are regular summer visitors, 93 are sporadic summer visitors, six are regular winter visitors and 16 are sporadic winter visitors. The freshwater component of the fish fauna includes 46 species which normally inhabit the coastal plain and 32 species which occur only occasionally as strays from above the fall line or which rarely enter the Chesapeake drainage through the Dismal Swamp.

Fish make up the bulk of the Chesapeake Bay nekton species, although various life stages may be part of the benthos or plankton. Nekton are those animals which are free swimming and essentially independent of water movements. Fish are divided into two groups based upon the primary feeding area of the adult: demersal and pelagic. Demersal fishes are those which are associated with the bottom and feed chiefly on benthic organisms, such as spot (*Lieostomus xanthurus*). Pelagic species feed in the water column chiefly on fish and microinvertebrates, or plankton.

Controlling factors of distribution and abundance. Finfish population sizes are a basic concern in the Chesapeake Bay. This is due to their direct economic importance and recognition by the general public.

Much is known of the biology of the economically important species and a few others which are important forage species (bay anchovy, silversides). There is also considerable literature on the physiology of certain species which are suitable for laboratory experimentation (mummichog and oyster toadfish). However, many species remain poorly understood from a biological viewpoint because they are infrequently collected or seem to have little direct economic importance.

Population size can be considered in numbers of organisms (population) or weight of organisms (biomass). Of these, biomass is often considered the most ecologically useful parameter.

The population growth of any particular species of fish is based upon current population plus recruitment minus exports. Recruitment is a function of birth rate, survival rate of juvenile fishes, growth rate, and import from sources outside the Bay. Exports include out migration from the Bay, natural death, loss as prey for other animals, and harvest. These factors in turn depend upon such things as feeding pressure of predators, fishing pressure, food availability, ability to switch food source, salinity, temperature, precipitation, water quality, availability of suitable spawning habitat, crowding and competition.

There are population growth equations available for individual economically important species which take this information into account. However, biomass determinations for

the fish of the Chesapeake Bay and tributaries are sparse. Thus population and biomass estimates are frequently made from landings data. In addition to the National Marine Fisheries Service Annual Statistical Digest giving landings by species and by state, ten localized studies are available within the Study Area giving landings and sometimes catch per unit effort over a range of years for many major species. Researchers have tried to correlate physical factors with commercial fish and shellfish landings. These studies have shown that more than 50 percent of the catch variation in most species can be explained by annual variations in temperature, salinity and precipitation. This suggests that economic effects such as market-value may be less important than previously thought, and that catch data can be a useful indicator of ecosystem productivity, at least to a limited degree for most fish species.

Juvenile fish survival and growth is an important component of the adult population and available catch. Many marine, estuarine, and freshwater fishes utilize the low salinity of the Bay as a nursery. The importance of this common nursery is illustrated in Figure E-II-12. Alosid juveniles depend upon anchovy and silversides as well as young menhaden for their growth in this nursery area.

Dietary requirements are most specific for larval fishes particularly in terms of food value, food availability, and food particle size. For example, the concentration of Brachionis (a rotifer) and Bosmina (a cladoceran) in the nursery area has been shown to strongly influence larval growth rates and survival of larval Alosa and Morone fishes.

Habitat modifiers are important factors in the growth of many fish. For example the oyster Crassostrea is a habitat modifier for a variety of benthic invertebrates which in turn are food for the croaker. Croakers tend to associate with oyster reefs and major changes in the extent or condition of the oyster reefs would be reflected in the growth and condition of the croaker. Another habitat modifier for fish is eel grass, Zostera marina. Eelgrass provides cover for forage fish, richer species diversity for benthic grazers and an additional food source in the form of epiphytes. Zostera beds are important to the juvenile populations of silverside, spot, croaker and white perch.

### Wildlife

Importance to the Bay. Grouped under the wildlife heading are marine birds, waterfowl, amphibians, reptiles and mammals. These animals are all important to the productivity and ecological balance of the Bay, serving as both predator and prey. Many directly or indirectly contribute to the economy of the area and to the human enjoyment of the Bay.

The Chesapeake Bay is well-known for its waterfowl hunting. During the 1977 and 1978 hunting seasons the mallard was the species most frequently taken. Black ducks, scaup, wood duck and Canada geese were also taken. (See Figure E-II-13) Total harvest for the Chesapeake Bay in 1978 was 316,900 ducks, and 137,400 Canada geese.

The importance of waterfowl to the productivity of the Bay is evident by examining their food habits. Food habits of waterfowl on the Chesapeake Bay and adjoining estuaries vary greatly from one species to another, from one habitat to another, and also are influenced by seasonal changes in availability of foods. For the majority of waterfowl,

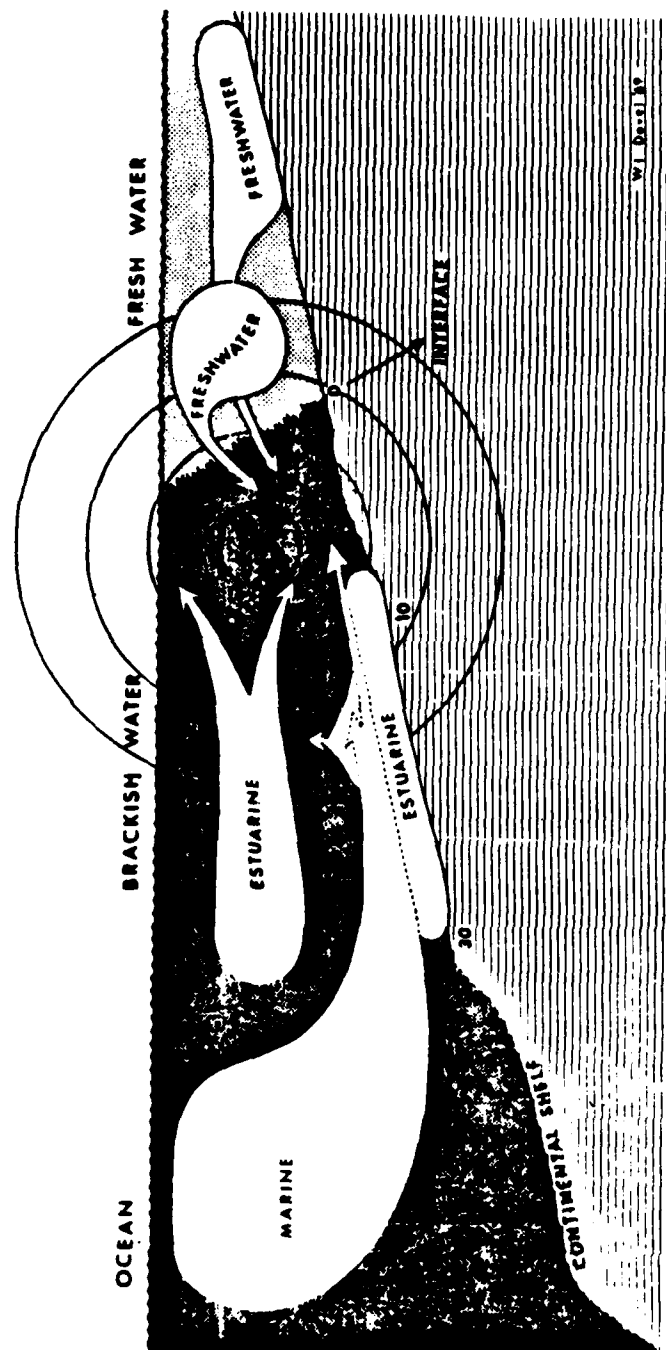


FIGURE E-II-12 SCHEMATIC DIAGRAM OF MOVEMENTS OF ESTUARINE-DEPENDENT FISH LARVAE AND JUVENILES TOWARD A COMMON LOW SALINITY NURSERY AREA

Numbers represent approximate salinity in parts per thousand (‰)

Source : Dove, 1969

FIGURE E-II-13

Percentage composition of the 1977 and 1978  
Hunting Kill for Maryland and Virginia

SPECIES	PERCENTAGE OF KILL IN EACH STATE			
	<u>Maryland</u>		<u>Virginia</u>	
	1977	1978	1977	1978
Mallard	33.3	38.8	23.5	30.3
Black Duck	12.9	24.7	8.4	14.1
Gadwall	0.8	1.8	4.8	5.6
Baldpate	2.2	4.1	6.0	6.0
Green-winged Teal	2.2	10.4	5.0	5.1
Blue-winged Teal	0.1	1.0	1.0	3.7
Shoveler	0.1	1.0	0.6	0.1
Pintail	2.2	1.8	2.4	1.5
Wood Duck	0.5	4.9	21.6	17.4
Redhead	0.0	0.0	0.0	0.0
Canvasback	0.0	0.0	0.0	0.0
Greater Scaup	3.3	0.2	0.8	0.4
Lesser Scaup	20.6	0.2	10.5	0.3
Ringneck	0.1	0.2	4.3	6.0
Goldeneye	0.7	2.0	2.1	1.3
Bufflehead	3.9	2.6	4.0	3.1
Ruddy	0.7	0.2	0.2	0.6
Old Squaw	3.8	1.8	0.8	0.0
Scoters	6.2	1.1	0.4	0.0
Hooded Mergansers	0.3	0.0	1.8	2.3
Other Mergansers	0.0	0.0	0.5	0.0
Other ducks	0.0	0.0	0.0	0.0
-----				
TOTAL RETRIEVED KILL (number of ducks)	74,995	183,772	130,077	133,140

Source: Administrative report, U.S. F.W.S., 21 June 1979.

widgeongrass (Ruppia maritima) probably is the most important single food item. Corn, is an important food for many kinds of waterfowl. Other food plants that are commonly used include wildcelery (Vallisneria americana), eelgrass (Zostera marina), olney threesquare (Scirpus olneyi), and dotted smartweed (Polygonum punctatum). The more important animal foods in the region are the bivalve Baltic macoma (Macoma balthica), the little surf clam (Mulinia lateralis), the saltmarsh snail (Melampus bidentatus), various tiny gastropod mollusks (including Littoridinops sp., Bittium sp., and Acteocina canaliculata), amphipod crustaceans (Gammaridae), mud crabs (Xanthidae), and inidge larvae (Chironomidae).

Aside from serving as favorite game species for many sportsmen, ducks and geese are preyed upon by mammalian and avian predators, including the red fox, gray fox, mink, otter, raccoon and various hawks and owls. In addition, dead waterfowl are utilized as food by carrion-eaters, including the turkey vulture, common crow, fish crow, herring gull, and ring-billed gull. During the spring and early summer, the eggs of breeding ducks along the Eastern Shore are often devoured by crows, gulls, raccoons, skunks, and pilot black snakes.

There are no estimates of the overall abundance of amphibians in the Chesapeake Bay region, and there is little information on the relative abundance of the various species. However, the numbers of individuals within single populations of certain species may be very large. It has been reported that a single breeding congress of Hyla cinerea may contain thousands of individuals.

Although a number of species of amphibians are seldom observed during most of the year (and might consequently be considered rare), they are conspicuously abundant during the time of breeding. Examples include Scaphiopus holbrooki, Ambystoma maculatum, and Ambystoma tigrinum.

Although no specific estimates exist, it is probable that Bay amphibia are important factors in the food chains of marsh and aquatic areas. Amphibians are eaten by fish, reptiles and mammals. Amphibians in turn eat a variety of food items. Tadpoles are usually regarded as vegetarians, but are occasionally carnivorous, and sometimes cannibalistic. Salamander larvae, and adult toads, frogs, and salamanders are entirely carnivorous, and primarily insectivorous, although they also consume reptiles, amphibians and fish. The importance of amphibians in controlling pest insects such as the mosquito has not been studied in the Chesapeake area, but this control function is likely, given observations in other systems.

The importance of the reptiles to the productivity, ecological balance and health of the Bay is apparent from a description of the trophic interactions of lizards, snakes, fresh water turtles and sea turtles. Lizards and snakes are preyed upon by a wide variety of reptiles, birds, and mammals, and form a significant link in the food chain in the Chesapeake Bay region. Except for hatchlings, which are sometimes eaten by birds, turtles have few natural enemies. Some species, however, are harvested by man.

Regional lizards are predominately insectivorous, although all of them consume a variety of other invertebrates including snails, spiders, and millipedes. Large specimens of Eumeces occasionally eat young lizards and mice. Bay area snakes are all carnivorous, and the food varies greatly from species to species. The diet of a single species may contain a wide variety of food items. For example, it has been documented that Coluber constrictor feeds on reptiles, mammals, birds, insects and amphibians (arranged in

decreasing order to percent frequency). Certain water snakes subsist almost exclusively on frogs and fish while the king snake, Lampropeltis getulus, frequently feeds on other reptiles including the copperhead, Agkistrodon contortrix. The smaller snakes (Diadophis, Storeria, Virginia) feed, collectively, on insects, insect larvae, and salamanders. Only one regional snake, Farancia erytrogramma, has a highly specialized diet. Studies have shown that it feeds exclusively on the common eel, Anguilla rostrata.

Among the fresh water turtles, at least five species (Clemmys insculpta, Chrysemys picta, Terrapene carolina, Chelydra serpentina, and Sternotherus odoratus) are omnivorous. Diets vary widely, however, among these species. Thus 61 percent of the diet of Chrysemys picta consists of plants, while Sternotherus odoratus consumes fish, carrion, crayfish, insects, snails, clams, and plants (arranged in decreasing order of frequency eaten). Clemmys guttata is almost exclusively insectivorous. Chelydra serpentina is a voracious feeder, and sometimes attacks and drowns ducks floating in the water. Figures of percent composition of its food, however, indicate that it feeds mainly on plants, fish, and carrion.

Malaclemys terrapin, restricted as it is to the estuarine environment, feeds mainly on crustaceans and molluscs. With the exception of Chelonia mydas, which is exclusively vegetarian, the sea turtles are omnivorous. As a group they consume aquatic vegetation, jellyfish, sea urchins, molluscs, crabs, sponges, and fish. The leatherback turtle may feed selectively on jellyfish, and the throat of this species is especially modified to assist in swallowing this prey.

Mammals contribute to the trophic structure of the Bay by serving as both predator and prey. Some are also harvested by man. Mammals inhabit a variety of habitats from open water (whales, dolphins, seals) to marshes (mole, rabbit, nutria, raccoon) and adjacent uplands (raccoon, fox). A variety of foods support the mammals. For example, the preferred food of muskrat is olney three-square, cattails and peckeril weed; beavers prefer sweetgum, pine and red cedar trees; otters feed heavily upon crayfish and minnows; and mink consume mice, rabbits, frogs, snakes, salamanders, birds, crawfish and muskrat. Mammals are consumed by a variety of animals including birds, reptiles and amphibians. Deer are hunted by man.

**Physical Description.** Numerous waterfowl and shorebirds, and some water-oriented amphibians, reptiles, and mammals use the estuary and adjacent wetlands for food, shelter, and breeding areas. The dependence on the estuary varies from species to species.

There are 223 known species of birds dependent upon the open waters or wetlands of the Chesapeake Bay. Many birds are migrants and utilize the area seasonally. Birds have been categorized into habitat groups: open water (86 species), wooded swamps (30 species), fresh marsh (29 species), salt marsh (28 species), fresh and salt marsh (23 species) and beach (20 species). Open water species include the osprey and caspian tern. The marsh, swamp, and beach categories are mostly waders, ducks, rails, shorebirds, terns and passerines.

Chesapeake Bay is the constricted neck in the gigantic funnel pattern that forms the Atlantic Flyway. Most of the waterfowl reared in the area between the western shore of Hudson Bay and Greenland spend some time in the marshes of the Bay and its tributaries during their migrations. Good wintering areas adjacent to preferred upland feeding grounds attract more than 75 percent of the wintering population of Atlantic Flyway Canada geese. The marshes and grain fields of the Delmarva Peninsula are particularly attractive to Canada geese and grain-feeding swans, mallards, and black ducks. The Susquehanna Flats, located at the head of the Bay, support flocks of American widgeon in the early fall, while several species of diving ducks, including canvasback, redhead, ringneck, and scaup, winter throughout Chesapeake Bay. About half of the 80,000 whistling swans in North America winter on the small estuaries in or around the Bay. While the Chesapeake is primarily a wintering ground for birds that nest further north, several species of waterfowl, including the black duck, blue-winged teal, and wood duck, find suitable nesting and brood-raising habitat in the Bay Region.

In addition to waterfowl, many other species of birds are found in the Bay Area. Some rely primarily on wetlands for their food and other habitat requirements. These include rails, various sparrows, marsh wrens, red-winged blackbirds, snipe, sandpipers, plovers, marsh hawk, shorteared owl, herons, egrets, gulls, terns, oyster catcher, and curlews. Many of the above species are insectivores, feeding on grasshoppers, caterpillars, beetles, flies, and mosquitoes, while others feed on seeds, frogs, snakes, fish, and shellfish. There are numerous other birds which rely more heavily on the wooded uplands and agricultural lands for providing their basic habitat and food requirements. Among these species are many game birds, including wild turkey, mourning dove, bobwhite quail, woodcock, and pheasant. It should be emphasized that some of these species require both an upland and a wetland habitat. Significant populations of ospreys and American bald eagles also inhabit the Bay Region.

There are 43 species of amphibians known to occur in the vicinity of the Chesapeake Bay. This includes 17 species of salamanders, 25 species of frogs, and 1 species of siren. Most of these amphibians roam freely through a variety of habitats. Frogs of the Chesapeake Bay normally reproduce from early spring to mid-summer. Salamanders are reproductively active throughout most of the year. All of the regional amphibians hibernate during the winter, but the extent of hibernation varies considerably from species to species.

There are 58 species of reptiles reported to occur in the Chesapeake Bay Region. This includes 24 species of turtles, 7 species of lizards, and 28 species of snakes. Reptiles occur in a variety of habitats. Most reptiles show a definite habitat preference, but are not wholly restricted to the preferred habitat. Exceptions include Malaclemys terrapin which is found only in brackish water; Clemmys muhlenbergi which is restricted to wet grassy meadows laced with flowing water and having good plant cover; and Farancia erytrogramma which is generally restricted (probably as a consequence of its specialized diet) to large coastal spring runs having fast-flowing clear water, cool summer temperatures, and neutral pH. The sea turtles and leatherbacks are wholly aquatic and restricted to marine or estuarine waters having relatively high salinities.

There are no estimates of population densities of individual species of reptiles within the Chesapeake Bay Region. Most of the species are generally abundant within their preferred habitat.

Generally speaking, reptiles mate in May and June in the Chesapeake Bay Region, and young are produced from July to early October. All of the regional lizards and turtles are oviparous, while the snakes may be either oviparous or oviviparous. The sea turtles (families Cheloniidae and Dermochelyidae) undertake extensive breeding migrations, usually to specific nest sites on tropical and sub-tropical beaches and do not breed in the Chesapeake Bay Region. All of the regional reptiles hibernate during the colder months, but the extent of hibernation varies considerably from species to species. Thamnophis sirtalis, for example, may emerge as early as February, while Agkistrodon contortrix is seldom seen before May.

The Chesapeake Bay Region is also home for most of the common mammals which are native to the coastal Mid-Atlantic Region. The interspersed forest and farmland and the proximity of shore and wetland areas form the basis for a great variety of ecological systems. The abundance of food such as mast and grain crops and the high quality cover vegetation found on the wooded uplands and agricultural lands support good populations of white-tailed deer, cottontail rabbit, red fox, gray fox, gray squirrel, woodchuck, opossum, and skunk. The various vegetation types found in wetland areas provide indispensable natural habitat requirements for beaver, otter, mink, muskrat, marsh rabbit, and nutria. In addition, there are numerous species of small mammals which inhabit the Study Area and are integral parts of both the upland and wetland food cycles.

Controlling factors of distribution and abundance. The distribution and abundance of the wildlife of the Chesapeake Bay are generally a function of available food, cover and breeding areas. So any factors which affect these variables will affect the dependent organisms.

Because these organisms feed high up the food web, they are dependent upon the success of lower trophic items for their food (i.e. phytoplankton, zooplankton, emergent aquatic vegetation, submerged aquatic vegetation, benthic organisms and fish). Some wildlife are omnivorous and can switch food depending upon what is available. For example, there are indications that canvasbacks have shifted their diets from predominantly plant to primarily animal, possibly as a result of the decline in submerged aquatic vegetation in the Bay. It has shown that canvasbacks in the Maryland part of Chesapeake Bay have moved from areas where submerged aquatic vegetation was abundant to areas in the Bay where the bivalve Macoma balthica has become abundant.

Some species are more specific in their food requirements and therefore are more dependent upon the survival of that particular species. Some waterfowl, such as the redhead, seem to be this type of animal. The decline of submerged aquatic vegetation, an important food source for the redhead, has affected the distribution and abundance of that species in the Chesapeake Bay.

Submerged aquatic vegetation and emergent aquatic vegetation both serve as food cover and/or breeding areas to a variety of organisms up and down the food web and thus are a controlling factor in the distribution and abundance of wildlife.

Competition with other species for food cover and breeding areas is another factor affecting wildlife. Many species may be affected by a change to one species. For example, the introduced species nutria occupies the same habitat as muskrat, and

muskrat have shown a decline since the introduction of nutria. Nutria also compete with small birds although the impact has not been quantified.

## BIOLOGICAL INTERACTIONS

The above paragraphs described seven major groups of organisms in the Bay. In order to understand the entire system the interrelationships of the biological components must be examined. One way of illustrating and studying these interactions is by way of trophic diagrams. A generalized trophic diagram for the Bay and its major components was shown as Figures E-II-1 and E-II-2. This section will examine the dynamics of the major components by using more detailed trophic diagrams and species interaction tables. Major pathways of energy and material transfer within the Bay's ecosystem are illustrated from WESTECH's Biota Assessment. All diagrams and tables referenced in this discussion are included as Attachment A to this appendix.

Phytoplankton Associations (Figures A-1, A-2 and A-3). Energy fixed by photosynthesis is transferred from the phytoplankton compartment along several major pathways. Herbivorous zooplankton consume a major proportion of the phytoplankton in most areas, and are thus a key link in the transfer of phytoplankton production to higher trophic levels. The calanoid copepod Acartia tonsa alone is estimated to consume about half of the phytoplankton production in the Patuxent River during summer months. A certain amount of the ingested phosphorus and nitrogen-containing compounds are excreted by these zooplankton; these in turn are utilized by phytoplankton. In Chesapeake Bay, a major proportion of phytoplankton biomass and production is represented by nanoplankton, small species less than 10 microns in diameter. Probably, the majority of production by these species is consumed by micro-zooplankton, such as rotifers, tintinnids and other protozoans, and nauplii of copepods. Relatively little is known about the role of these small zooplankton in Chesapeake Bay; however, larger invertebrates, primarily benthic suspension feeders, also consume a significant proportion of phytoplankton in Chesapeake Bay; however, larger invertebrates, primarily benthic suspension feeders, also consume a significant proportion of phytoplankton. In addition, feces and pseudofeces of invertebrates are acted upon by bacteria - either while suspended in the water column or deposited on the sediment. Such bacteria-rich particles serve as food for other organisms, and as a substrate for the remineralization of nutrients.

Another major pathway for phytoplankton production is through the menhaden, Brevoortia tyrannus, a planktivorous fish. Menhaden are particularly important as they represent a major pathway from primary producers directly to large harvestable organisms. They are also an important food source for piscivorous fish. Minor pathways are represented by ctenophores and invertebrate meroplankton.

Emergent Aquatic Vegetation (Figures A-4 and A-5). EAV's are primary producers, and are used directly as food by a variety of animals, although the fresh water marsh species are primarily used indirectly. The major pathway through which marsh derived energy enters the estuarine trophic web is by detritus-based food chains. Dead and decaying plant material are acted upon by bacteria and other microorganisms, and these enriched particles serve as a food source for herbivorous zooplankton, such as Eurytemora affinis, and a variety of benthic detritivores and omnivores, such as Palaemonetes. EAV's provide a major habitat for fish and invertebrates, which can enter flooded marshes at high tide. Waterfowl and aquatic mammals (such as muskrats) also utilize marshes as habitat.

Submerged Aquatic Vegetation (Figures A-6 and A-7). SAV are primary producers, and are directly used as food by a variety of other species, particularly ducks, geese and other waterfowl, aquatic mammals, and some invertebrates. Dead and decaying plant tissue also enters the bay food web through the detritus pathway. Bacteria and other microorganisms act upon the plant material, and these enriched particles provide food for a number of benthic detritivores and omnivores, suspension feeders and zooplankton. The major role of SAV, however, is as a habitat for a host of other species, including epiphytes, epifauna, larval, juvenile, and adult invertebrates and fish. This diverse community has declined along with the reduction in SAV occurrence. The current "threatened or endangered" status of a number of invertebrates in Virginia is reported to be due to the loss of extensive stands of Zostera marina.

Herbivorous Zooplankton (Figures A-8 and A-9). These primary consumers channel phytoplankton-derived energy to a number of pathways. A major fraction of this compartment is consumed during the summer months by ctenophores and cnidaria. It is estimated that ctenophores could consume about 30 percent of the Acartia in the Patuxent during summer months. One observer found that where Mnemiopsis occurred in high densities, copepods were virtually eliminated in areas of the York River. Copepods also represent an important food source for larval and adult fish, including menhaden. The latter species feed extensively on zooplankton when phytoplankton are predominantly less than 15 mm in size. The importance to ichthyoplankton and juvenile fish is well established, and high densities of certain copepods, cladocerans, and rotifers is critical to the survival and development of larval anadromous species in Chesapeake Bay. Minor pathways of energy transfer from herbivorous zooplankton run through carnivorous zooplankton other than ctenophores (e.g., arrowworms), and larval invertebrates. Fecal material from the compartment enters the detritus/bacteria pathway, and may be in turn utilized as food by other species (including some herbivorous zooplankton). The benthic harpacticoid copepod Scottolana feeds more upon benthic diatoms, and bacteria-rich detritus. It represents a major food source for juveniles of demersal fish, especially sciaenids and flounder.

Carnivorous Zooplankton (Figure A-10). Only one study species Evadne tergestina, falls into this sub-category, although in the Bay's ecosystem it shares the niche with a variety of other cladocerans, chaetognaths, microplankton, and ichthyoplankton. Evadne feeds primarily on large phytoplankton, particularly dinoflagellates, as well as rotifers, tintinnids and other protozoans, copepod nauplii and copepodites, and small cladocerans (including young Evadne). In turn, it is a source of food for other carnivorous zooplankton, especially the chaetognath Sagitta, juvenile and adult planktivorous fish, ctenophores, and cnidarians.

Ctenophores and Cnidarians (Figure A-11). Combjellies and jellyfish are an important fraction of the Bay's zooplankton community. Particularly during the summer months, they exert a significant grazing pressure on other zooplankton. In addition, these primitively organized species excrete a large proportion of their ingested organic nitrogen and phosphorus, and are thus important to nutrient cycling. While the primary food for these organisms is zooplankton, they also ingest a certain amount of larger phytoplankton, detritus (and associated bacteria), ichthyoplankton, and in the case of cnidarians, juvenile and small adult fish. Ctenophores and cnidarians are fed upon by relatively few other organisms, although the predaceous ctenophore Beroe ovata significantly reduces the numbers of Mnemiopsis in the lower Bay. Chrysaora also feeds

upon ctenophores to an extent. The butterfly and harvestfish (Peprilus sp.), more common in the lower Bay, are also predators of ctenophores and cnidarians. The sessile polyp stages of Chrysaora and other jellyfish feed upon zooplankton.

Infaunal Deposit Feeders (Figures A-12, A-13 and A-14). This subcomponent includes a wide variety of benthic organisms, including oligochaete and polychaete worms, mollusks, and some crustaceans. Six study species are represented in this category. The major energy/material pathway for this subunit is through ingestion of sediment detritus and associated bacteria, micro-organisms, and benthic algae. Occasionally, suspended detritus is taken. Feces and pseudofeces return to the substrate, to be acted upon by bacteria and protozoans; these particles are reingested by deposit feeders. These organisms are an important source of food for invertebrate and vertebrate predators, particularly demersal fish, crabs, and waterfowl. In addition, they play an important role in nutrient recycling through release of nitrogen and phosphorus from the sediment.

Epifaunal Suspension Feeders (Figure A-15). Organisms in this category typically live attached to hard or firm substrates. The relative paucity of such substrates in Chesapeake Bay limits the available habitat for these species. However, they occur with abundance on oyster beds, pilings, and are often referred to as "fouling organisms." Suspension feeders derive a major portion of their energy from phytoplankton and suspended detritus (with associated micro-organisms), and in many cases also ingest microzooplankton, and even larger organisms. A major study species, Crassostrea, feeds primarily on particles less than 12  $\mu$  size, with 1-3 the largest single size fraction. Thus, they represent a major pathway from nannoplankton and bacterial production to a large, harvestable species. Balanus ingests a wider range of food, including small zooplankton and larger phytoplankton, and even its own nauplii. Pelagic larvae of suspension feeders become food for a wide variety of planktivorous invertebrates and fish. Feces and pseudofeces are deposited, and enter the detritus food chain. A wide variety of invertebrate predators feed upon these organisms, particularly crabs, flatworms, and carnivorous mollusks.

Infaunal Suspension Feeders (Figure A-16). This category includes a wide variety of mollusks, crustaceans, and a few worms. Five study species are represented. These organisms derive a major portion of their energy from phytoplankton; a few may also feed upon microzooplankton. Suspended detritus, with its associated microorganisms, is also ingested. These species serve as food for predaceous invertebrates, particularly crabs, as well as demersal fish, and waterfowl. Many are harvested by man. Feces and pseudofeces are deposited, and acted upon, by bacteria and other microorganisms. If resuspended, these bacteria-rich detrital particles become a source of food for suspension feeders. Pelagic larvae of a number of species are fed upon by planktivorous invertebrates and fish.

Benthic Omnivores (Figure A-17). This category includes a group of mixotrophic feeders, which derive their energy from a variety of pathways. Most feed upon detritus. They also consume living organisms — benthic algae and small benthic animals — as well as decaying plant and animal tissue. They are opportunistic feeders, and are rarely selective or restrictive in their diets. In turn, they are fed upon by pelagic and demersal fish, large invertebrate predators such as crabs, waterfowl, and shorebirds. Certain of these omnivorous species represent an important link between relatively refractory material such as marsh plant detritus and higher trophic levels.

Invertebrate Predators (Figure A-18). This category includes relatively large, mobile organisms which actively seek and capture living prey. It is composed chiefly of crustacea, such as crabs, and carnivorous gastropods. Snails such as Urosalpinx feed primarily upon hard-shelled prey organisms, drilling through the shell and rasping out the flesh. Crabs and other crustacea are more opportunistic feeders, and also ingest soft bodied prey, small fish, detritus, decaying plant and animal material, submerged aquatic vegetation, and benthic macroalgae. Included in this subunit are such species as the starfish Asterias, and the whelk Busycon, both of which feed on bivalves by forcing open the prey's shells. The latter two species may invade the lower Bay in greater numbers during reduced flow regimes. Pelagic crab larvae feed upon larger zooplankton such as copepods and cladocerans. Invertebrate predators are in turn fed upon by their conspecifics, predaceous fish and waterfowl. Some are harvested by man.

Vertebrates (Figures A-19 to A-26). Piscivorous fish are not highly specialized feeders in general. This can be seen in the number of study species fish which serve as food for other study species fish. For top predators, the single most important forage fish is the menhaden because of its dense schooling and high food value. Significant changes in the menhaden population within the Bay would be reflected in increased or decreased feeding pressure directed against other species. Alosid juveniles depend on anchovy and silversides, as well as young menhaden, for their growth in the shallow, low salinity regions.

Dietary requirements are most exact for larval fishes. Because of their restricted mobility, food must be available in high densities. Due to their small size and weak mouth structure the size of the food particles is also critical. In order to maximize the return on energy spent for capture, the food quality must be high. Rotifers such as Brachionis and cladocerans such as Bosmina are critical items in the diet of larval Alosa and Morone species. The concentration of these species in the nursery area has been shown to strongly influence larval growth rates and survival.

Three species of larval fish (menhaden, spot, croaker), which have highly specific food requirements, are in the low salinity portions of the estuary during the winter months and early spring. The major food organism for these larvae appears to be Scottolana canadensis which occurs in very high densities on the substrate during the winter and early spring. As these fish grow, the menhaden switches to pelagic plankton and the drums move to larger benthic prey organisms. Changes in the concentration of Scottolana would impact the growth and survival of larval spot, croaker and, to some extent, menhaden, although the food requirement of the latter is by no means clear cut.

Croakers tend to associate with oyster reefs. The oyster Crassostrea is a habitat modifier for a variety of benthic invertebrates which in turn are food for the croaker. Major changes in the extent or condition of the oyster reefs would be reflected in the growth and condition of the croaker. Spot are primary grazers of the soft bottom where they may harvest the bulk of the new production of worms and clams. To the extent that croakers are forced from the hard bottom and oyster communities, they will come into increasing competition with the spot.

Eel grass, Zostera marina, is a major habitat modifier for fish, providing cover for forage fish, richer species diversity for benthic grazers and an additional food source in the form of epiphytes. An increase in the extent of Zostera beds would increase the juvenile populations of silverside, spot, croaker and white perch.

The current dependence of the canvasback duck, Aythya valisineria, on Macoma balthica, has been noted elsewhere in this report. The species formerly depended on wild celery, Vallisneria americana. If neither of these items of diet are abundant in the future, the recovery of the canvasback to its former numbers may be in doubt.

### CHAPTER III

#### SELECTION OF STUDY SPECIES

In order to assess the effects of reduced freshwater inflow on the biota of Chesapeake Bay, a methodology was developed involving the quantification of habitat and the determination of habitat change for a select group of Bay organisms and/or species associations. The results of that analysis are presented in Appendix A, Problem Identification. The process used to select the group of 57 study species that were used to conduct the biota assessment is described in this chapter.

The identification of the 57 species was accomplished by WESTECH as part of their Phase I work on the biota assessment. Much of the following description of the procedure was taken from their report. If the reader desires, more detail as well as specific sources may be found there.

Participation and review by the scientific community and general public were included in the development of the list of study species. A panel of knowledgeable Bay researchers, known as the Anchor Team was established by the contractor to provide technical and procedural review. The Corps Steering Committee also provided review and guidance as the study proceeded. Several seminars were held by the contractor during the process. The invited public generally included more than 150 persons representing education and research organizations, regulatory agencies and conservation groups in Virginia, Maryland, Delaware, Pennsylvania, and the District of Columbia.

A literature search was also accomplished as part of the biota assessment. A bibliography was compiled of studies of living organisms inhabiting the Chesapeake Bay and the factors affecting their distribution and abundance. The bibliography was not limited to studies conducted in the Bay, but also included studies of other estuaries. This compilation was done using computerized bibliographic and abstracting services supplemented by intensive manual searches of journals and other sources.

Five abstract services were searched under more than 14 topics each. Journals, reports to government agencies and industry, books, symposia proceedings, theses and dissertations were systematically searched for potentially useful information. More than 33 journals were utilized. Libraries of 13 institutions and agencies were searched. Also five computerized data banks were consulted. The literature was collected and organized by topic.

In addition to published material, contact was made with those that have an active interest in research on the Chesapeake Bay. Drawing on the personal knowledge of the WESTECH staff, Corps of Engineers staff, and the Chesapeake Research Consortium's Chesapeake Bay Directory, individual scientists with government agencies, academic institutions and private firms were contacted. Nearly 100 individual scientists from 28 organizations were contacted. These personal contacts revealed the existence of maps, surveys, unpublished data files and notebooks which often served as valuable information sources.

As illustrated above, a substantial body of knowledge on the Chesapeake Bay was collected. This information formed a solid basis for both the subsequent study species selection and the biota assessment. The specifics on sources consulted are given in WESTECH's report, Phase I, Volume I.

A systematic screening procedure was developed which insured the selection of study species with the minimum of personal bias from either the WESTECH staff or reviewers. A sequential screening process was adopted. The screening and selection of study species required consideration of the amount of information availability on the life history of the species, its tolerance to physical variables, its linkage to other species in the ecosystem and its human importance, both recreationally and commercially. The screening process was done in stages as shown in Figure E-III-1.

#### PRELIMINARY LIST

There is no complete catalogue of species found in the Chesapeake Bay; however, some 2650 species have been identified to date, as described in the Existing Conditions Report. From the immense universe of Bay species, a preliminary list of 167 candidate study species was selected. The preliminary study species are listed in Table E-III-1. The selection criteria, public review and sources are described below.

#### Selection Criteria

Eight selection criteria were used to choose species for the preliminary list. These are listed below. Following the list is a description of why the criteria were important and how it was applied.

1. Sensitivity to Salinity
2. Sensitivity to Other Factors
  - Circulation
  - Temperature
  - Food
  - Substrate
3. Affected by Biological Interactions
4. Represent Key Tropic Links
5. Perform Key Ecosystem Processes
6. Commercially or Recreationally Important Species
7. Threatened or Endangered Species
8. Availability of Data.

Sensitivity to Salinity: Salinity tolerances for candidate species were evaluated from several sources: laboratory studies; field studies; and extrapolation from field collection data. Although the majority of estuarine organisms tend to be rather euryhaline, many exhibit greater stenotopy at certain stages of their life cycle; e.g. *Rangia cuneata*, (brackish water clam) the larvae of which require salinities between 2 - 10ppt to survive. The literature indicates that laboratory studies commonly demonstrate a wider range of salinity tolerance than the species exhibits under field conditions. This may reflect interaction of salinity with some other factor such as temperature or substrate; range restriction due to predation or competition; or a stenotopic life stage.

Sensitivity to Other Factors. Chief among the considerations are factors which themselves might be affected by salinity or low fresh water inflows i.e., circulation, temperature, food and substrate.

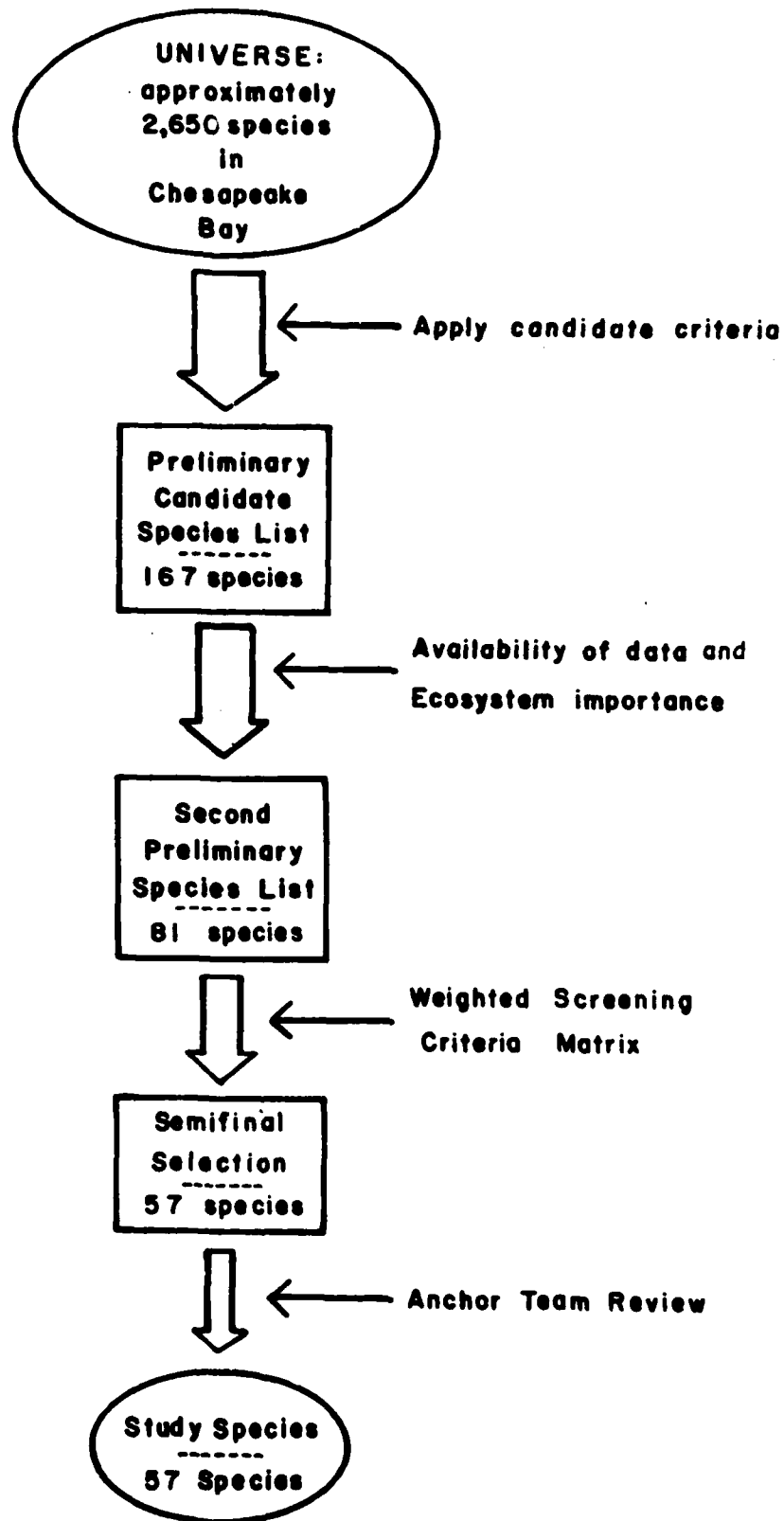


FIGURE E-III-1 SCREENING PROCESS FOR SELECTION OF STUDY SPECIES

TABLE E-III-1  
PRELIMINARY LIST OF STUDY SPECIES

PLANTS	Division: <u>Chlorophyta</u>	(green algae)
	<i>Calycomonas ovalis</i>	
	<i>Microactinium ruminatus</i>	
	<i>Pandorina morum</i>	
	Division: <u>Chrysophyta</u>	(golden-brown algae)
	<i>Calycomonas ovalis</i>	
	<i>Pseudopedinella pyriforme</i>	
	Division: <u>Bacillariophyta</u>	(diatoms)
	<i>Asterionella japonica</i>	
	<i>Ceratulina bergonii</i>	
	<i>Chaetoceros affinis</i>	
	<i>Chaetoceros septentrionalis</i>	
	<i>Leptocylindricus danicus</i>	
	<i>Melosira granulata</i>	
	<i>Navicula tripunctata</i>	
	<i>Nitzschia frustulum</i>	
	<i>Nitzschia pungens atlantica</i>	
	<i>Skeletonema costatum</i>	
	Division: <u>Pyrrophyta</u>	(dinoflagellates)
	<i>Ceratium furca</i>	
	<i>Gonyaulax monilata</i>	
	<i>Gymnodinium nelsoni</i>	
	<i>Gymnodinium splendens</i>	
	<i>Katodinium rotundatum</i>	
	<i>Prorocentrum minimum</i>	
	Division: <u>Cyanophyta</u>	(blue-green algae)
	<i>Anabaena flos-aquae</i>	
	<i>Anacystis cyanea</i>	
	<i>Microcystis aeruginosa</i>	
	Division: <u>Anthophyta</u>	(seed plants)
	<i>Seratophyllum demersum</i>	(horn wort)
	<i>Distichlis spicata</i>	(spike grass)
	<i>Elodea canadensis</i>	(elodea)
	<i>Juncus roemerianus</i>	(needle rush)
	<i>Sagittaria arifolia</i>	(watermilfoil)

TABLE E-III-1 (cont'd)

<i>Najas minor</i>	(naiad)
<i>Najas guadalupensis</i>	(southern naiad)
<i>Potamogeton pectinatus</i>	(sago pondweed)
<i>Potamogeton perfoliatus</i>	(redhead grass)
<i>Ruppia maritima</i>	(widgeon grass)
<i>Scirpus americanus</i>	(common three-square)
<i>Scirpus olneyi</i>	(olney three-square)
<i>Spartina alterniflora</i>	(salt marsh cordgrass)
<i>Spartina cynosuroides</i>	(big cordgrass)
<i>Spartina patens</i>	(salt meadow cordgrass)
<i>Taxodium distichum</i>	(bald cypress)
<i>Typha angustifolia</i>	(cattail)
<i>Typha latifolia</i>	(broadleaf cattail)
<i>Zanichellia palustris</i>	(horned pondweed)
<i>Zostera marina</i>	(eelgrass)

ANIMALS

Phylum: Protozoa

<i>Minchinia nelsoni</i>	(MSX)
<i>Perkinsus marinus</i>	(dermo)
<i>Tintinnopsis</i> spp.	(bell animal)

Phylum: Porifera

<i>Cliona truitti</i>	(boring sponge)
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Phylum: Cnidaria

<i>Chrysaora quinquecirrha</i>	(sea nettle)
<i>Diadumene leucolela</i>	(sea anemone)

Phylum: Ctenophora

<i>Mnemiopsis leidyi</i>	(sea walnut)
<i>Beroe ovata</i>	(mermaid purse)

Phylum: Platyhelminthe

<i>Stylochus ellipticus</i>	(flat worm)
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Phylum: Rhyncocoela

<i>Micuiria leidyi</i>	(proboscis worm)
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Phylum: Phoronida

<i>Phoronis architecta</i>	(beard worms)
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TABLE E-III-1 (cont'd)

Phylum: Rotifera (wheel animals)

*Brachionus calyciflorus*  
*Brachionus plicatilis*  
*Synchaeta* spp.

Phylum: Annelida

Class Polychaeta (bristle worms)

*Glycera dibranchiata* (blood worm)  
*Heteromastus filiformis* (tube worm)  
*Hypaniola grayi*  
*Nephtys incisa*  
*Nereis succinea* (clam worm)  
*Paraprionospio pinnata* (tube worm)  
*Pectinaria gouldii*  
*Polydora ligni* (tube worm)  
*Scolecopides viridis*  
*Spiochaetopterus ocelatus*  
*Streblospio benedicti* (tube worm)

Class Oligochaeta (earth worms)

*Limnodrilus hoffmeisteri*  
*Pelosclex gabriellae*  
*Pelosclex heterochaetus*  
*Pelosclex multichaetus*  
*Pelosclex multisetosus*

Phylum: Mollusca

Class Gastropoda (snails)

*Bittium varium* (eelgrass snail)  
*Busycon carica* (knobbed whelk)  
*Eupleura caudata* (oyster drill)  
*Hydrobia* spp.  
*Massarius vibex* (mud snail)  
*Pyrusa canaliculata*  
*Trosalpinx cinerea* (oyster drill)

Class Bivalvia (bivalves)

*Bankia gouldi* (shipworm)  
*Brachiodontes recurvus* (curved mussel)  
*Carteria leucophaeta* (Conrad's false mussel)  
*L. chusula maniliensis* (Asian clam)  
*Crassostrea virginica* (oyster)

TABLE E-III-1 (cont'd)

Order <u>Mysidacea</u>	
<i>Neomysis americana</i>	(opossum shrimp)
Order <u>Decapoda</u>	
	(shrimps & crabs)
<i>Callinectes sapidus</i>	(blue crab)
<i>Crangon septemspinosa</i>	(sand shrimp)
<i>Palaemonetes pugio</i>	(grass shrimp)
<i>Palaemonetes vulgaris</i>	(grass shrimp)
<i>Ogyrides limnicola</i>	(shrimp)
<i>Rhithropanopeus harrisii</i>	(mud crab)
Class <u>Insecta</u>	
<i>Chaoborus punctipennis</i>	(mosquito)
<i>Chironomus attenuatus</i>	(midge)
<i>Clinotanytus sp.</i>	(midge)
<i>Cryptochironomus fulvus</i>	(midge)
Phylum: <u>Echinodermata</u>	
<i>Leptosynapta inharaens</i>	
Phylum: <u>Chaetagnatha</u>	
	(arrow worms)
<i>Sagitta elegans</i>	
<i>Sagitta tenuis</i>	
Phylum: <u>Chordata</u>	
Class <u>Ascidiacea</u>	
	(tunicates)
<i>Molgula manhattensis</i>	
Class <u>Pisces</u>	
<i>Alosa pseudoharengus</i>	(alewife)
<i>Alosa sapidissima</i>	(shad)
<i>Anchoa mitchelli</i>	(bay anchovy)
<i>Anguilla rostrata</i>	(American eel)
<i>Brevoortia tyrannus</i>	(menhaden)
<i>Cynoscion regalis</i>	(weakfish)
<i>Fundulus heteroclitus</i>	(mummichog)
<i>Gobiosoma boscii</i>	(naked goby)
<i>Ictalurus catus</i>	(white catfish)
<i>Leiostomus xanthurus</i>	(spot)
<i>Lepomis gibbosus</i>	(pumpkinseed)
<i>Menidia beryllina</i>	(tidewater silverside)
<i>Menidia menidia</i>	(Atlantic silverside)

TABLE E-III-1 (cont'd)

<i>Gemma gemma</i>	(gem clam)
<i>Lyonsia hyalina</i>	
<i>Macoma balthica</i>	(baltic macoma)
<i>Macoma mitchelli</i> (= <i>M. phenax</i> )	
<i>Mercenaria mercenaria</i>	(hard clam)
<i>Mulinia lateralis</i>	(coot clam)
<i>Mya arenaria</i>	(soft clam)
<i>Rangia cuneata</i>	(brackish water clam)
<i>Sphaerium</i> spp.	(fingernail clam)

Phylum: ArthropodaClass CrustaceaSubclass Branchiopoda (water fleas)

*Bosmina longirostris*  
*Evadne tergistina*  
*Penilia avirostris*  
*Podon polyphemoides*

Subclass Copepoda (copepods)

*Acartia clausi*  
*Acartia tonsa*  
*Centropages haematus*  
*Eurytemora affinis*  
*Mesocyclops edax*  
*Oithona colcava*  
*Scottolana canadensis*

Subclass Cirripeda (barnacles)

*Balanus eburneus*  
*Balanus improvisus*

Subclass MalacostracaOrder Isopoda (isopods sowbugs)

*Cyathura polita*  
*Edotea triloba* (sea roach)

Order Amphipoda (amphipods)

*Ampelisca abdita*  
*Ampelisca verrilli*  
*Corophium lacustre*  
*Leptochelirus plumulosus*

TABLE E-III-1 (cont'd)

<i>Micropogon undulatus</i>	(Atlantic croaker)
<i>Micropterus salmoides</i>	(large mouth bass)
<i>Morone americana</i>	(white perch)
<i>Morone saxatilis</i>	(striped bass)
<i>Peprillus triacanthus</i>	(butterfish)
<i>Perca flavescens</i>	(yellow perch)
<i>Pomatomus saltatrix</i>	(bluefish)
<i>Pseudopleuronectes americanus</i>	(winter flounder)
<i>Rachycantron canadum</i>	(cobia)
<i>Rhinoptera bonasus</i>	(cow nosed ray)
<i>Trinectes maculatus</i>	(hog croaker)

Class Aves

<i>Anas platyrhynchos</i>	(mallard)
<i>Anas rubripes</i>	(black duck)
<i>Aythya affinis</i>	(lesser scaup)
<i>Aythya americana</i>	(redhead)
<i>Aythya valisineria</i>	(canvasback)
<i>Bucephala albeola</i>	(bufflehead)
<i>Bucephala clangula</i>	(common goldeneye)
<i>Branta canadensis</i>	(Canada goose)
<i>Chen hypoborea</i>	(snow goose)
<i>Haliaeetus leucocephalus</i>	(bald eagle)
<i>Olor columbianus</i>	(whistling swan)
<i>Oxyura jamaicensis</i>	(ruddy duck)
<i>Pandion haliaetus</i>	(osprey)

Class Mammalia

<i>Ondatra zibethicus</i>	(muskrat)
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Circulation. A partially mixed, moderately stratified estuary such as Chesapeake Bay is characterized by a net seaward flow of lower salinity water in the upper layers and a net upstream flow of higher salinity deep water. In general, the outflow at the surface is the driving force for the rate of inflow of higher salinity bottom water. The literature shows that many organisms use the upstream movement of water at depth to transport themselves into and maintain themselves within the estuary. Reduced freshwater inflow could alter the rate of transport, and allow breakdown of density stratification, particularly in the tributary rivers. This could have effects beyond simple salinity tolerances if important commercial species such as blue crabs, croaker and spot are prevented from reaching their upstream nursery areas, or oysters their upstream beds.

Temperature. The synergistic effects of temperature and salinity have been described by several researchers. Temperature stress can narrow the salinity tolerance zone for many organisms, and vice versa. For example, in lower salinities, the copepod Acartia tonsa has a competitive advantage over A. clausi at temperatures from 11 to 18° C, as it is less affected by the salinity stress. Another example of the synergistic effects of temperature and salinity is afforded by organisms at the edge of their range. Chesapeake Bay represents the maximum northward range extension of several southern species such as Rangia cuneata (brackish water clam) and the southernmost extension of others such as Mya arenaria (soft clam). Adverse salinities during cold or warm periods, respectively, could have a more severe effect than that produced by salinity alone.

Food. Some species, themselves euryhaline, are dependent on a more stenotopic food source. For example, the redhead (Aythya americana) feeds extensively on Potamogeton spp. (pondweeds), plants restricted to oligohaline and low mesohaline areas.

Substrate. Although most benthic organisms show a certain eurytopy as to substrate, sediment preferences do exist. For example, sandy substrates are most numerous in the lower Bay, particularly near the Bay mouth. Research has shown that the restriction of certain species to this section of the estuary is less a reflection of their stenohalinity as it is of their psamphilic nature.

Affected by Biological Interactions. These biological interactions include predation, parasitism, competition, and disease. Many estuarine endemics and euryhaline opportunists find the estuary a refuge from predation and competition. There are numerous examples of euryhaline species having restricted ranges due to increased predation in higher salinities. For example, the oyster Crassostrea virginica is preyed upon in salinities above 15 percent by the oyster drill Urosalpinx cinerea, and suffers heavy mortalities in salinities above about 12 percent due to the protozoan parasites Minchinia nelsoni (MSX) and Perkinsus marinus ("dermo"). Although predation seems to be the most important habitat factor, at least for benthic forms, evidence exists that competitive exclusion may also restrict ranges of some species (e.g. Macoma balthica versus M. tenta).

Represent Key Trophic Links. Certain species, because of their numbers, productivity, or distribution, represent major links in the Chesapeake Bay food web. Results of caging experiments, stomach analyses, and laboratory feeding studies have been used to identify major food items, food selectivity, ingestion rates and vulnerability to predation for candidate study species. Some abundant species are numerous because they have evolved means to avoid predation, and are thus not key trophic links; however, they may be important for other reasons, such as substrate modification or nutrient cycling.

Perform Key Ecosystem Processes. These key ecosystem processes might include nutrient recycling, substrate modification or habitat production. Benthic organisms (particularly the meio- and micro-components), as well as zooplankton and fish, excrete compounds containing nitrogen and phosphorous. These can be utilized by phytoplankton and rooted aquatics for primary production. Modification of substrate can be positive or negative. Certain species, particularly polychaetes, produce tubes which bind loose sediments and stabilize the bottom, allowing colonization by other organisms. On the other hand, bioturbation by benthic infauna, as well as accumulation of fecal material, can create a loose flocculant substrate inhibitory to many species. Also, prey-seeking behavior by fish and crabs can also disrupt the substrate, reducing the numbers and diversity of species found.

Certain species so physically dominate their environment that they themselves constitute the habitat. In Chesapeake Bay, major examples are the oyster reef and its associates, and submerged aquatic vegetation beds. The density and diversity of species in these habitats are greater than in surrounding sand or mud bottoms, and productivity can be significantly higher.

Commercially or Recreationally Important Species. Organisms which are harvested by man, or which provide non-consumptive recreation, are the measure by which much of the public tends to gauge the "health and productivity" of the estuary. Most of these species (e.g. fish, crabs, and waterfowl) are large and conspicuous; many feed fairly high on the trophic chain. Their continued abundance depends on the integrity of the trophic web supporting their populations.

Threatened and Endangered Species. According to the U.S. Fish and Wildlife Service, a number of threatened and endangered species inhabit the Chesapeake Bay area. Some of these are birds and mammals which are more or less water-oriented, and may depend on the estuary seasonally or for some aspect of their needs (e.g. food, shelter). Examples of the water oriented animals are the bald eagle (*Haliaeetus leucocephalus*), and the Delmarva fox squirrel (*Sciurus niger cinereus*). Other threatened or endangered species are fish or reptiles which have been known to enter the Chesapeake Bay, or which at one time were resident. Examples of these animals are the Shortnose Sturgeon (*Acipenser brevirostrum*), and the Maryland darter (*Etheostoma sellare*).

Availability of Data. Some organisms are important based on the above criteria, but adequate information is lacking on their biomass, distribution, tolerance, and trophic interactions. Thus, the organism is not a useful study species. Only those that have been well studied in terms of distribution were included in the preliminary list.

#### Public Review

This preliminary list of 167 species and the criteria used in their selection were reviewed by WESTECH's Anchor Team and at the first seminar, held on 15 November 1979 at the Chesapeake Bay Model. An announcement for the seminar was sent to 150 persons representing education and research organizations, regulatory agencies and conservation groups in the four adjacent states and the District of Columbia. Input received at this seminar was incorporated into the selection process. Some additional study species were added to the preliminary list, at the suggestion of reviewers. This supplemented list was carried into the next screening.

## Sources.

The preliminary list of 167 species was based upon a variety of sources, including:

- Chesapeake Bay Existing Conditions Report (USACE 1973): A list of 110 species recommended for bioassay or condition indices, in order to assess effects of environmental stress.
- Chesapeake Bay Future Conditions Report (USACE 1977): A list of 126 important species and genera based on a survey of Bay researchers. Species were included on this list on the basis of 15 criteria, including importance to trophic structure, and distribution. An attempt was made to include species representing as many Chesapeake Bay habitats as possible.
- Maryland Department of Natural Resources list of 44 representative species from tidal and non-tidal waters. These species were to be used in studies assessing the impacts of discharges into natural waters.

In addition, numerous reports, papers, and data sets were consulted to identify major species, and their general distribution in regard to salinity. Some of the more important of these were:

Phytoplankton: Patten et al. 1965; Marshall 1966, 1967; Mackiernan 1968; Mulford 1972; Dahlberg et al. 1973; Van Valkenberg and Flemer 1974; Seliger et al. 1975; Lear and Smith 1976; Mountford 1977; Van Valkenburg et al. 1978.

Submerged Aquatic Vegetation: Orth 1975; Stevenson and Confer 1978; Anderson 1979 unpublished data; Orth et al. 1979; Munro 1979; Migratory Bird Habitat Research Laboratory, unpublished data.

Emergent Aquatic Vegetation: Maryland Wetlands Survey, DNR, 1967 - 1968; Keefe 1973; Metzgar 1973, Virginia State Wetlands Survey Series, VIMS, 1973 - 1978; Doon et al.

Zooplankton: Heinle 1966, 1969; Herman et al. 1968; Bosch and Taylor 1968, 1973; Goodwyn 1970; Burrell & Van Engle 1976; Dahlberg et al. 1973; Heinle et al. 1975; Sage et al. 1976; Bryan 1977; Grant 1977; Sage and Olsen 1977; Jacobs 1978; Grant and Olney 1979; Lippson et al. 1979.

Benthic Organisms: Corey 1967; Pfitzenmeyer 1961, 1970, 1973, 1975, 1976; Boesch 1971, 1972, 1973, 1977; Wass et al. 1972; Hamilton and LaPlante 1972; Davies 1972; Orth 1973; Larsen 1974; Diaz 1977; Mountford et al. 1977; Virnstein 1977, 1979; Haven et al. 1977, 1979; Lippson et al. 1979; Reinhartz, Bricker & O'Connell 1979; Cory and Dresler 1980, unpublished data.

Fish: Hildebrand and Schroeder 1928; Smith et al. 1966; Ritchie 1970; Douglas and Stroud 1971; National Marine Fisheries Service Fishery Statistics of the U.S. 1976 - 1978; Scott and Boone 1973; Lippson and Moran 1974; W.R. Carter, unpublished data; NMFS Current Fishery Statistics 1975 - 1978.

Birds and Mammals: Dozier 1947; Stewart 1962; Willner et al. 1975; Perry and Uhler 1976; Maryland Dept. of Natural Resources, Midwinter Waterfowl Surveys 1975 - 1980; Virginia Fish and Game, Midwinter Waterfowl Surveys 1975 - 1980; Rawls, unpublished M.S.

## INTERMEDIATE LIST

Reduction of the preliminary list of 167 species required two subsequent screening steps. In the first step, the preliminary list, with some additions by reviewers, was reduced to an intermediate list of 81 species and associations. For each of the species on the preliminary list, information was gathered to determine the adequacy of data, ecosystem importance and sensitivity to environmental change. Information was gathered in eight subject areas:

- a. Salinity range and tolerance, both in the field and from laboratory studies, for each potentially sensitive life stage. If the study was from an area other than Chesapeake Bay, this was noted.
- b. Temperature tolerances, both from field and laboratory information. Of particular importance were lethal temperatures, and temperature ranges affecting periods of reproduction and growth.
- c. Biomass and abundance information, from Chesapeake Bay and other areas. Seasonality, as it affected biomass, and abundance was noted.
- d. Physiological rates, including respiration, growth, and production (of plants). Variations in these rates, as correlated with salinity or temperature, were noted when available. Many of these rates were taken from studies conducted on candidate species in areas other than Chesapeake Bay.
- e. Preferred substrates for species (when applicable).
- f. Trophic relationships, including preferred food or prey, major predators, feeding rates and predation rates, both from Chesapeake Bay and from other areas. Changes in rates due to salinity or temperature were noted.
- g. Competitors, disease, predators, and other limiting biotic factors. Information from areas other than Chesapeake Bay was taken when the same species were involved (i.e. candidate species and its competitor or disease). Historical changes in distribution of important diseases or predators due to salinity changes were noted.
- h. Other limiting factors of a physical nature, such as light, depth, and turbidity were noted when the information was available.

The task of gathering this information for each of the 167 candidate species provided a chance to evaluate the adequacy and scope of information for each. Gaps in the literature were so extensive that some organisms were immediately eliminated.

Due to the nature of the available data, the decision was made to use associations rather than species for both phytoplankton and emergent aquatic vegetation. In the case of phytoplankton, this decision was made because overall seasonal associations are relatively stable, but the dominance of individual phytoplankton species varies from year to year. In terms of the emergent aquatic vegetation, difficulty in integrating differences in Maryland and Virginia wetlands surveys necessitated the use of the recurrent plant associations rather than individual species.

In developing this intermediate list, an attempt was made to include representative organisms from the various salinity ranges and from the major ecological groups (e.g., estuarine endemics, euryhaline marine). The list is shown in Table E-III-2.

This intermediate list of 81 species and the selection process were reviewed by WESTECH's Anchor Team members and later by the public at a second seminar held by WESTECH on 20 March 1980 at the Potomac River Fisheries Commission in Colonial Beach, Virginia. Announcements of the seminar were mailed to nearly 200 persons. In addition to interaction through the seminars, review and comment were received from the Steering Committee and the Fish and Wildlife Service, Annapolis Field office. The intermediate list and comments from the public were considered in arriving at the final list.

## FINAL LIST

Reduction of the intermediate list of 81 species and associations to the final list of 57 species involved a species screening matrix and review by WESTECH's Anchor Team and other members of the Bay Community. The screening procedure, public review, and results are described below.

### Screening Methodology and Criteria

Reduction of the intermediate list to the final list involved construction of a species screening matrix. The 81 species and associations were evaluated against eighteen weighted factors shown in Table E-III-3. Each species was ranked on a scale of 0 - 4 in each of these criteria. Each value was then weighted and summed for a final score for each species. Species with scores above certain levels became final study species. Cutoff values varied between functional groups (i.e., zooplankton, benthos) because all eighteen screening factors did not apply to every group.

Considerable discussion entered into the assigning of weighting values to the final screening criteria, and these values generated a predictable amount of comment from reviewers. Selective judgments had to be made in assigning weight to the screening factors and in ranking each species against them. However, this methodology minimized the bias inevitable in developing any list of major species.

Screening criteria used were essentially an expansion of the eight criteria used in arriving at the preliminary list. The greatest weight was given to factors which could be affected by low freshwater inflow (e.g., salinity sensitivity, dependence on estuarine circulation) or which measured a species' importance to the ecosystem (trophic dominance, biomass, major predator, etc.). Also, by necessity, the availability of data needed for the mapping of known and potential habitat, and trophic information for ecosystem analysis were heavily weighted. Values for other criteria were assigned by comparing their relative importance with the heavily weighted factors discussed above. The rationale for each of the weighting values:

- Sensitive to salinity. Since the major anticipated effect of low flow conditions is an alteration of salinity regimes, this factor was weighted "4."
- Trophic importance. Certain organisms are extremely important to the production and flow of energy through the estuarine ecosystem. Disruption of these species could have severe impact on other levels of the trophic web. For this reason, "Trophic Importance" was ranked "4."

TABLE E-III-2

## INTERMEDIATE LIST OF SPECIES AND ASSOCIATIONS

Phytoplankton

## WINTER -SPRING ASSOCIATIONS:

<i>Cyclotella meneghiniana</i>	Tidal Fresh Water
<i>Melosira granulata</i>	
<i>Katodinium rotundatum</i>	Oligo - Low Mesohaline
<i>Skeletonema costatum</i>	
<i>Asterionella japonica</i>	Mesohaline
<i>Ceratulina bergonii</i>	
<i>Skeletonema costatum</i>	
<i>Asterionella japonica</i>	Polyhaline
<i>Chaetoceros decipiens</i>	
<i>Nitzschia pungens</i> var <i>atlantica</i>	
<i>Skeletonema costatum</i>	
<i>Thalassiosira rotula</i>	

## SUMMER -FALL ASSOCIATIONS:

<i>Anacystis cyanea</i>	Tidal Fresh Water
<i>Microcystis aeruginosa</i>	
<i>Gymnodinium nelsoni</i>	Oligo - Low Mesohaline
<i>Gymnodinium splendens</i>	
<i>Prorocentrum minimum</i>	
<i>Skeletonema costatum</i>	
<i>Chaetoceros affinis</i>	High Mesohaline - Polyhaline
<i>Cochlodinium heterolobatum</i>	
<i>Ditylum brightwellii</i>	
<i>Gymnodinium nelsoni</i>	
<i>Skeletonema costatum</i>	

TABLE E-III-2 (cont'd)

Submerged Aquatic Vegetation  
(associations)

<i>Ceratophyllum demersum</i>	
<i>Elodea canadensis</i>	
<i>Najas</i> spp.	Tidal Fresh Water - Oligohaline
<i>Nitella</i> spp.	
<i>Myriophyllum spicatum</i>	
<i>Potamogeton pectinatus</i>	
<i>Potamogeton perfoliatus</i>	
<i>Ruppia maritima</i>	Oligohaline - Low Mesohaline
<i>Vallisneria americana</i>	
<i>Zanichellia palustris</i>	
<i>Ruppia maritima</i>	
<i>Zostera marina</i>	Upper Mesohaline - Polyhaline

Emergent Aquatic Vegetation  
(the following indicate associations)

<i>Spartina cynosuroides</i>	
<i>Typha</i> spp.	Tidal Fresh Water
<i>Juncus roemerianus</i>	
<i>Spartina cynosuroides</i>	
<i>Spartina patens</i> / <i>Distichlis spicata</i>	Oligohaline - Mesohaline
<i>Scirpus</i> spp.	
<i>Spartina alterniflora</i>	Mesohaline - Polyhaline
<i>Taxodium distichum</i>	
(Bald Cypress)	Tidal Fresh Water

TABLE E-III-2 (cont'd)

Zooplankton

*Acartia clausi*  
*A. tonsa*  
*Beroe ovata*  
*Brachionis calcyiflorus*  
*B. plicatilis*  
*Chrysaora quinquecirrha*  
*Eurytemora affinis*  
*Mnemiopsis leidyi*  
*Podon polyphemoides*  
*Scottolana canadensis*

Other cladocerans:

*Bosmina longirostris*  
*Evadne tergistina*  
*Penilia avirostris*

Diseases

Protozoa

*Minchinia nelsoni*  
*Perkinsus marinus*

"MSX"

"Dermo"

TABLE E-III-2 (cont'd)

Benthos

Cnidaria	<i>Diadumene leucolena</i>
Annelida	<i>Heteromastus filiformis</i> <i>Limnodrilus hoffmeisteri</i> <i>Mediomastus ambiseta</i> <i>Nereis succinea</i> <i>Paraprionospio pinnata</i> <i>Pectinaria gouldii</i> <i>Peloscolex</i> spp. <i>Scolecopides viridis</i> <i>Streblospio benedicti</i>
Mollusca	<i>Corbicula manilensis</i> <i>Crassostrea virginica</i> <i>Macoma balthica</i> <i>M. mitchelli</i> <i>M. tenta</i> <i>Mercenaria mercenaria</i> <i>Mulinia lateralis</i> <i>Mya arenaria</i> <i>Rangia cuneata</i> <i>Retusa canaliculata</i> <i>Urosalpinx cinerea</i>
Crustacea	<i>Ampelisca abdita</i> <i>Balanus improvisus</i> <i>Callinectes sapidus</i> <i>Corophium lacustre</i> <i>Gammarus daiberi</i> <i>G. fasciatus</i> <i>G. mucronatus</i> <i>Leptocheirus plumulosus</i> <i>Palaemonetes pugio</i>
Urochordata	<i>Molgula manhattensis</i>

TABLE E-III-2 (cont'd)

Vertebrates

(Fish)

Pisces	<i>Alosa sapidissima</i>
	<i>Anchoa mitchelli</i>
	<i>Brevoortia tyrannus</i>
	<i>Cynoscion regalis</i>
	<i>Leiostomus xanthurus</i>
	<i>Lepomis gibbosus</i>
	<i>Menidia beryllina</i>
	<i>M. menidia</i>
	<i>Morone americana</i>
	<i>M. saxatilis</i>
	<i>Peprillus triacanthus</i>
	<i>Pomatomus saltatrix</i>
	<i>Rhinoptera bonasus</i>

(Birds)

Aves	<i>Anas platyrhynchos</i>	mallard
	<i>Anas rubripes</i>	black duck
	<i>Aythya americana</i>	redhead
	<i>Aythya valisineria</i>	canvasback
	<i>Branta canadensis</i>	Canada goose
	<i>Olor columbianus</i>	whistling swan
	<i>Pandion haliaetus</i>	osprey
Mammalia	<i>Ondatra zibethicus</i>	muskrat

TABLE E-III-3  
FINAL SPECIES SCREENING CRITERIA

<u>Factor</u>	<u>Weighting Value</u>
Sensitive to Salinity	4
Sensitive to Circulation Changes	3
Sensitive to Substrate	2
Important to Nutrient Cycling	2
Affects Water Quality	1
Major Biomass Contribution	3
Wide Distribution in Bay	1
Rare or Endangered Species	1
Trophic Importance	4
Specialized Food Requirements	3
Major Predators	3
Major Competitors	1
Economic or Social Importance	1
Opportunistic Colonizer	1
Modifies Habitat for Other Species	2
Distribution Data Available	4
Trophic Data Available	3
Sensitive Life Stages	2

- Distribution data availability. Pragmatically, it is necessary to have reasonably accurate and complete distribution information on a species to either map it or to assess changes in distribution due to low freshwater inflow. Thus, this factor was weighted as "4."
- Sensitive to circulation changes. Changes in circulation due to low inflows, or altered salinity patterns, can also be anticipated, and could affect distribution of some species. For this reason this factor was given a weight of "3."
- Major biomass contributor. Biomass is a measure of a species importance or dominance in the ecosystem. Additionally, a certain minimum level of abundance is necessary for a species to be useful as an indicator organism. Thus, this factor was weighted "3."
- Specialized food requirements. Species with restricted food requirements at some point of their life cycle could be more severely affected by environmental perturbations than less specialized forms. For example, some species may themselves be eurytopic in regard to salinity, but rely on a more stenotopic food species. This criterion was ranked "3" for the above reason.
- Major predator. Predation has been shown to be an important factor limiting distribution of many organisms. Change in distribution of a major predator might have significant effects on the Bay ecosystem; therefore this factor was ranked "3".
- Trophic data available. Complete and accurate information on a species ecological importance is needed to assess what effects changes in its distribution might have on Bay's ecosystem. Thus, this factor was also heavily weighted, as "3."
- Sensitive to substrate. Substrate changes are not an anticipated major effect of low inflow, although the area of specified substrate within a certain salinity range will probably change. This factor was therefore weighted "2."
- Important to nutrient cycling. Although nutrient cycling is an important ecosystem function, the role many species play in it is not well-known. To reduce bias in favor of a few well-studied forms, this factor was only weighted "2."
- Modifies habitat for other species. Species which provide habitat for other organisms (or conversely, which unfavorably alter habitat), can have significant ecological impact. This criterion was rated "2."
- Sensitive life stages. Many species have a period in their life cycle which is potentially sensitive to environmental perturbation. This is typically a larval or juvenile stage. Although species which have such life stages will also score high on other factors (such as sensitive to salinity) it seemed better to also augment their score with an additional factor. This screening criterion was ranked "2."

- Affect water quality. A few species can cause deleterious changes in water quality (e.g., algae blooms), and these might be enhanced by reduction in flushing rates due to low inflow. Since these effects will probably be local, this criterion was only weighted "1."
- Wide distribution in Bay. A species with very restricted, localized distribution may not be a useful indicator. On the other hand, to minimize bias for very widespread eurytopic species, this criterion was only weighted "1."
- Rare and endangered species. Because of restricted ranges and the usually minor ecosystem role of these species, this factor was rated "1". However, it was suggested that because of these organisms legal importance, the entire group should be handled as an entity in the assessment.
- Major competitor. Competition appears not to be as important in mediating organism distribution as predation, so this factor was ranked "1."
- Economic or social importance. Although these are the factors through which the public perceives the Bay's health, it was felt that the fact that an organism was economically important was not, a priori, a measure of that species' sensitivity to low inflow. Many of these species do have life stages sensitive to salinity changes, or have predators or diseases which could be affected by low inflow, but these species would receive high scores on those particular criteria. For these reasons, this factor was ranked as "1."
- Opportunistic colonizer. Species which are adapted to rapid colonization of disturbed habitats may respond quickly to habitat alterations due to low inflow. However, too high a ranking on this factor might bias the selection of species in favor of estuarine opportunitists, most of which are quite eurytopic. This factor received a "1" rating.

The absence of threatened and endangered species is notable in the final list. Most of the Bay's rare or uncommon species were not included as study species. There are several rather clear reasons that uncommon species did not rate highly on this system which is geared toward salinity and trophic relationships:

- Insufficient data (on distribution, feeding, salinity tolerance, etc.).
- Not coupled tightly to the estuarine system.
- Minor quantitative importance in the food web, as known at this time.
- Sensitive stages not well known.

#### Public Review

The draft final list was reviewed by the WESTECH Anchor Team and presented at the final seminar for peer review, held March 20, 1980, at the Naval Academy, Annapolis, Maryland.

Input from this review process was used to generate the final list. In particular, the fish species were re-evaluated in response to comments that life stages should each have been screened independently. Ranking each life stage separately changed the relative order to some of the candidate species, resulting in additions and deletions from the original list. One species which elicited wide-spread comment was the American shad, Alosa sapidissima. In light of its severely depressed populations, its suitability as a study species was questioned. However, the apparent current stresses on this fish are such that additional pressures due to low freshwater inflow might prove critical, if such effects can be separated out and evaluated. Thus the species was retained as a study species.

Several benthic species were also re-evaluated on the basis of comments, and additions and deletions were made. In particular, two species important in the oligohaline zone, the area where pronounced effects of low fresh water inflows are expected, were added: Gammarus daiberi and Cythaura polita. Corbicula manilensis was deleted due to its limited distribution.

### Results

The final list of 57 species and associations includes 7 phytoplankton and 3 emergent vegetation associations, 5 submerged aquatic vegetation, 10 zooplankton, 19 benthic invertebrates, 10 fish and 3 waterfowl. The final list is given in Table E-III-4.

Although 57 species represent only 3 percent of the total Chesapeake Bay biota, these study species include many of the major organisms in the estuary. In addition, they are representatives of various salinity zones and estuarine habitats, and can serve as "models" for other species with similar requirements. Thus, impacts of low freshwater inflows can be assessed in a specific manner for the study species, and to a certain extent extrapolated for the entire Chesapeake Bay ecosystem.

TABLE E-III-4  
FINAL STUDY SPECIES LIST

PHYTOPLANKTON ASSOCIATIONS		
Winter/Spring Associations	<i>Cyclotella meneghiniana</i> / <i>Melosira granulata</i> tidal freshwater association	
	<i>Katodinium rotundatum</i> / <i>Skeletonema costatum</i> oligohaline, low mesohaline association	
	<i>Asterionella japonica</i> / <i>Skeletonema costatum</i> dominated mesohaline association	
	<i>Nitzschia pungens atlantica</i> / <i>Skeletonema costatum</i> / <i>Chaetoceros</i> spp. dominated polyhaline association	
Summer/Fall Associations	<i>Anacystis</i> / <i>Microcystis</i> tidal freshwater association	
	<i>Gymnodinium</i> spp./ <i>Prorocentrum minimum</i> dominated oligohaline, low mesohaline associations	
	<i>Gymnodinium</i> / <i>Chaetoceros</i> / <i>Skeletonema</i> dominated high mesohaline polyhaline associations	
SUBMERGED AQUATIC VEGETATION		
<i>Ceratophyllum demersum</i>	hornwort	
<i>Potamogeton</i>	pondweeds	
<i>Ruppia maritima</i>	widgeon grass	
<i>Zanichellia palustris</i>	horned pondweed	
<i>Zostera marina</i>	eelgrass	
EMERGENT AQUATIC VEGETATION ASSOCIATIONS		
Tidal Freshwater Associations		
<i>Spartina</i> spp. dominant, brackish tidal marsh		
<i>Juncus roemerianus</i> dominant, brackish tidal marsh		
ZOOPLANKTON		
Ctenophora	<i>Mnemiopsis leidyi</i>	ctenophore
Cnidaria	<i>Chrysaora quinquecirrha</i>	sea nettle
Rotifera	<i>Brachionus calyciflorus</i>	rotifer

TABLE E-III-4 (cont'd)  
FINAL STUDY SPECIES LIST

ZOOPLANKTON Cont.		
Crustacea	<i>Acartia clausi</i>	copepod
	<i>Acartia tonsa</i>	"
	<i>Eurytemora affinis</i>	"
	<i>Scottolana canadensis</i>	"
	<i>Bosmina longirostris</i>	cladoceran
	<i>Evadne tergestina</i>	"
	<i>Podon polyphemoides</i>	"
BENTHOS		
Annelida	<i>Limnodrilus hoffmeisteri</i>	oligochaete worm
	<i>Heteromastus filiformis</i>	polychaete worm
	<i>Pectinaria gouldii</i>	"
	<i>Scolecopides virdis</i>	"
	<i>Streblospio benedicti</i>	"
Mollusca	<i>Urosalpinx cinerea</i>	oyster drill
	<i>Crassostrea virginica</i>	oyster
	<i>Macoma balthica</i>	Baltic macoma
	<i>Mercenaria mercenaria</i>	hard clam
	<i>Mulinia lateralis</i>	coot clam
	<i>Mya arenaria</i>	soft clam
	<i>Rangia cuneata</i>	brackish clam
Crustacea	<i>Ampelisca abdita</i>	amphipod
	<i>Balanus improvisus</i>	barnacle
	<i>Callinectes sapidus</i>	blue crab
	<i>Cyathura polita</i>	isopod
	<i>Gammarus daiberi</i>	amphipod
	<i>Leptocheirus plumulosus</i>	"
	<i>Palaemonetes pugio</i>	grass shrimp

TABLE E-III-4 (cont'd)  
FINAL STUDY SPECIES LIST

FISH	
<i>Alosa sapidissima</i>	American shad
<i>Alosa pseudoharengus</i>	alewife
<i>Brevoortia tyrannus</i>	menhaden
<i>Anchoa mitchilli</i>	bay anchovy
<i>Leiostomus xanthurus</i>	spot
<i>Menidia menidia</i>	Atlantic silverside
<i>Micropogon undulatus</i>	Atlantic croaker
<i>Morone saxatilis</i>	striped bass
<i>Morone americana</i>	white perch
<i>Perca flavescens</i>	yellow perch
WILDLIFE (BIRDS)	
<i>Anas platyrhynchos</i>	mallard
<i>Anas rubripes</i>	black duck
<i>Aythya valisineria</i>	canvasback

## CHAPTER IV

### LIFE HISTORY SUMMARIES OF STUDY SPECIES

The final list of study species contains 57 species and associations. Chosen species included 7 phytoplankton associations, 3 emergent aquatic vegetation associations, 5 submerged aquatic vegetation species, 10 zooplankton, 19 benthic invertebrates, 10 fish, and 3 waterfowl; the complete list is given in Table E-III-4. In order to more clearly explain the characteristics of each of the 57 study species, individual species discussions were prepared by WESTECH and are included as Attachment B.

The study species discussions define the most widely accepted common name(s) and identify organism type. Their general range in the Bay and seasonality of distribution or behavior are then discussed. Sensitivity to salinity or other potential effects of low inflow conditions form the focus of each species discussion.

For some species, relevant aspects of "potential habitat" are discussed. The purpose of this is to define habitat areas which may not have been completely documented in the literature, but which possess environmental conditions within which the species can survive. This is followed by a brief discussion of the species trophic importance. The discussion ends with a recapitulation of the particular selection factors relied upon in the selection of the study species in question. Primary source material is listed at the end of each species discussion. Format is slightly different for the various organism groups when certain factors require additional emphasis.

The life history summaries of study species are central to the Low Freshwater Inflow Study. As described in the problem identification appendix, the purpose of the Low Freshwater Inflow Study is to evaluate the effects of alternative fresh water inflows to the Chesapeake Bay system and recommend a salinity regime in the Bay. The environmental impact assessments are nearly entirely dependent upon an evaluation on the effects of the biota of various salinity regimes. Also, social and economic considerations are partially dependent upon biotic effects. The species life histories are the basic data needed to perform these evaluations.

## GLOSSARY

abiotic:	referring to the absence of living organisms.
absorption:	the process by which a substance is taken up by, or penetrates into, another.
acclimation:	the physiological and behavioral adjustments of an organism to changes in its immediate environment.
adsorption:	the adhesion of a substance to the surface of a solid or liquid.
aerobic:	refers to life process occurring only in the presence of oxygen or air.
algae:	any of a group of plants found in water, with chlorophyll, but without true root, stem, or leaf; includes diatoms.
amphibian:	any of a clan of vertebrate animals passing through an aquatic larval stage with gills, and a terrestrial stage with lungs; includes frogs, toads, salamanders.
amphipod:	any of several crustaceans with one set of feet for jumping and another for swimming (e.g., the sand flea).
anadromous:	type of fish that ascend rivers from the sea to spawn.
anaerobic:	refers to life or process occurring in the absence of oxygen or air.
angiosperm:	any of a class of plants, including all the flowering plants, having the seeds enclosed in an ovary (opposed to gymnosperm).
anoxic:	totally deprived of oxygen.
aphotic zone:	bottom region of a water body which supports more respiration than photosynthesis. (as opposed to euphotic zone).
aquatic:	of or pertaining to fresh or salt water; growing or living in or upon water.
benthic:	of or pertaining to the bottom of a water body.

<b>benthos:</b>	those organisms living on or in the bottom of a water body.
<b>bioassay:</b>	method for quantitatively determining the concentration of a substance by its effect on the growth of an animal, plant or microorganism under controlled conditions.
<b>biomass:</b>	total mass or amount of living organisms in a given area.
<b>biota:</b>	the plant and animal life of a region.
<b>biotic:</b>	of or pertaining to life and living organisms.
<b>bivalve:</b>	any of a class of mollusks having two shells hinged together, e.g., clams and oysters.
<b>biochemical oxygen demand (BOD):</b>	a measure of the oxygen depleting power of the organics in a waste water discharge.
<b>calanoida:</b>	a suborder of the crustacean order Copepod, including the larger and more abundant of the pelagic species.
<b>catadromous:</b>	going back or toward the sea to spawn; said of certain freshwater fishes, including American eel.
<b>chlorinated hydro-carbons:</b>	a class of generally long-lasting insecticides, variously hazardous through accumulation in the food chain and persistence in the environment.
<b>clupeid:</b>	any of a family of soft-finned fishes, as herring.
<b>community:</b>	(in biology) an accumulation of diverse organisms living together in an orderly, interrelated manner.
<b>consumer, primary:</b>	an organism which consumes green plants.
<b>consumer, secondary:</b>	an organism which consumes the primary consumer.
<b>copepods:</b>	any of a subclass of small crustaceans of fresh or saline waters; a component of the zooplankton.
<b>crustacean:</b>	a large class of invertebrate animals, usually aquatic, bearing a horny shell (e.g., lobster, shrimp, and barnacles).
<b>DDT:</b>	most infamous of the chlorinated hydrocarbon insecticides.

demersal:	living at or near the bottom of the sea.
dissolved oxygen (DO):	oxygen gas dissolved in water, necessary for life of fish and other aquatic organisms; becomes depleted by high BOD-containing waste.
detritus:	a non-dissolved product of disintegration or decay; organic detritus forms the basis of the estuarine food chain.
detritivores:	animal that eats detritus.
diadromous:	fish migrating between salt and freshwater.
diatom:	any of a class of minute, planktonic or attached unicellular or colonial algae.
dinoflagellates:	an order of the phylum protozoa, mostly free living, having a wide distribution and making up much of the plankton in both fresh and marine waters.
dominant:	said of an organism that controls the habitat or has profound influence in a biotic community, often the most conspicuous.
ecology:	the interrelationships of living things to one another and their environment; or the study thereof.
ecosystem:	the interacting system of a biological community and its environment.
ecotone:	a zone of intergradation between ecological communities.
endemic:	indigenous or characteristic of a particular locale.
epifauna:	species which live attached on or above the bottom.
epiphyte:	a plant that grows on another plant but is not a parasite, producing its own food by photosynthesis.
epizootic:	an epidemic disease among the animals.
estuary:	the zone of mixing of freshwater runoff from the land and salt water from the intruding ocean.
ethology:	the scientific study of the behavior patterns of animals.
euphotic zone:	the upper layers of a water body in which sufficient light penetrates to allow growth of green plants.

euryhaline:	of/aquatic organisms capable of surviving a wide range of salinities.
eurythermal:	of/an organisms capable of living in a wide range of temperatures.
eurytopy:	rich in dissolved nutrients but often shallow and seasonally deficient in oxygen.
eutrophication:	(lit. "well fed") a process whereby waterways become overgrown with plant growth due to overenrichment; generally caused by nutrient loads from waste discharges and agricultural runoff.
fauna:	the animals of a given region, as opposed to the "flora."
flora:	organisms of the plant kingdom occurring in a particular area.
freshet:	a stream or rush of freshwater flowing into an area.
gastropods:	a diverse class of the phylum Mollusca, containing snails, slugs, limpets and conchs.
game fish:	those species of fish sought by sport fishermen.
habitat:	the total of environmental conditions affecting an organism, population, or community.
herbicide:	a chemical substance used to kill plants or inhibit plant growth.
herbivore:	animal that eats only vegetation.
heterotrophs:	organism that obtains nourishment from ingestion and breakdown of organic matter.
holoplankton:	an organism which spends its entire life cycle as a member of the plankton community.
hydrophyte:	a plant which grows in water or very wet earth.
hypoxia:	oxygen deficient.
ichthyoplankton:	life stages of fish which are part of the plankton.
indigenous:	of/native species, not introduced.
infauna:	species which burrow into the substrate.

interstitial waters:	that occurring in the voids of bottom sediments.
intertidal:	of or having to do with the region of shoreline extending from low to high tide marks.
invertebrate:	any animal lacking a backbone (e.g., insects, mollusks, and crustaceans).
isohaline:	a line of constant salinity.
larva:	an early developmental stage of an animal which changes structurally to become an adult (e.g., caterpillars, tadpoles).
life cycle:	the phases, changes, or stages in which an organism exists during its lifetime.
limiting factor:	a variable in the environment which limits the distribution or abundance of a particular organism.
limnology:	the study of the biological, chemical, and physical features of inland waters.
littoral zone:	zone of rooted vegetation.
macrofauna:	the large (visible to the naked eye) animals of an area.
marine:	of or pertaining to the sea or ocean.
marsh:	a tract of low-lying, soft, wet land; a swamp dominated by grasses or grass-like vegetation.
meroplankton:	organisms that spend only a part of their life cycle as a member of the plankton.
microbiota:	the microscopic organisms present in an area.
mollusk:	any of a phylum of invertebrate animals, including clams, oysters, snails, and octopi.
morphology:	the study of the form and structure of an organism.
motile:	capable of spontaneous movement.
muck:	soils composed of decaying plant materials.
nanoplankton:	microscopic, free-floating aquatic organisms.
nekton:	free-swimming aquatic animals, whose movements are largely independent of water currents, e.g., adult fish and crabs.

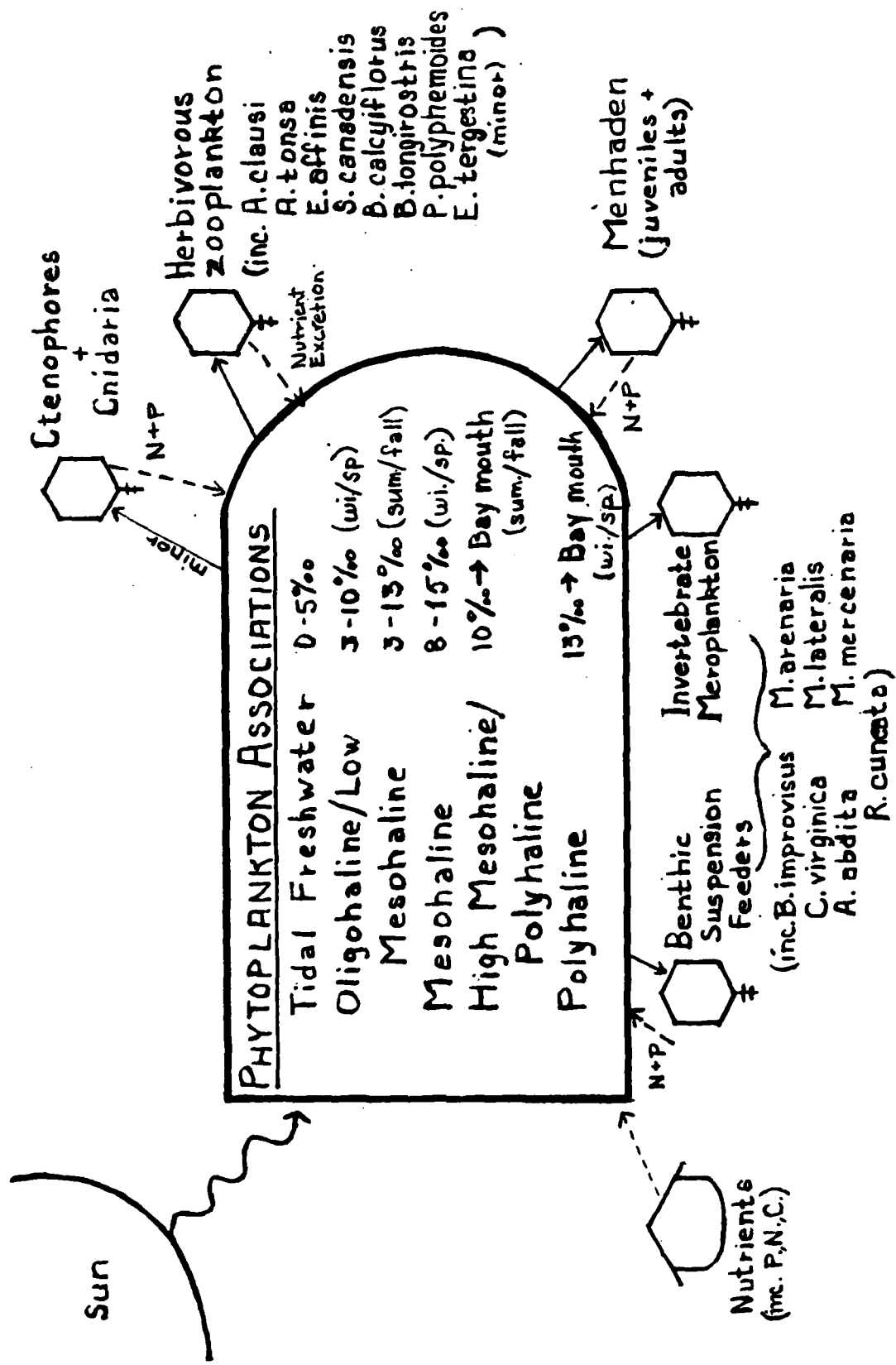
net plankton:	large plankton (greater than 0.07 mm mesh net size) as opposed to nanoplankton.
nocturnal:	occurring or active during hours of darkness; said of owls, bats, and many other animals.
non-vascular plants:	plants without specialized conductive tissues, e.g., algae, mosses.
nutrients:	elements or compounds essential for biological productivity; a pollutant when in excess in waterways, causing excessive plant growth.
nutrient cycling:	the movement of nutrients from the non-living (abiotic) component of the environment, through the living, and with time, back to the abiotic.
nymph:	immature stage of arthropods (primarily insects) that is not markedly different from the adult.
oligohaline:	of or pertaining to low chloride concentrations.
omnivorous:	eating a wide variety of food, both plant and animal.
organic:	of or derived from living organisms; typically contains carbon and hydrogen.
organism:	any individual plant or animal having parts or organs that function together to maintain life and its activities.
oviparous:	reproducing by eggs that hatch outside the parents body.
oxygen sag:	a drop in $O_2$ concentration; caused in streams by gradual decay of organics in waste discharges.
parameter:	a measurable, variable quantity.
passerine:	chiefly perching; songbirds, as opposed to waterfowl and raptors.
pelagic	inhabit open water.
periphyton:	community of organisms usually small but densely set, closely attached to stems and leaves of rooted aquatic plants or other surfaces projecting above the bottom.
pesticide:	toxic chemical used to kill problem plants and animals--insecticides, herbicides.

pH:	a numerical expression of acidity; the negative logarithm of hydrogen ion concentration.
photosynthesis:	the process in plants of production of carbohydrates from carbon dioxide and water, using sunlight as energy, and chlorophyll as a mediator.
phytoplankton:	plankton consisting of plants; e.g., algae.
piscivorous:	feeding on fishes.
planktivorous:	feeding on plankton.
plankton:	usually microscopic plant and animal life found drifting or floating in a water body; if mobile, only weakly so.
pollution:	an additive to a particular environment rendering it of reduced utility or benefit.
polyp:	any of various coelenterates having a mouth fringed with many small slender tentacles at the top of a tube-like body.
predator:	an organism living by capturing and feeding upon other animals.
productivity:	the rate of production of organic matter produced by biological activity in an area (measured in units of weight or energy per unit volume and time).
protist:	any of a large group of one-celled organisms having both plant and animal characteristics, e.g., algae, bacteria, protozoans.
psammofauna:	animals living in water held between sand grains in waterlogged sands.
psamophilic:	sand loving.
raptors:	any of a group of birds of prey, including hawks, falcons, eagles, and owls.
red tide:	an excessive bloom of red-pigmented plankton, capable of causing massive fish kills.
relict:	said of a species "left behind," belonging to an earlier period or community type, now living in isolation in a small local area.

reptiles:	one of the major groups of cold-blooded vertebrate animals, generally having scales and true lungs (e.g., snakes, turtles, lizards).
resilience:	in biology, the ability of an ecosystem to resist or recover from stress.
respiration:	breathing; in biology, the oxidative breakdown of food by organisms to produce life energy.
rhizome:	an underground horizontal stem possessing buds, nodes and scale-like leaves.
salinity:	a measure of the concentration of dissolved solids in water.
salt marsh:	grass-dominated, flat, intertidal area, inundated periodically (seasonally or by the tides) with saline water.
saprophyte:	any organism living on dead or decaying organic matter, includes some fungi and bacteria.
sedentary:	remaining in one locality; not migratory.
sedge:	a type of low grass-like plant with a triangular cross-section, usually occurring in wet areas.
sessile:	attached, stationary, non-moving (e.g., oysters, barnacles).
seston:	a collective term for everything floating or suspended in water, including plankton and detritus.
shell fish:	aquatic animals having a shell or exoskeleton, usually mollusks (clams and oysters).
siltation:	a process whereby small suspended particles are deposited in a water body as sediment.
spawn:	to produce or deposit eggs, sperm, or young.
species:	a distinct kind; a population of plant or animal all having a high degree of similarity and that can generally only breed among themselves.
stenohaline:	of/organisms which can endure only a narrow range of salinities.
stenotopy:	narrow range of food.

sublittoral zone:	below mean sea level to boundary to rooted vegetation.
succession:	the replacement of one community by another through a regular sequence of changes over time.
supra-littoral zone:	above mean sea level to the level affected by sea spray.
synergism:	the superimposed effects of separate pollutants or substances so that the total effect is greater than the sum of the effects independently.
taxonomy:	the system of arranging animals and plants into related groups based on structure, embryology, biochemistry, etc.
terrestrial:	of or pertaining to dry ground, as opposed to "aquatic."
thermal pollution:	the abnormal raising or lowering of water temperatures above or below seasonal ranges.
toxicity:	the quality or degree of being poisonous or harmful to an organism.
trophic level:	comprised by all organisms in a complex community that derive their food a common step away from the primary producer.
turbidity:	the condition of water containing conspicuous amounts of suspended material.
upland:	all areas of land above the depressions occupied by lakes, rivers, swamps, or seas.
vascular plants:	plants that have xylem and phloem to convey water and food.
vertebrate:	those animals possessing a backbone or spinal column, i.e., fishes, birds, reptiles, amphibians, and mammals.
waterfowl:	birds frequenting water, including game birds such as ducks and geese.
wetlands:	an area characterized by high soils moisture and high biological productivity, where the water table is at or near the surface for most of the year.
zooplankton:	plankton consisting of animals, as protozoa.

ATTACHMENT A  
BIOLOGICAL INTERACTIONS



Phytoplankton Associations - Trophic Diagram

Key for Figures A-3 through A-26  
(for visual clarity, latin names are not underlined)

Species Lifestages

l - larvae  
j - juvenile  
a - adult  
m - medusa  
p - polyp

Organisms

na - nanoplankton  
net - net phytoplankton

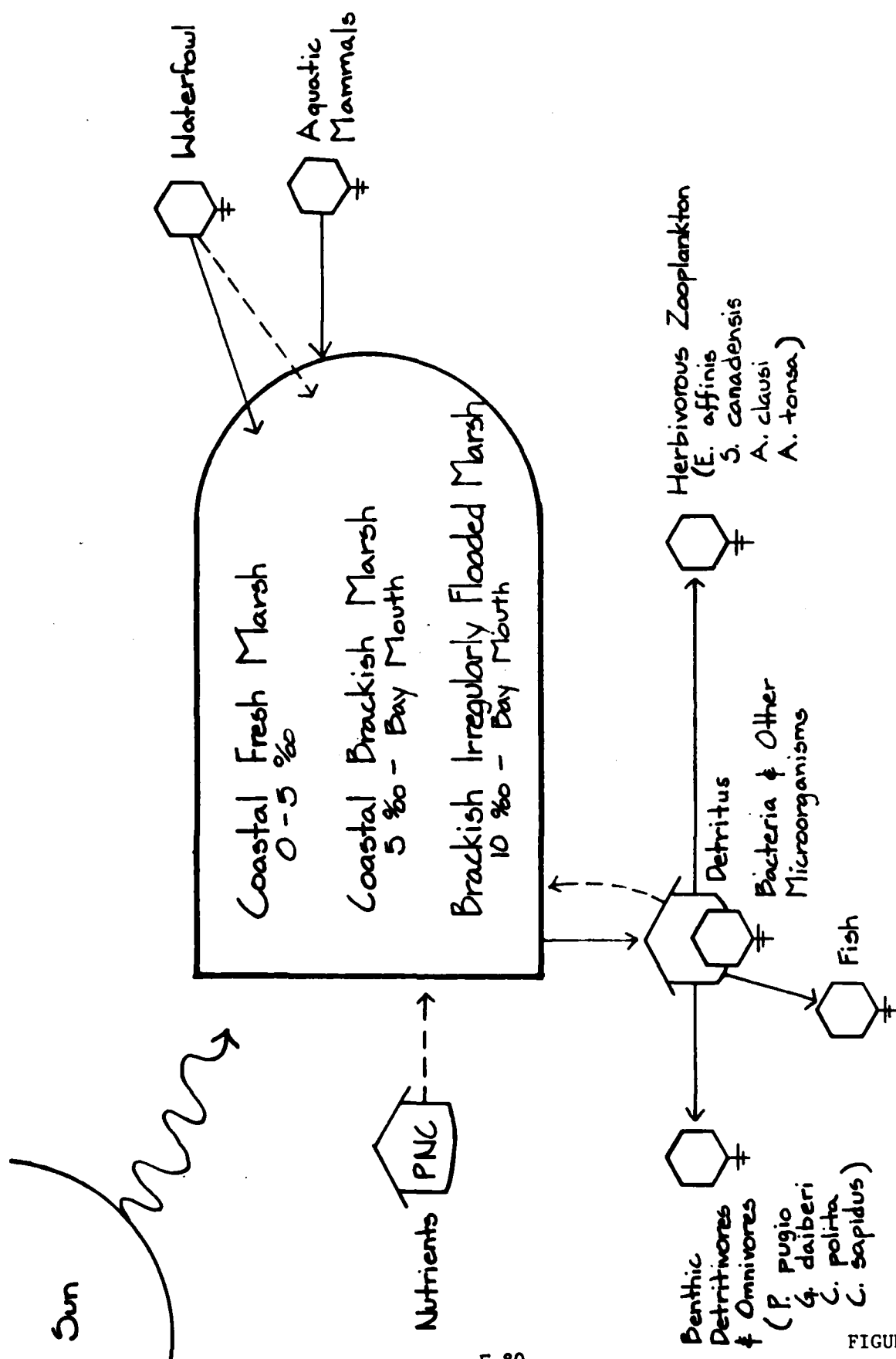
Interactions

P - predator  
F - food  
D - disease  
O - overlap  
H - forms habitat  
M - habitat modifier  
C - competitor  
PH - predator on habitat provided by the organism  
(i.e. epiphytes)

Method of reading - Begin with a species in the column on the left hand side of the page. The interactions indicate this species effect on a species in the top row: i.e. "P" indicates the species in the side column is a predator on the corresponding species on the top row. An "F" indicates the side column species provides food for the species in the top row, etc.

Table III-6. Phytoplankton

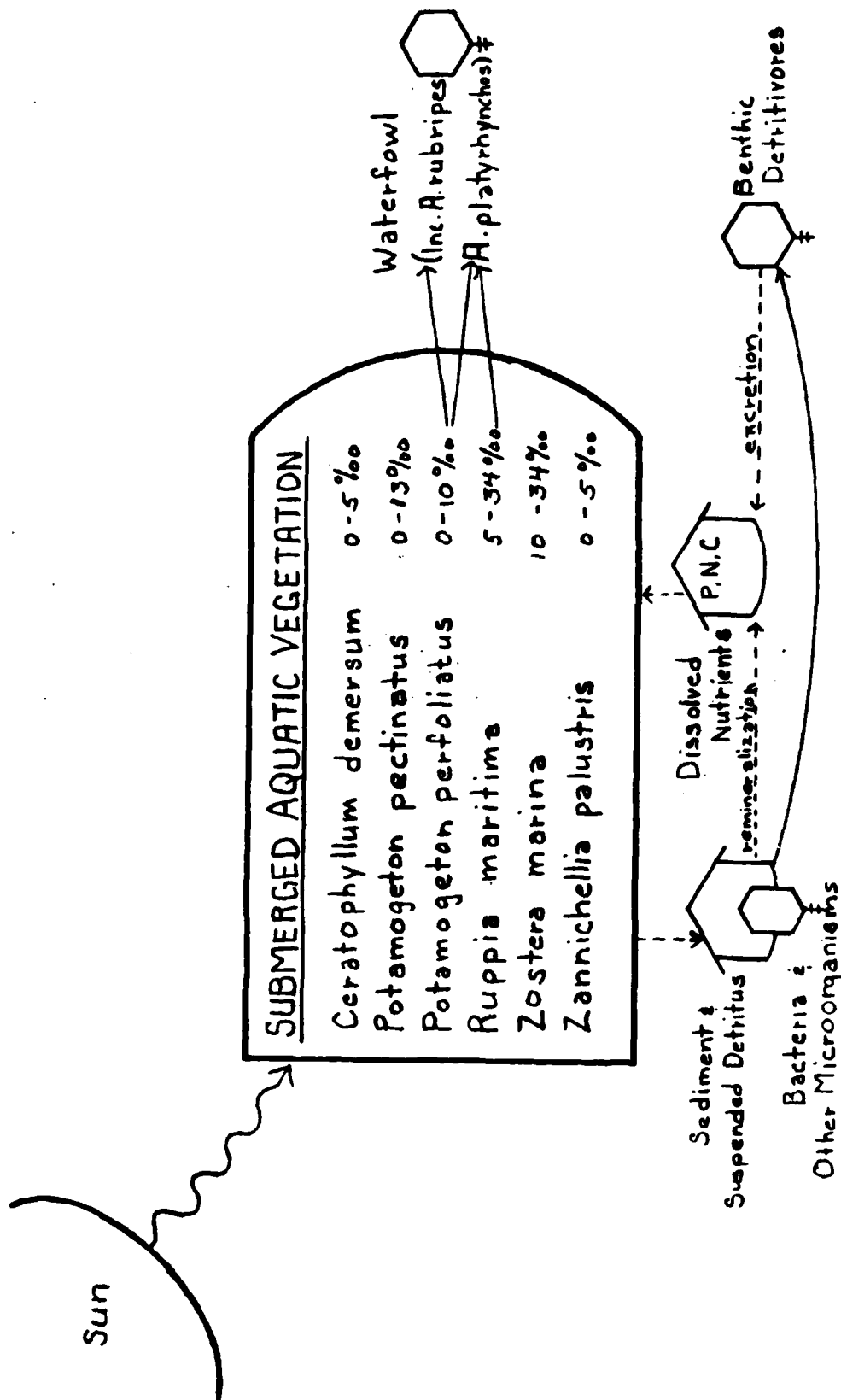
Study Species	Tidal Freshwater Assoc. W/Sp	Tidal Freshwater Assoc. S/F	Oligo-low Mesohaline W/Sp	Oligo-Low Mesohaline S/F	Mesohaline W/Sp	High Mesohaline Polyhaline S/F	Polyhaline W/Sp	Prorocentrum minimum/Su	Prorocentrum minimum/W
Tidal FW Phyto		C	C						
Oligo-low Meso Phyto	C	C			C	C			
Mesohaline Phytos		C	C				C		
High Meso/Poly Phyto				C		C			
Polyhaline Phytos				C					
P. minimum		C/M	C/M	C/M	C/M				
Cnidaria & Ctenophores		P	P	P	P	P	P		
Brachionis	P*/na	P*/na	P*/na	P*/na					
Other Microzooplankton	P/nan	P/na	P/na	P/na	P/na	P/na	P/na		
Bosmina	p*	p*	p*	p*/l					
Evadne					P/net	P/net	P		
Podon		p*	p*	p*	p*	p*	p*	p*	
A. clausi		p*		p*		p			p*
A. tonsa		P	P	p*	P	P*	P	P	
E. affinis	p*	p*	p*	p*	p*				
S. canadensis	P	P	P	P	P				
copepod nauplii	p*	p*	p*	p*	p*	p*	p*		
crustacean larvae	P	P	P	P	P	P	P	P	
molluscan larvae	P	P	P	P	P	P	P	P	
Brevoortia (adult)								p*	
Brevoortia(juv.)								P	p*
Balanus improvisus		P	P	P	P				
Crassostrea		P/na	P/na	P/na	P/na	P/na			
Mya		P	P	P	P	P	P		
Mulinia		P	P	P	P	P	P		
Mercenaria				P	P	P	P		
Rangia	P	P	P	P					
Ampelisca					P	P	P		P
other suspension feeders	P	P	P	P	P	P	P	P	P
bacteria	M	M	M	M	M	M	M	M	M



Emergent Aquatic Vegetation - Trophic Diagram

Ecological Relationships  
Emergent Aquatic Vegetation

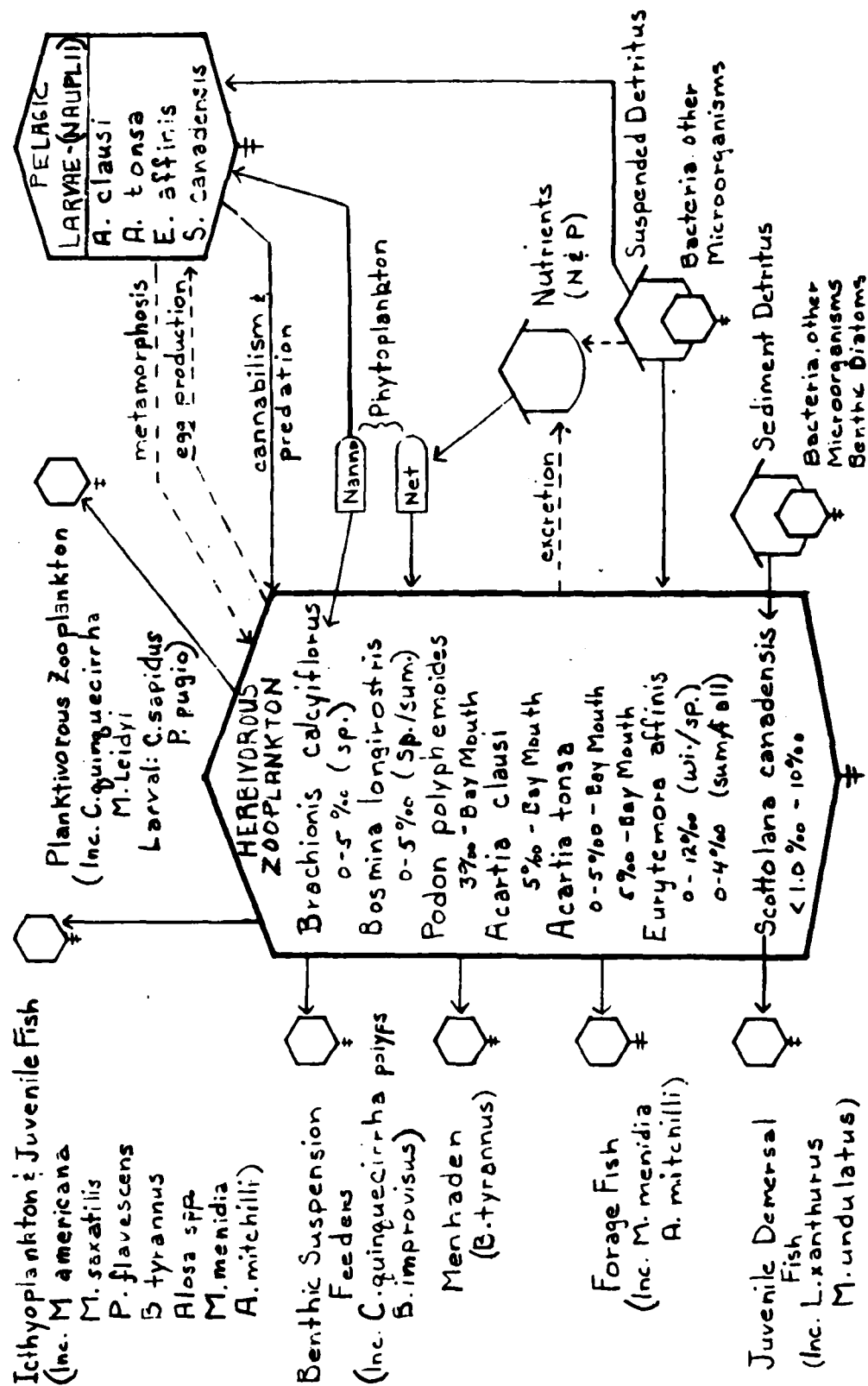
Study Species →	Coastal Fresh Marsh	Coastal Brackish Marsh	Brackish Irreg. Flooded Marsh
Coastal Fresh Marsh		C	C
Coastal Brackish Marsh	C		C
Brackish Irreg. Flooded		C	
Eurytemora affinis	P		
herbivorous zoopl.	P	P	P
Palaemonetes pugio	P/H	P/H	P/H
C. polita	P	P	P
G. daiberi	P	P	P
C. sapidus & other crabs	P/H	P/H	P/H
Benthic detritivores	P	P	P
Fish	H*	H*	H*
Waterfowl	F*/H*	F/H*	H*
Aquatic mammals	F*/H*	F/H*	F/H*



Submerged Aquatic Vegetation - Trophic Diagram

Ecological Relationships  
Submerged Aquatic Vegetation

Study Species →	<i>Ceratophyllum demersum</i>	<i>Potamogeton pectinatus</i>	<i>Potamogeton perfoliatus</i>	<i>Ruppia maritima</i>	<i>Zostera marina</i>	<i>Zannichellia palustris</i>
<i>Ceratophyllum</i>					C	
<i>Potamogeton perf.</i>	C					
<i>Potamogeton pectin.</i>		C				
<i>Ruppia maritima</i>				C		
<i>Zostera marina</i>				C		
<i>Zannichellia</i>	C					
Epifaunal invertebrates	PH	PH/P	PH/P	PH/P	PH/P	PH
<i>Palaemonetes</i>		PH	PH	PH	PH	
<i>Callinectes</i>		PH	PH	PH	PH	
<i>Gammarus</i>	PH	PH	PH	PH	PH	PH
Cow-nosed Ray				M	M	
Epiphytic algae	PH/C	PH/C	PH/C	PH/C	PH/C	PH/C
<i>Athyra valisineria</i>	P	P*				P
<i>Anas rubripes</i>	P	P	P*	P*	P*	P
<i>A. platyrhynchos</i>	P	P	P*	P*		P
other ducks & geese	P	P*	P*	P*	P*	
other waterfowl	P	P	P	P*		
benthic detritivores	PF	PF	PF	PF	PF	PF
Bacteria	PF	PF	PF	PF	PF	PF
larval & juvenile fish	PH*	PH*	PH*	PH*	PH*	PH*
aquatic mammals	P	P	P			P



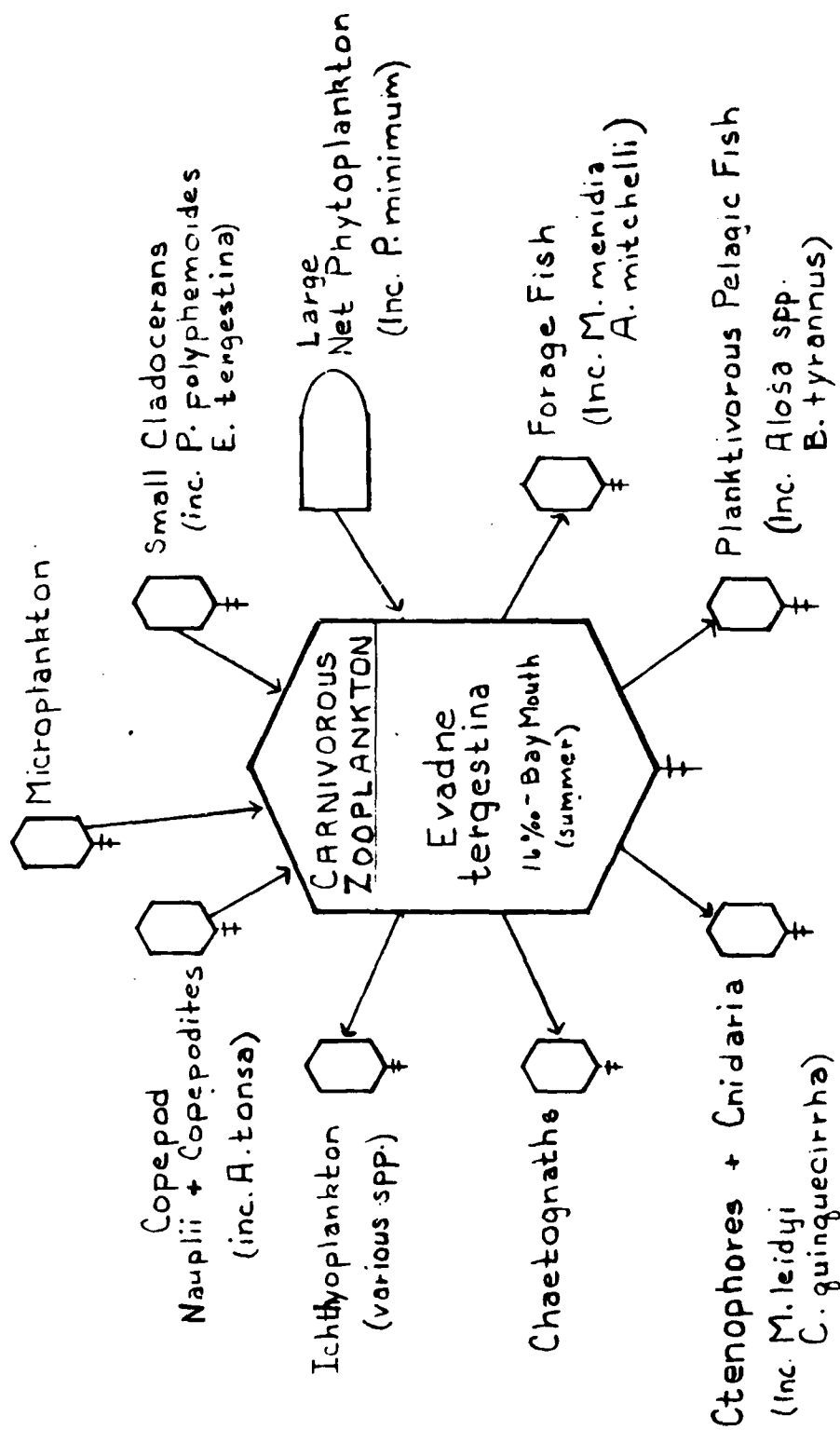
Herbivorous Zooplankton - Trophic Diagram

Zooplankton		Study Species												
	Mnemiopsis leidy													
		M	M	M/F	M/F	M	F	F*	F*	F*	F*	F*	F*	F*
Nannoplankton														
Net Phytoplankton														
Mnemiopsis														
Chrysaora														
Beroe ovata														
Brachionis														
Bosmina														
other microzooplankton														
Podon														
Evadne														
Acartia clausi														
Acartia tonsa														
Eurytemora affinis														
Scottolana														
Copepod nauplii														
Callinectes larvae														
Palaemonetes larvae														
other meroplankton														
Brevoortia (adult)														
Leiostomus (juv)														
Micropononias (juv.)														

FIGURE A-9

Zooplankton (cont.)		Study Species →													
Memipops leidy	Chrysaora quinquecirrha m.	Chrysaora quinquecirrha p.	Brachionus calyciflorus	Bosmina longirostris	Podon polyphemoides	Evadne tergestina	Acartia clausi	Acartia tonsa	Eurytemora affinis	Scotolana canadensis	Copepod nauplii				
			</												

FIGURE A-9 Cont'd



Carnivorous Zooplankton - Trophic Diagram

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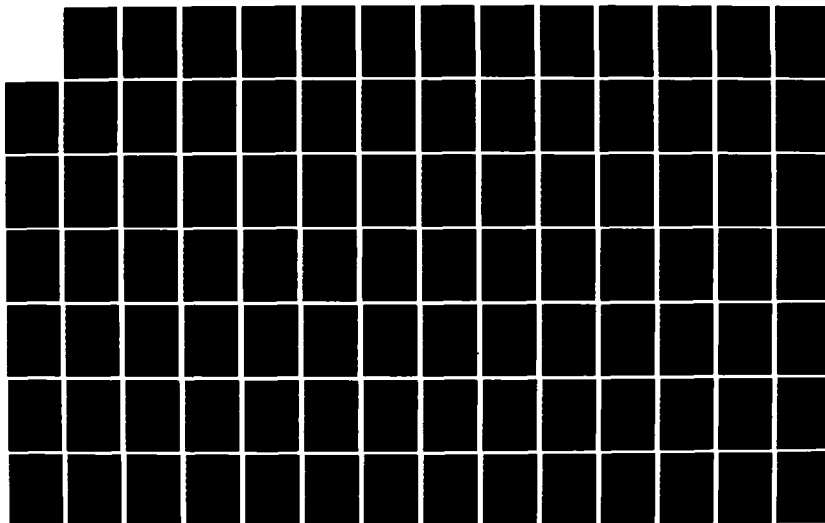
CHESAPEAKEBAY LOW FRESHWATER INFLOW STUDY APPENDIX E  
BIOTA(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE  
DISTRICT SEP 84 CHB-84-L-APP-E

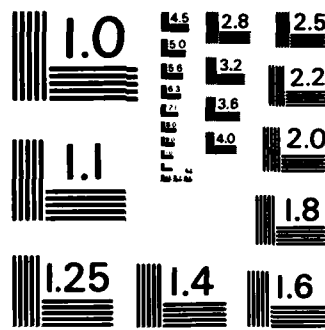
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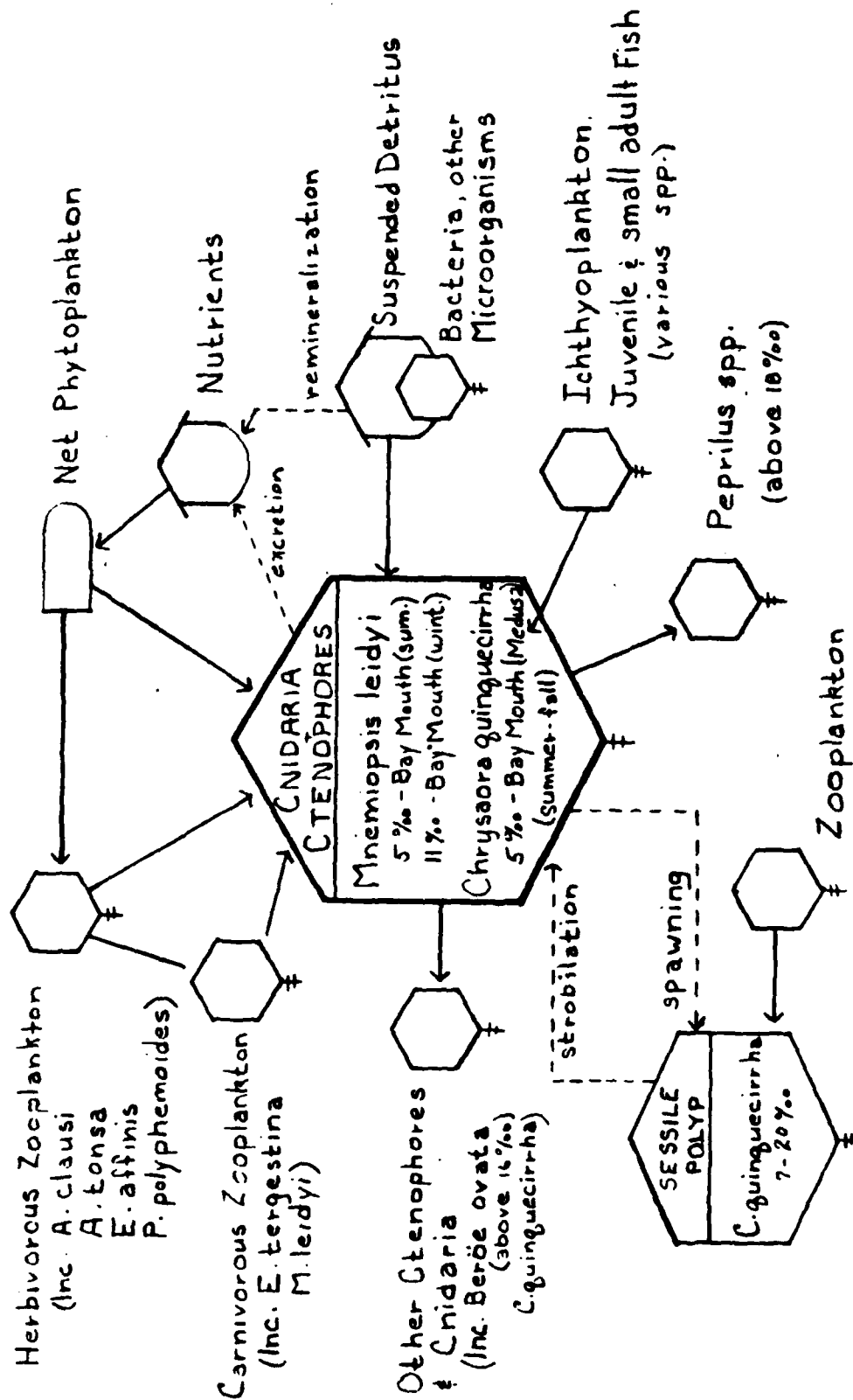
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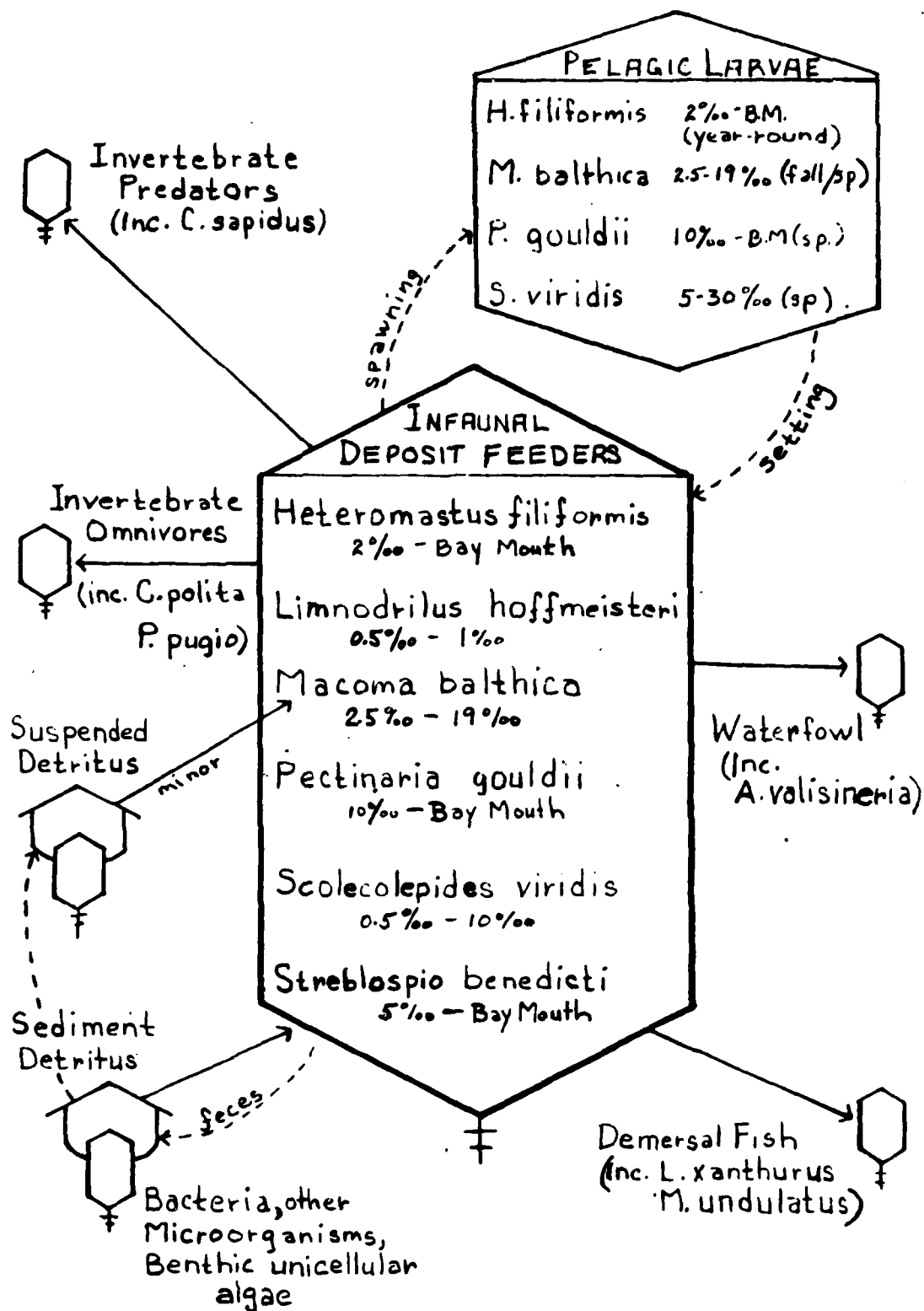




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Ctenophores and Cnidaria - Trophic Diagram



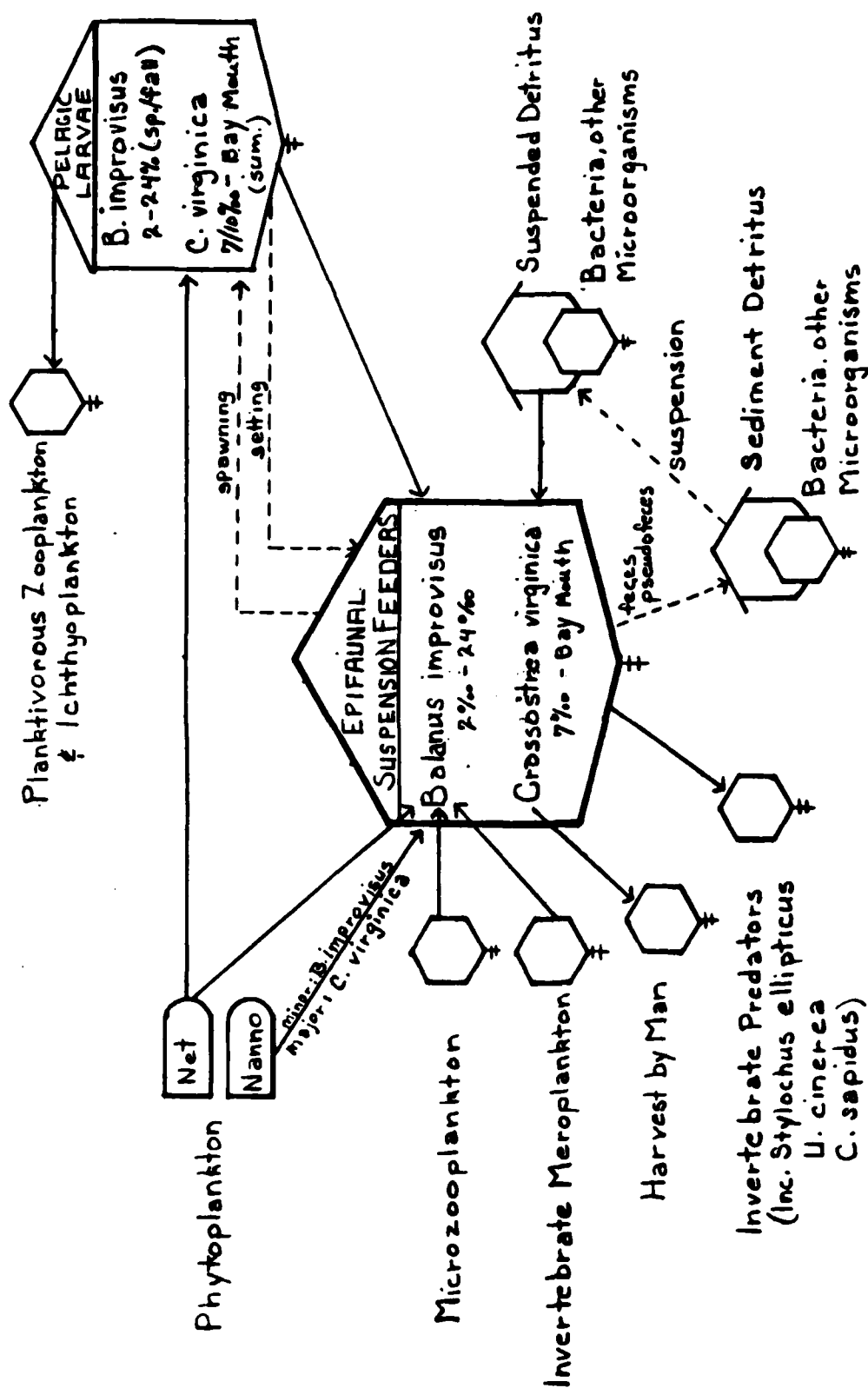
Infaunal Deposit Feeders - Trophic Diagram

Benthic Organisms	Study Species →										
	<i>Heteromastus filiformis</i>	<i>Lianodrilus hoffmeisteri</i>	<i>Macoma balthica</i>	<i>Pectinaria gouldii</i>	<i>Scolecoclepidus viridus</i>	<i>Streblospio benedicti</i>	<i>Cyathura polita</i>	<i>Gammarus dalmani</i>	<i>Leptocheritos plumulosus</i>	<i>Palaemonetes pugio</i>	<i>Balanus improvisus</i>
nannoplankton		F						F		F	
net phytoplankton								F		F	
benthic algae	F*	F*	F*	F*	F*	F	F	F			
<i>Zostera marina</i>	M	M				M			F/H*		
<i>Ruppia maritima</i>	M	M				M			F/H*		
other SAV		M		M		M	F/H		F/H*		
<i>Chrysaora</i>											
<i>Chrysaora polyps</i>											
<i>Mnemiopsis</i>											
microzooplankton								F		F*	
copepods (A. & nauplii)				F				F		F*	
cladocerans											
<i>Palaemonetes pugio</i>			P			P*					
<i>Callinectes</i> <sup>other</sup> <del>crabs</del>	P*	P	P	P*	P*	P*	P*	P*	P	P*	
<i>Cyathura polita</i>		P		P	P	P*					
<i>Urosalpinx cinerea</i>		P									P*
<i>Stylochos ellipticus</i>											P*
<i>Leiostomus</i> (A. & J.)	P*		P*	P*	P*	P*	P*	P*	P*	P*	
<i>Micropogonias</i> (A. & J.)	P*		P*	P*	P*	P*	P*	P*	P*	P*	
<i>Morone saxatilis</i>	P		P	P		P				P*	
<i>Morone americana</i>	P	P		P		P	P	P	P	P*	
<i>Perca flavescens</i>	P	P		P		P	P	P	P	P*	
<i>Balanus improvisus</i>											
<i>Aythya valisineria</i>		P	P*								
other waterfowl	P	P	P	P	P*		P	P	P	P	
Bacteria	F*	F*	F*	F*	F*	F*	F	F	F*	F*	F*
detritus, <sup>decaying</sup> <del>water</del>	F*	F*	F*	F*	F*	F*	F*	F*	F*	F*	F
invertebrate larvae				F			F	F			F
<i>Crassostrea</i>						M					M
mollusks				F		F	F		F		
polychaete worms			C	F		F	F		F		
<i>Minchinia</i> (MSX)											
<i>Perkinsus</i> ("dermo")											
<i>Streblospio</i>	M	M									

FIGURE A-13

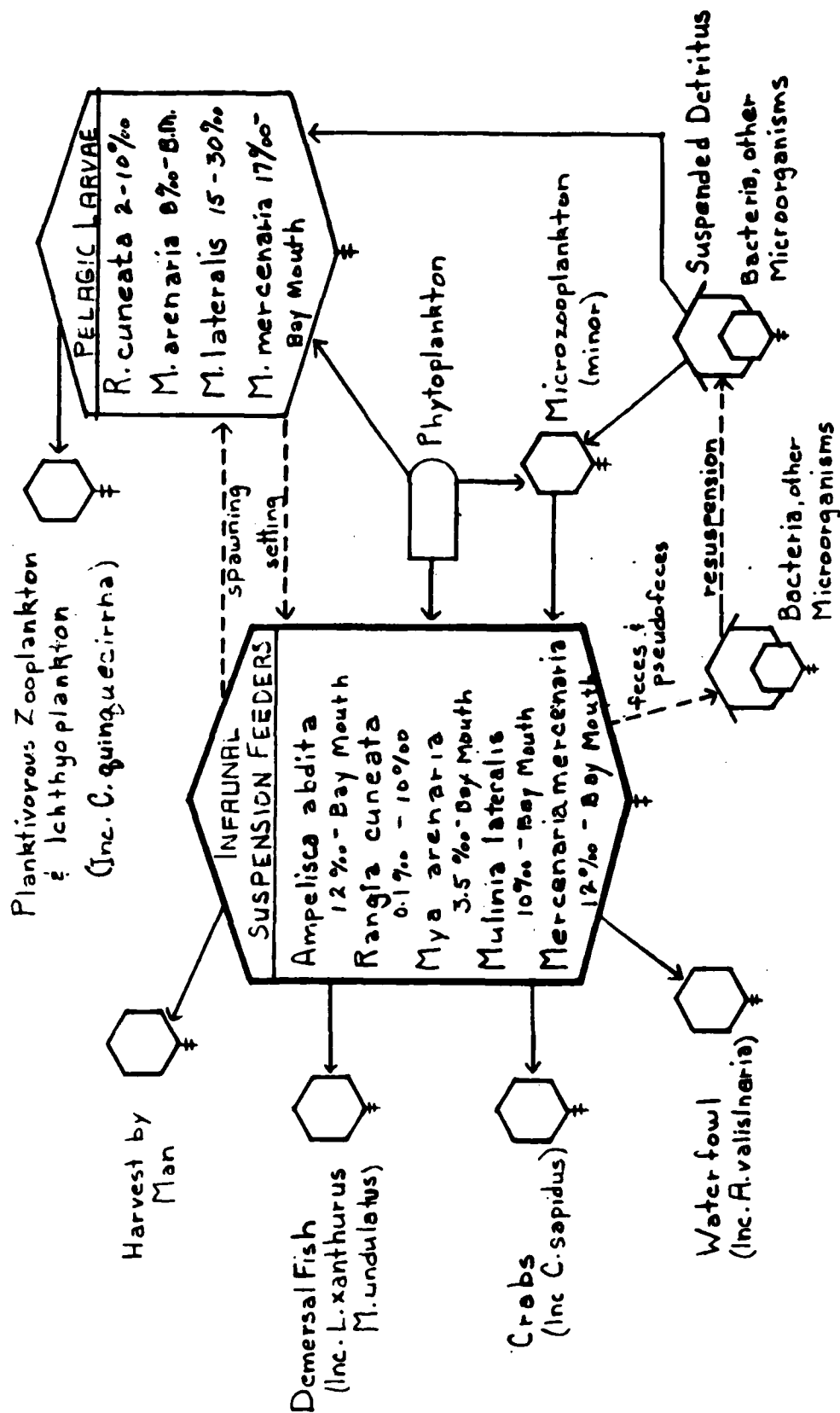
Benthic Organisms (cont.)	Crassostrea virginica (adult)	Crassostrea larvae	Rangia cuneata	Mya arenaria	Mulinia lateralis	Mercenaria mercenaria	Other bivalve larvae	Urosalpinx cinerea	Ampelisca abdita	Callinectes sapidus (adult)	Crustacean larvae
Study Species →											
nannoplankton	F*	F*	F*	F*	F*	F*	F*	F		F*	
net phytoplankton	F		F*	F*	F*	F*	F*	F		F*	
benthic algae				F	F			F*	F		
Zostera marina	M			M	M	M			F/H*		
Ruppia maritima	M			M	M	M			F/H*		
other SAV	M		M	M	M	M			F/H*		
Chrysaora	P*						D*				P*
Chrysaora polyps		P					P				P
Mnemiopsis		P*					P*				P*
microzooplankton		C		F*	F*		C				C
copepods (A. & nauplii)		C					C				C/F
cladocerans		C/P					C/P				C/F
Palaemonetes pugio										F	
Callinectes & other crabs	P*		P*	P*	P*	P		P	P	F	
Cyathura polita										F	
Urosalpinx cinerea	P*		P/juv	P	P/juv						
Stylochos ellipticus	P*										
Leiostomus (A. & J.)		P/juv	P*/juv	P*p/juv				P	P		
Micropogonias (A. & J.)		P/juv	P*/juv	P* p/juv				P	P		
Morone saxatilis			/juv	P	P/juv					P*	
Morone americana		P/juv								P	
Perca flavescens		P juv									
Balanus improvisus	C	P					P	F*		F	P*
Aythya valisineria			P	P/juv	P						
other waterfowl	P		P	P	P			P	P		
Bacteria	F*	F*	F*	F*	F*	F*	F*	F*		F*	
detritus, decaying matter	F*	F	F*	F*	F*	F*	F*	F	F*	F*	F*
invertebrate larvae		C									C
Crassostrea	C	H			M	M	F*/H		F*	M	
mollusks	M	M				M/C	F*		F*		
polychaete worms	M	M				M			F*		
Minchinia (MSX)	D*										
Perkinsus ("dermo")	D*										
Streblospio			M	M		M		C			

FIGURE A-14

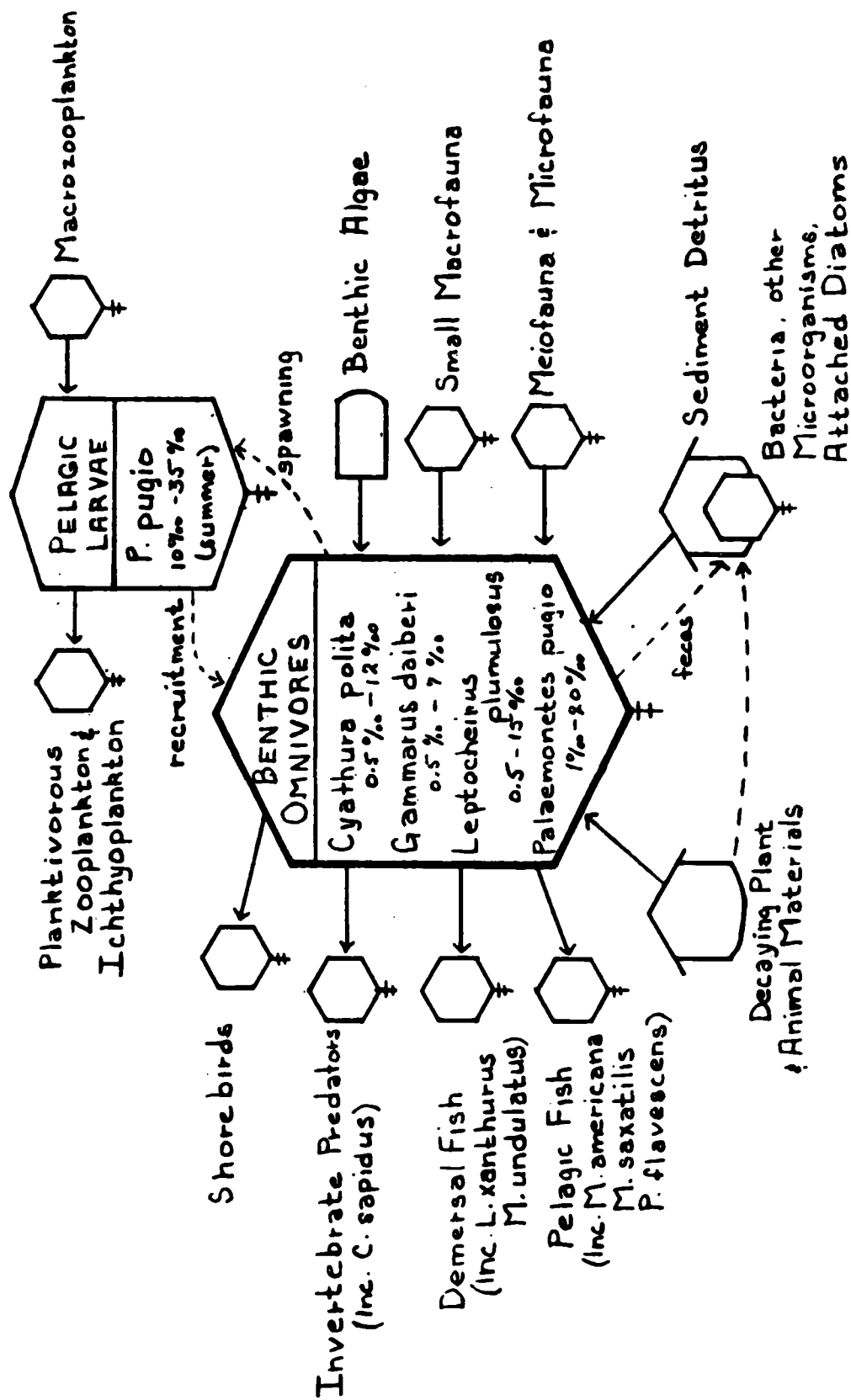


Epifaunal Suspension Feeders - Trophic Diagram

FIGURE A-15

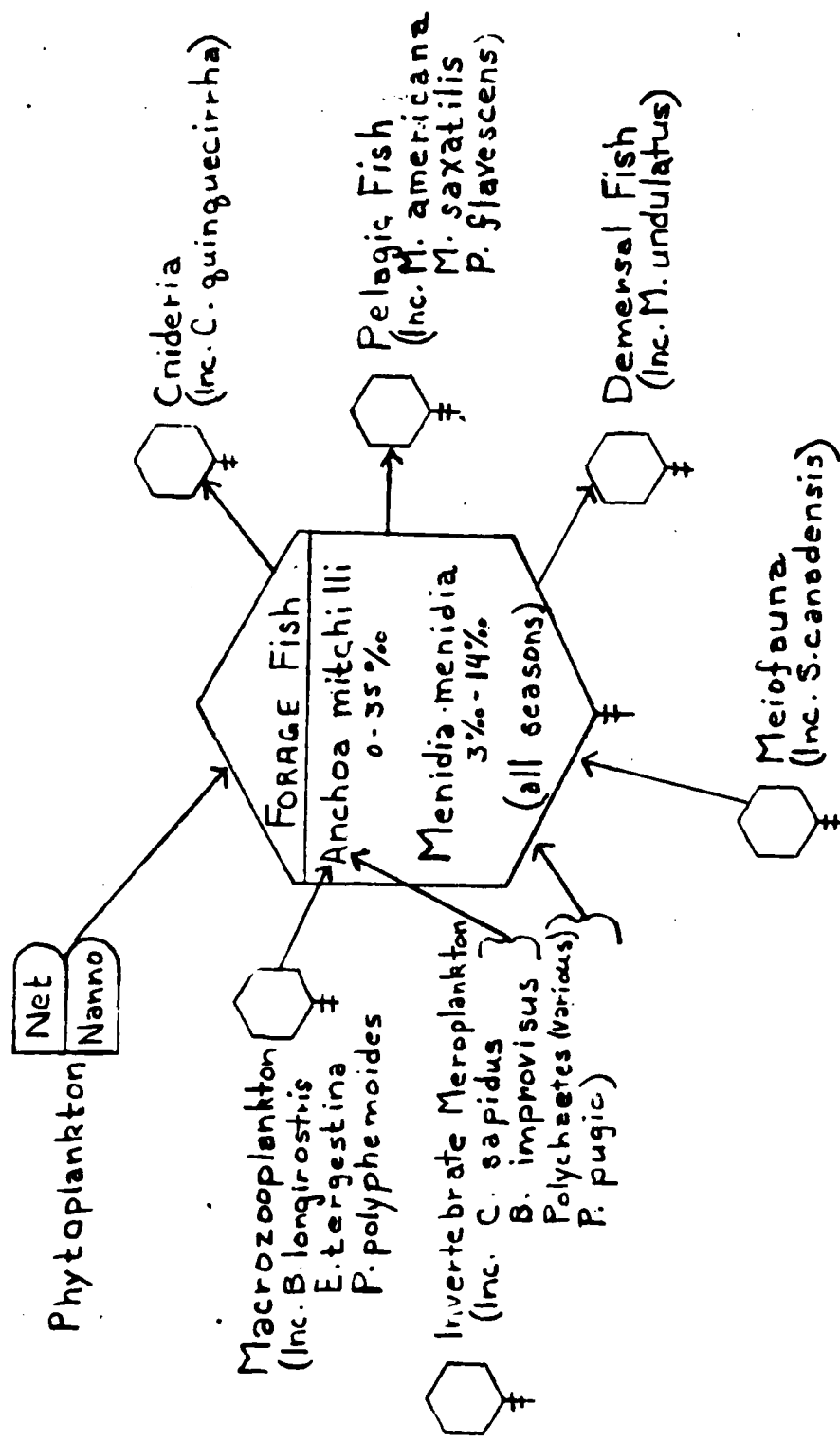


Infaunal Suspension Feeders - Trophic Diagram



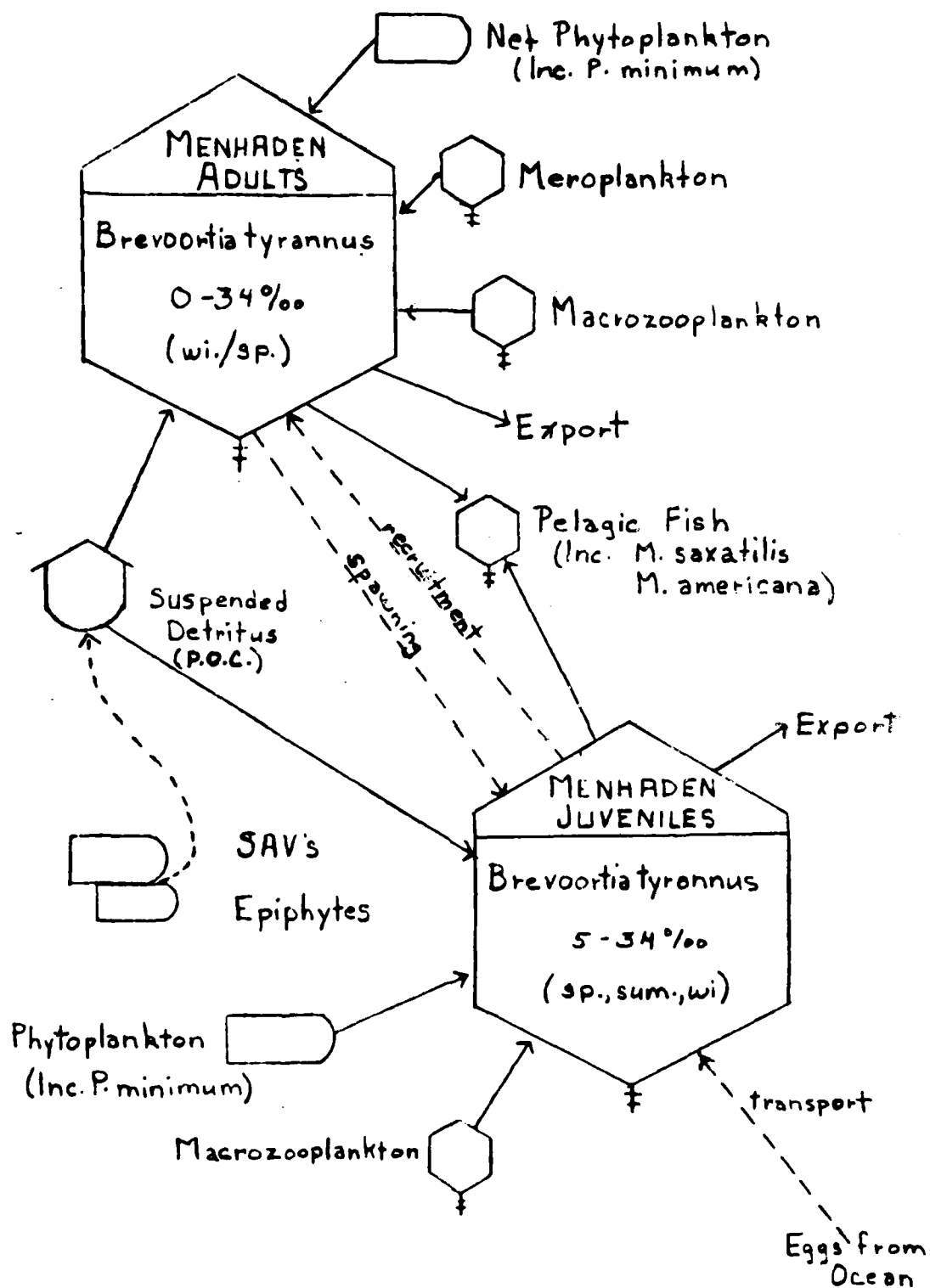
Benthic Omnivores (Mixotrophic Feeders) - Trophic Diagram





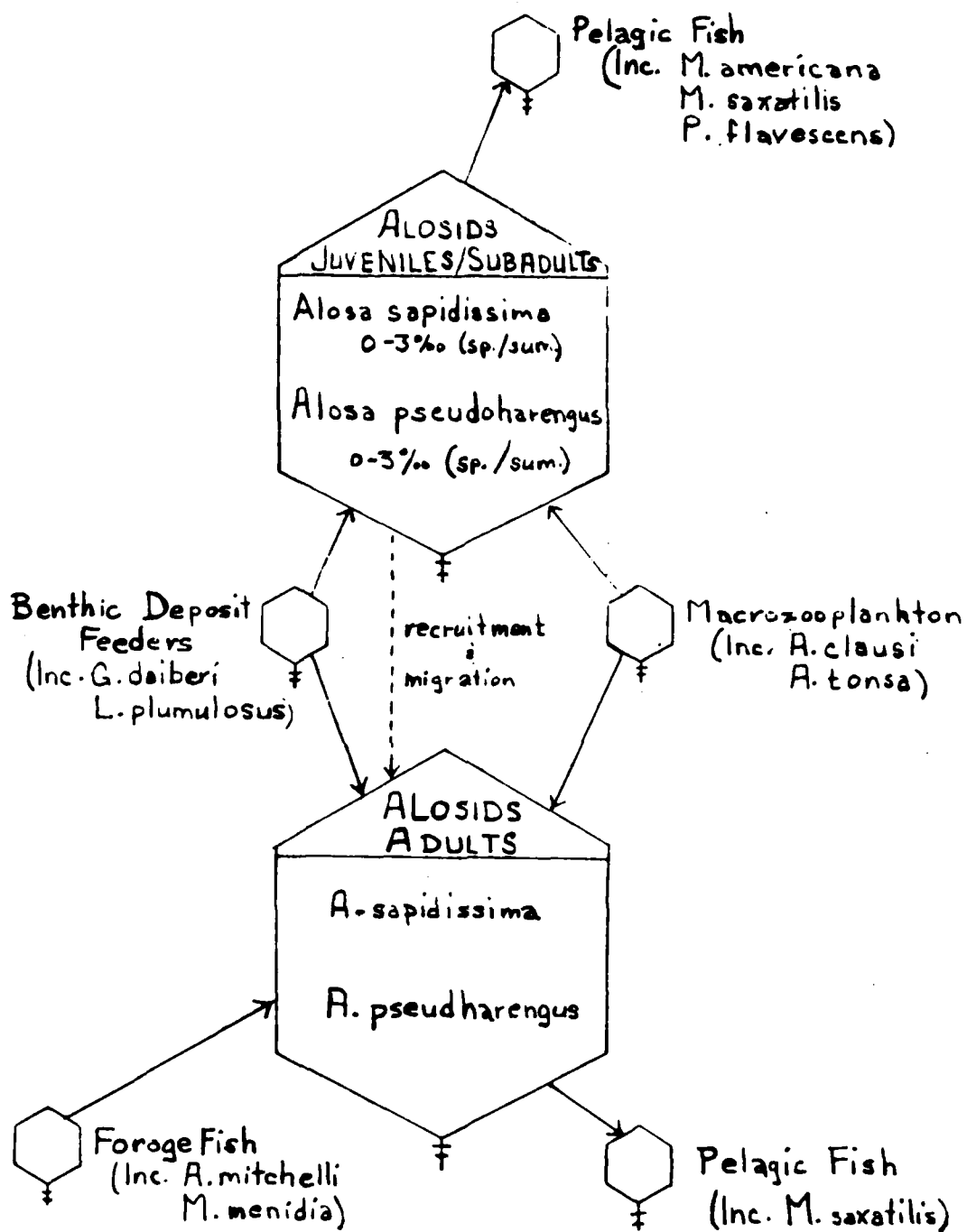
FORAGE FISH - TROPHIC DIAGRAM

FIGURE A-19



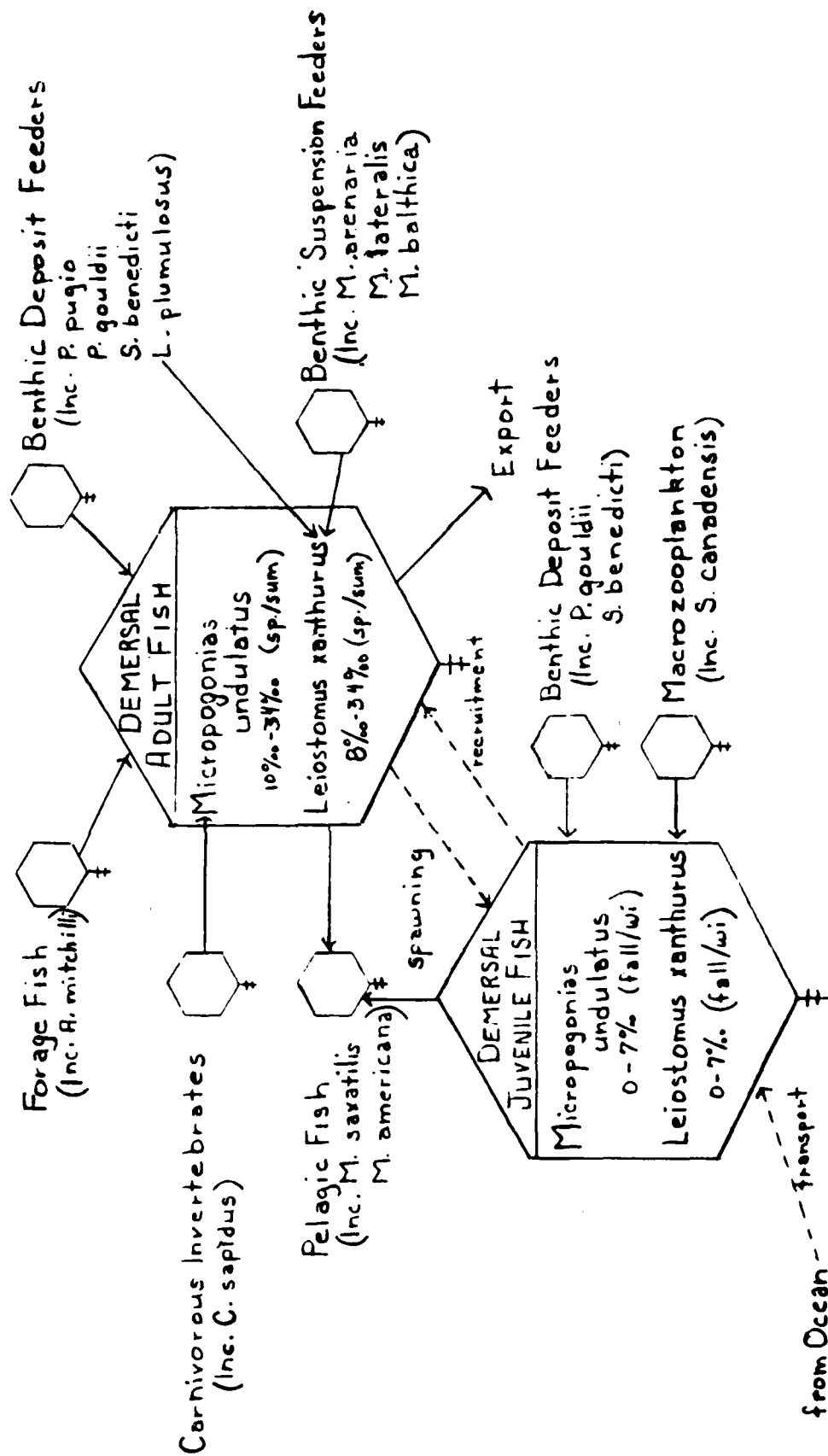
MENHADEN - Trophic Diagram

FIGURE A-20

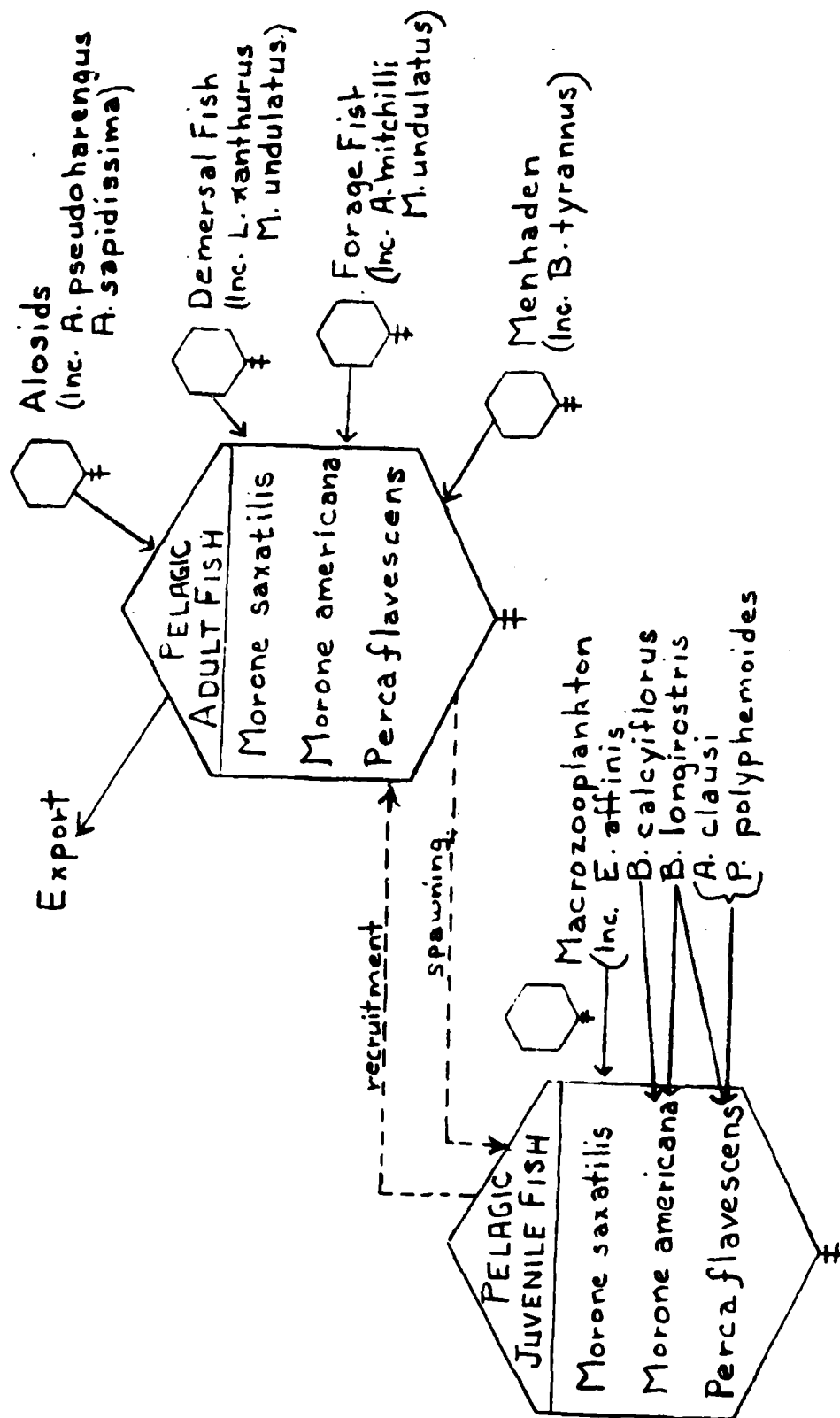


ALOSIDS - Trophic Diagram

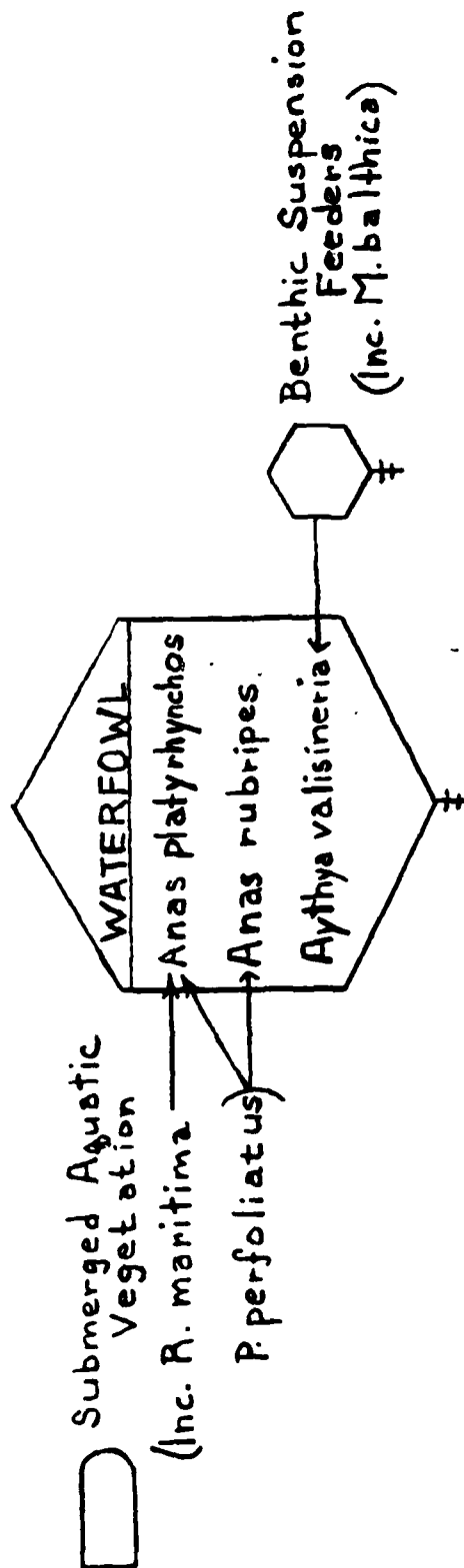
FIGURE A-21



DEMERAL FISH - Trophic Diagram



PELAGIC FISH - Trophic Diagram



WATERFOWL - Trophic Diagram

Study Species	Vertebrates													
	<i>Alosa sapidissima</i> juveniles	<i>Alosa pseudoharengus</i> juveniles	<i>Brevoortia tyrannus</i> larvae	<i>Brevoortia tyrannus</i> adults	<i>Anchoa mitchelli</i> larvae & adult	<i>Leiostomus xanthurus</i> larvae & juv.	<i>L. xanthurus</i> adults	<i>Microgobias undulatus</i> -1 & 2	<i>M. undulatus</i> adults	<i>Menidia menidia</i>	<i>Morone americana</i> larvae & juv.	<i>M. americana</i> adults	<i>M. saxatilis</i> larvae & juv.	<i>M. saxatilis</i> adults
<i>Alosa sapidissima</i> -J.	C	P	P	P	P	P								
<i>Alosa pseudoharengus</i> -J. C		P	P	P	P									
<i>Brevoortia tyrannus</i> -L. F	F													
<i>B. tyrannus</i> -A.														
<i>Anchoa mitchelli</i> -L. F	F													
<i>A. mitchelli</i> -A.														
<i>Leiostomus xanthurus</i> -L.														
<i>L. xanthurus</i> -A.														
<i>Microgobias undulatus</i> L. P	P													
<i>M. undulatus</i> -A.														
<i>Menidia menidia</i>	F													
<i>Morone americana</i> -J. F	F													
<i>M. americana</i> -A. P	P													
<i>M. saxatilis</i> -J.														
<i>M. saxatilis</i> -A. P	P													
<i>Perca flavescens</i> -L.														
<i>P. flavescens</i> -A. P	P	P	P											
<i>Evadne</i>														
<i>Drachionis</i>	F	F	F	F	F									
<i>Basmina</i>	F*	F*	F	F	F									
<i>Acartia clausi</i>	F	F		F	F									
<i>Acartia tonsa</i>	F	F	F	F	F									

Vertebrates (cont.)	Study Species →
	<i>Alosa sapidissima</i> juveniles
	<i>Alosa pseudoharengus</i> juveniles
	<i>Brevortia tyrannus</i> larvae
	<i>Brevortia tyrannus</i> adults
	<i>Anchoa mitchelli</i> larvae & adults
	<i>Leiostomus xanthurus</i> larvae & juv.
	<i>L. xanthurus</i> adults
	<i>Micropterus</i> undulatus - L. & J.
	<i>M. undulatus</i> adults
	<i>Morone americana</i> larvae & juv.
	<i>M. americana</i> adults
	<i>M. saxatilis</i> larvae & juv.
	<i>M. saxatilis</i> adults
	<i>Perces floridensis</i> larvae
	<i>P. flavescens</i> adults
	<i>Myctophya</i> valisineria.

Podon	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	
Palaeomonetes																
Neomysis																
Pectinaria																
Streblospio																
Scolecoplepides																
Scottolana																
Leptocheirus																
Gommarus	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	
Mya																
Hulinea																
Macoma																
Jalanus-L.																
Callinectes																
Chrysaora	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Crassostrea																
Phytoplankton																
Zostera																
Potamogeton	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	
Zannichellia	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	
Vallisneria																

FIGURE A-26

**ATTACHMENT B**  
**LIFE HISTORY SUMMARIES OF STUDY SPECIES**

## LIFE HISTORY SUMMARIES OF STUDY SPECIES

The information contained in this attachment is taken from Volume III, Phase I of the Chesapeake Bay Low Flow Study: Biota Assessment. This report was prepared by WESTECH under contract to the Corps as part of the Low Freshwater Inflow Study, and is available from the National Technical Information Service. The following information provides a comprehensive summary of the life history of those species selected for study as part of this program.

CHESAPEAKE BAY LOW FLOW STUDY:

BIOTA ASSESSMENT

PHASE I: FINAL REPORT

VOLUME III

APPENDICES

August 1980

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U.S. ARMY CORPS OF ENGINEERS  
Baltimore District  
Chesapeake Bay Study Branch

ATTACHMENT B

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20.	<i>Scottolana canadensis</i> - Copepod

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21.	<i>Bosmina longirostris</i> - Cladoceran
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28.	<i>Streblospio benedicti</i> - Polychaete Worm
29.	<i>Urosalpinx cinerea</i> - Oyster Drill
30.	<i>Crassostrea virginica</i> - Oyster
31.	<i>Macoma balthica</i> - Baltic Macoma
32.	<i>Mercenaria mercenaria</i> - Hard Clam
33.	<i>Mulinia lateralis</i> - Coot Clam
34.	<i>Mya arenaria</i> - Soft Clam
35.	<i>Rangia cuneata</i> - Brackish Clam
36.	<i>Ampelisca abdita</i> - Amphipod
37.	<i>Balanus improvisus</i> - Barnacle
38.	<i>Callinectes sapidus</i> - Blue Crab, Summer
39.	<i>Callinectes sapidus</i> - Blue Crab, Winter
40.	<i>Cyathura polita</i> - Isopod
41.	<i>Gammarus daiberi</i> - Amphipod
42.	<i>Leptocheirus plumulosus</i> - Amphipod
43.	<i>Palaemonetes pugio</i> - Grass Shrimp
44.	<i>Alosa sapidissima</i> - American Shad <i>Alosa pseudoharengus</i> - Alewife

<u>Life History No.</u>	<u>Title</u>
45.	<i>Brevoortia tyrannus</i> - Menhaden
46.	<i>Anchoa mitchilli</i> - Bay Anchovy
47.	<i>Leiostomus xanthurus</i> - Spot <i>Micropogon undulatus</i> - Atlantic Croaker
48.	<i>Menidia menidia</i> - Atlantic Silverside
49.	<i>Morone americana</i> - White Perch
50.	<i>Morone saxatilis</i> - Striped Bass
51.	<i>Perca flavescens</i> - Yellow Perch
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SYNOPSIS OF HABITAT CRITERIA  
KEY TO TABLE B-1

DEFINITION OF TERMS:

**SPECIES:** Study Species or Association (may be more than one species on one map.

**SEASON:** Season mapped for species or life stage in question. This is usually the season of greatest abundance, sensitivity to low flow, reproduction, or trophic importance.

**LIFE STAGE:** Life stage(s) mapped.

**SALINITY:** Salinity ranges which delineate distribution, abundance, or seasonality. These represent typical or observed ranges from field data for the most part, not laboratory tolerances or anomalous occurrences.

**DEPTH:** Typical depth ranges for species' occurrence, based on field observations and season mapped. Some organisms may inhabit deeper water during cold months, or when dissolved oxygen is high at depth, although normally restricted to more shallow water.

**SEDIMENT:** Distribution and abundance in relation to sediment type are mapped for those species where this relationship has been demonstrated. Sediment types used are as follows:

Sand (S) = 75% sand  
Muddy sand (M/S) = 50% sand, 25% silt and clay  
Sandy mud (S/M) = 50% silt and clay, 25% sand  
Mud (M) = 75% silt and clay

**NUMBERS:** These figures represent the typical abundance range of the species mapped, as taken from field data used in this project. Extreme maximum values encountered in this study are in parentheses.

**N/A:** Information not applicable to this species, or not available.

TABLE B-1. SYNOPSIS OF MAPPING CRITERIA

Phytoplankton SPECIES	SEASON	LIFE STAGE	SALINITY	DEPTH	SEDIMENT	NUMBERS
1						
Winter/Spring phytoplankton associations:	Spring					
Tidal Freshwater			0 - .5‰	Euphotic zone	n/a	n/a
Oligohaline/low mesohaline			3 - 10 ‰	Euphotic zone	n/a	n/a
Mesohaline			8 - 15 ‰	Euphotic zone	n/a	n/a
Polyhaline			13 - Bay mouth	Euphotic zone	n/a	n/a
Summer/Fall phytoplankton associations:						
Tidal Freshwater			0 - .5‰	Euphotic zone	n/a	n/a
Oligohaline/low mesohaline			3 - 13 ‰	Euphotic zone	n/a	n/a
High mesohaline/polyhaline			10‰- Bay mouth	Euphotic zone	n/a	n/a
3						
<u>Prorocentrum minimum</u> (dinoflagellate)	Winter		upstream to ca. 18 ft.	Usually below pycnocline	n/a	10 - 1000/ml * (to 10,000/ml)
	Summer		upstream to 5 ft., down- stream to ca. 18 ft.	Euphotic zone	n/a	500 - 10,000/ml * (to 1,000,000/ml)
					*In area of accumulation	

Submerged Aquatic Vegetation SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
4 Submerged aquatic vegetation beds Note: These beds are mapped from aerial survey, and show only beds large enough to show up on these surveys. Zones of individual species distribution in maps 5 - 9 reflect verified occurrence both in surveyed beds and in beds too small to be included on Map 4.	general	all	n/a	generally less than 3 meters	non-hard substrates	n/a
5 <u>Oeratothylus demersum</u> (hornwort)	Spring	all	0 - 7‰	less than 3 meters	soft	n/a
<u>Potamogeton pectinatus</u> (sago pondweed)	Spring	all	0 - 12‰	less than 3 meters	all non-hard substrates	n/a
<u>Potamogeton perfoliatus</u> (redhead grass)	Spring	all	0 - 12‰	less than 3 meters	all non-hard substrates	n/a
8 <u>Zostera marina</u> and <u>Ruppia</u> <u>maritima</u> (eelgrass and widgeon grass)	<u>Z. marina</u> (Spring) <u>R. maritima</u> (Summer)	all	10 - Bay mouth 5 - Bay mouth	less than 3 meters	soft	n/a
9 <u>Zernichellia palustris</u> (horned pondweed)	Spring	all	0 - 15‰	less than 3 meters	soft	n/a

Emergent Aquatic Vegetation	SPECIES	STATUS	LIFE STAGE	SALINITY (‰)	DEPTH	SUBSTRATE	NUMBERS
10	Emergent Aquatic Vegetation Note: This map represents known distribution of wetlands based on various surveys, and includes only marshes large enough to show up on aerial photography.	general	all	n/a	Emergent	n/a	n/a
11	Coastal Fresh Marsh Associations	n/a	all	0 - 5 ‰*	Emergent	soft	n/a
	Coastal Brackish Marsh	n/a	all	5 ‰ - Bay mouth *	Emergent	soft	n/a
	Brackish Irregularly Flooded Marsh	n/a	all	10 ‰ - Bay mouth *	Emergent	soft	n/a
				* Period of inundation as important as salinity			
	Zooplankton						
14	<u>Mnemiopsis leidyi</u> (ctenophore)	Summer	adult	5 ‰ - Bay mouth	n/a	n/a	1 - 25/m <sup>3</sup> (to 100/m <sup>3</sup> )
		Winter	adult	11 ‰ - Bay mouth	n/a	n/a	0.1 - 1.0/m <sup>3</sup> (to 10/m <sup>3</sup> )
15	<u>Chrysaora quinquecirrha</u> (sea nettle)	Summer	medusa	5 ‰ - Bay mouth	n/a	n/a	0.5 - 5/m <sup>3</sup>
		Summer	polyp	7 ‰ - 20 ‰	0 - 10 m	hard substrates	10 - 50/m <sup>2</sup>

SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
16 <u>Brachionus calyciflorus</u> (rotifer)	Spring	Adult	0 - 0.5 ‰ (higher densities) 0.5 - 5 ‰ (lower densities)	n/a	n/a	500 - 10,000/m <sup>3</sup> (to 50,000/m <sup>3</sup> )
17 <u>Acartia clausi</u> (copepod)	Spring	adult	5 - 10 ‰, 18 ‰ - Bay mouth (lower densities) 10 - 18 ‰ (higher densities)	n/a	n/a	500 - 10,000/m <sup>3</sup> (to 50,000/m <sup>3</sup> )
18 <u>Acartia tonsa</u> (copepod)	Summer	adult	ca 0.1 - 1.0 ‰, 26 ‰ - Bay mouth (lower densities) 1.0 - 5 ‰, 20 - 26 ‰ (higher densities) 5 - 20 ‰ (high densities may be reduced by pre- dation)	n/a	n/a	500 - 20,000/m <sup>3</sup> (to 100,000/m <sup>3</sup> )
19 <u>Eurytemora affinis</u> (copepod)	Spring  Summer	adu.  	0 - 10 ‰ (higher densities) 10 - 12 ‰ (lower densities) 0 - 4 ‰	n/a	n/a	500 - 50,000/m <sup>3</sup> (to 100,000/m <sup>3</sup> )

SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
<u>Scottolana canadensis</u> (copepod)	Summer	adult and copepodites	less than 1.0 ‰ and 5 - 10 ‰ (lower densities) 1 - 5 ‰ (higher densities)	Surface and bottom to 10 m	sediment pre- ferences not known	50 - 1000/m <sup>3</sup> (to 10,000/m <sup>3</sup> )
<u>Boemina longirostris</u> (cladoceran)	Summer	adult	0 - 0.5 ‰ (higher densities) 0.5 - 5 ‰ (lower densities)	n/a	n/a	500 - 20,000/m <sup>3</sup> (to 100,000/m <sup>3</sup> )
<u>Evadne tergestina</u> (cladoceran)	Summer	adult	16 - 20 ‰ (lower densities) 20 - Bay mouth (higher densities)	n/a	n/a	1000 - 10,000/m <sup>3</sup> (to 100,000/m <sup>3</sup> )
<u>Podon polythemoideus</u> (cladoceran)	Spring	adult	3 - 8 ‰ and 22 ‰ - Bay mouth (lower densities) 8 - 22 ‰ (higher densities)	n/a	n/a	500 - 10,000/m <sup>3</sup> (to 100,000/m <sup>3</sup> )

Benthic	SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
24	<u>Liriodrilus hoffmeisteri</u> (oligochaete worm)	Spring	adult	0 - 0.5 ‰* (higher densities) 0.5 - 1.0 ‰* (lower densities) and may represent areas of organic enrichment. Also, species may occur in higher salinity under certain conditions (see Holland et al. 1980).	0 - 15 m	all	100 - 2,000/m <sup>2</sup> (to 15,000/m <sup>2</sup> )
	<u>Heteromastus filiformis</u> (polychaete worm)	Summer	adult	2 - 5 ‰ 5 ‰ - Bay mouth 6 - 10 m (lower densities)	0 - 10 m (lower densities) 0 - 6 m (higher densities) 6 - 10 m (lower densities)	all	10 - 500/m <sup>2</sup> (to 2000/m <sup>2</sup> )
26	<u>Pectinaria gouldii</u> (polychaete worm)	Spring	adult	10 - 15 ‰ 15 ‰ - Bay mouth	0 - 15 m (lower densities) 0 - 10 m (higher densities) 10 - 15 m (lower densities)	all	10 - 500/m <sup>2</sup> (to 4000/m <sup>2</sup> )
27	<u>Scolecopelodes viridis</u> (polychaete worm)	Spring	adult	0.5 - 1.0 and 10 - 15 ‰ (lower densities) 1.0 - 5 ‰ 5 - 10 ‰	0 - 10 m 0 - 10 m	all types { sand and M/S (higher dens.) S/M and mud (lower dens.) }	50 - 2000/m <sup>2</sup> (to 10,000/m <sup>2</sup> )

SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
<u>Streblospio benedicti</u> (polychaete worm)	Summer	adults	5 ‰ - Bay mouth	1 - 20 m	sand (lower dens.) M/S, S/M, mud (higher dens.)	10 - 1000/m <sup>2</sup> (to 5000/m <sup>2</sup> )
<u>Urosalpinx cinerea</u> (oyster drill) Mapping of this species is based both on historic	general	adults	ca. 12.5 ‰ to Bay mouth * and recent collection information, as well as salinity.	0 - 10 m	hard substrate	2 - 20/m <sup>2</sup> (to 200/m <sup>2</sup> )
<u>Crassostrea virginica</u> (American oyster) Mapping of this species is primarily based on extent and distribution of known oyster beds.	general	adults	ca. 7 ‰ to Bay mouth *	0 - 10 m	hard substrate	2 - 100/m <sup>2</sup> (to 300/m <sup>2</sup> )
<u>Macoma balthica</u> (Baltic macoma)	Fall	adult	2.5 - 5 ‰ and 18 - 19 ‰ (lower densities) 5 - 18 ‰ 0 - 10 m (higher densities) 10 - 15 m (lower densities)	0 - 15 m	all	50 - 2000/m <sup>2</sup> (to 5000/m <sup>2</sup> )
<u>Macoma balthica</u> (hard clam)	Summer	adult	12 - 12.5 ‰ (lower densities) 12.5 ‰ - Bay mouth	1 - 10 m 1 - 6 m 6 - 10 m	all shell, sand & M/S (higher densities) S/M & mud (lower dens.) shell, sand, M/S (lower densities)	2 - 15/m <sup>2</sup> (to 25/m <sup>2</sup> )

SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
<u>Mulinia lateralis</u> (oyst clam)	Fall/Winter	adult	10 - 15 ‰ (lower densities) 15 ‰ - Bay mouth	0 - 15 m 0 - 10 m (higher densities) 10 - 15 m (lower densities)	all	10 - 1000/m <sup>2</sup> (to 4000/m <sup>2</sup> )
<u>Mya arenaria</u> (soft clam)	Spring	adult	3.5 - 5 ‰ (occasional) 5 - 8 ‰ (lower densities) 8 ‰ - Bay mouth	0 - 6 m 0 - 6 m 0 - 6 m (higher densities) 6 - 10 m (lower densities)	all	10 - 500/m <sup>2</sup> (to 1000/m <sup>2</sup> )
<u>Rangia cuneata</u> (brackish water clam)	Summer	adult	0.1 ‰ (0) - 0.5 ‰ and 5 - 10 ‰ (lower densities) 0.5 - 5 ‰ (higher densities)	1 - 10 m	all	10 - 500/m <sup>2</sup> (to 2000/m <sup>2</sup> )
<u>Amphileta abdita</u> (amphipod)	Summer	adult	12 ‰ - Bay mouth	3 - 6 m 6 - 15 m	M/S, S/M, mud (lower dens.) sand, (lower densities) M/S, S/M, mud (higher dens.)	50 - 2000/m <sup>2</sup> (to 30,000/m <sup>2</sup> )

SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
<u>Balanus improvisus</u> (acorn barnacle)	Summer	adult	2 - 5 ‰ (lower densities) 5 - 10 ‰ (higher densities) 10 - 20 ‰ (higher densities, but may be reduced by pre- dation) 20 - 24 ‰ (occasional)	0 - 15 m	hard substrate	100 - 2000/m <sup>2</sup> (to 5000/m <sup>2</sup> )
<u>Callinectes sapidus</u> (blue crab)	Summer	adults and larger juveniles  spanning areas	0 - 15 ‰ (predominantly male) *  10 ‰ Bay mouth (predom- inately females) *  25 ‰ to shelf	0 - 6 m (higher densities) greater than 6 m (lower densities)  0 - 6 m (higher densities) greater than 6 m (lower densities) surface, primarily near shore	all types   n/a	0.05 - 5/m <sup>2</sup> (rough estimate from trawl data)   n/a
* This is relative, as some males are found in the lower Bay, and some females in the upper Bay.						
<u>Callinectes sapidus</u> (blue crab)	Winter	adults and larger juveniles	generally above 5 ‰ to about 20 ‰ (predomin- ately male) *  generally above 20 ‰ (predominately female) *	13 - 20 m (lower densities) greater than 20 m (higher densities)  10 - 15 m (lower densities) greater than 15 m (higher densities)	mostly M/M, mud   mostly M/S, S/M, mud, and some fine sand	n/a   n/a
* See note above						

SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
<u>Gyathura polita</u> (isopod)	Summer	adults	0.5 - 1.0 ‰ and 10 - 12 ‰ (occasional) 1 - 7 ‰  7 - 10 ‰ (lower densities)	0 - 6 m  0 - 6 m  0 - 6 m	all types  sand, S, and S/M (higher dens.) mu. (lower dens.) all types	50 - 500/m <sup>2</sup> (to 1000/m <sup>2</sup> )
<u>Gammarus dalmani</u> (amphipod)	Summer	adult	0.5 - 1 ‰ and 5 - 7 ‰ (lower densities) 1 - 5 ‰ (higher densities)	0 - 6 m (may also occur pelagically)	all types (where shelter exists)	50 - 500/m <sup>2</sup> (to 4000/m <sup>2</sup> )
42 <u>Leptochelirus plumulosus</u> (amphipod)	Spring	adult	0.5 - 1 ‰ and 10 - 15 ‰ (lower densities) 1 - 10 ‰  0 - 10 m (higher densities) 10 - 15 m (lower densities)	0 - 15 m	all	50 - 4000/m <sup>2</sup> (to 10,000/m <sup>2</sup> )
43 <u>Palaeomonetes pugio</u> (grass shrimp)	Summer	adult and older juveniles	1 - 5 ‰ (lower densities) 5 - 15 ‰ (higher densities) 15 - 20 ‰ (found with <u>P. vulgaris</u> )	0 - 3 m	all, where suitable habitat exists	5 - 50/m <sup>2</sup> (to 200/m <sup>2</sup> )

Fish	SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
	<u>Alosa sapidissima</u> (American shad)	Spring	eggs and larvae	surface head of tide - 3 ‰	greater than 3 m	n/a	n/a
	<u>A. pseudoharengus</u> (alewife)	Spring	eggs and larvae	surface head of tide - 3 ‰	less than 3 m		
	<u>A.S. and A.P.</u>	Summer/Fall	juveniles	0 - 5 ‰	shore to shore		
	<u>A.P.</u>	Summer/Fall	adult	(not mapped)			
	<u>Brevoortia tyrannus</u> (menhaden)	Summer	larvae and juveniles	surface 0 - 5 ‰	1 meter to depth	n/a	n/a
			adult	5 - 18 ‰ (higher concentrations)	1 meter to depth		
				5 - 34 ‰ (general distribution)	1 meter to depth		
46	<u>Anchoa mitchelli</u> (Bay anchovy)	Summer	eggs	5 - 15 ‰	shore to shore	n/a	n/a
			larvae	3 - 7 ‰	shore to shore	n/a	n/a
			adults	0 - 34 ‰	shore to shore	n/a	n/a
47	<u>Microponopias undulatus</u> (Atlantic croaker) <u>Leiostomus xanthurus</u> (spot)	Fall	larvae & juvenile (both species)	0 - 7 ‰	greater than 1 m	n/a	n/a

	SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
cont. 47-	<u>M. undulatus</u>	Summer	adult	10 - 34 ‰	greater than 3 m	n/a	n/a
	<u>L. xanthurus</u>	Summer	adult	8 - 34 ‰	greater than 1 m	n/a	n/a
48	<u>Meridia meridia</u> (Atlantic silverside)	Summer	adult	3 - 34 ‰	shallow, less than 1 meter, main Bay less than 7 m, rivers	n/a	n/a
E-122	<u>Morone americana</u> (white perch)	Spring	egg & larvae	tidal fresh	shore to shore	n/a	n/a
		Summer	juveniles	0 - 5 ‰	0 - 3 meters	n/a	n/a
		Summer	adults	0 - 34 ‰	shore to shore	n/a	n/a
50	<u>Morone saxatilis</u> (striped bass)	Spring	egg & larvae	tidal fresh	shore to shore	n/a	n/a
		Summer	adult	greater than 5 ‰	shore to shore	n/a	n/a
		Winter	adult	greater than 5 ‰	greater than 6 m	n/a	n/a
51	<u>Perca flavescens</u> (yellow perch)	Fall (in lieu of winter salinities) Summer	egg & larvae  juvenile & adult	tidal fresh  less than 12 ‰	shore to shore  shore to shore	n/a  n/a	n/a  n/a

Birds	SPECIES	SEASON	LIFE STAGE	SALINITY (‰)	DEPTH	SEDIMENT	NUMBERS
52	<u>Anas platyrhynchos</u> (mallard)	Winter	adult	n/a	concentrated in shallow areas	n/a	*100 - 1000/100km <sup>2</sup>
	<u>Anas rubripes</u> (black duck)	Winter	adult	n/a	concentrated in shallow areas	n/a	*100 - 1000/100km <sup>2</sup>
	<u>Arthya valisineria</u> (canoeback)	Winter	adult	n/a	various	n/a	*100 - 1000/100km <sup>2</sup>
							*Represents 5 year means.

## Winter/Spring Phytoplankton Associations

### Description:

Phytoplankton species which occur from late November through late April constitute the Chesapeake Bay winter/spring associations floras. These associations include only the larger, "net" phytoplankton, because of the paucity of distribution and seasonality data on the small nanoplankton. However, the latter groups account for approximately 80% of the primary productivity in Chesapeake Bay.

### Range and Composition:

Species which occur in Chesapeake Bay during colder months include both ubiquitous, year round forms, and boreal/cold temperatre species. Representation species for each of the four associations are:

#### Tidal Freshwater:

<i>Melosira granulata</i>	- diatom
<i>Cyclotella meneghiniana</i>	- diatom
<i>Skeletonema potamos</i>	- diatom
<i>Asterionella formosa</i>	- diatom
<i>Coscinodiscus curvatulus</i>	- diatom
<i>Pandorina morum</i>	- chlorophyte

#### Oligohaline/Low Mesohaline:

<i>Katodinium rotundatum</i>	- dinoflagellate
<i>Skeletonema costatum</i>	- diatom
<i>S. potamus</i>	- diatom
<i>Asterionella formosa</i>	- diatom
<i>Ankistrodesmus falcatus</i>	- chlorophyte

#### Mesohaline:

<i>Katodinium rotundatum</i>	- dinoflagellate
<i>Skeletonema costatum</i>	- diatom
<i>Ceratulina bergonii</i>	- diatom
<i>Asterionella japonica</i>	- diatom
<i>Chaetoceros sociales</i>	- diatom
<i>Calicomonas ovalis</i>	- chrysophyte

#### Polyhaline:

<i>Peridinium triquetum</i>	- dinoflagellate
<i>Prorocentrum micans</i>	- dinoflagellate
<i>P. minimum</i>	- dinoflagellate
<i>Nitzschia pungens</i>	- diatom
<i>Asterionella japonica</i>	- diatom
<i>Skeletonema costatum</i>	- diatom
<i>Chaetoceros decipiens</i>	- diatom
<i>C. socialis</i>	- diatom
<i>Rhizosolenia alata</i>	- diatom
<i>Ebria tripartita</i>	- silicoflagellate

From area to area, and year to year, the exact composition of the various associations changes as different species dominate. The above are typical assemblages for the winter/spring Chesapeake Bay.

#### Salinity Relationships:

There is considerable overlap in the distributions of the various

assemblages in regard to salinity, and the overall effect is a continuous gradation from one association to another, with few abrupt changes. The tidal freshwater oligohaline transition is probably the most marked.

General salinity ranges for the four associations are:

Tidal Freshwater	0-5 ‰
Oligohaline/Low Mesohaline	3-10 ‰
Mesohaline	8-15 ‰
Polyhaline	13 ‰-Bay mouth

Other Sensitivities:

Phytoplankton are limited by light penetration to the upper layers of the estuary. Depth of the euphotic zone varies from area to area within the Bay. As a generality it is shallowest at the fresh water estuarine transition zone, and deepest in the lower Bay. In winter, the euphotic zone is deeper than in summer months.

Temperature affects the Bay phytoplankton at both the community and the species level: first, by determining what species are present, and second, by affecting their rate of nutrient uptake, photosynthesis, and cell division. The winter/spring flora generally occurs in Chesapeake Bay when temperatures are less than 15°C.

Nutrient input from runoff is reduced during winter, but elimination of thermal stratification and overturn by wind action serves to mix nutrients into the euphotic zone. Increasing insolation, rising temperatures, and initiation of spring runoff triggers increased phytoplankton growth in spring. The spring phytoplankton bloom is most pronounced in the polyhaline areas of Chesapeake Bay (Heinle et al. 1980), and is dominated by diatom species.

Low flow conditions can be expected to shift the relative distribution of the four associations. In addition, changes in runoff could alter nutrient input, estuarine flushing rates (important to maintenance of phytoplankton within the estuary), turbidity, and stratification.

#### Trophic Importance:

Phytoplankton are the major primary producers for most estuarine food webs. Nannoplankton (species less than 10 $\mu$ ) dominate primary productivity in Chesapeake Bay (McCarthy et al. 1974, Van Valkenburg and Flemer 1974). Most copepods can utilize algae down to 8 $\mu$  or so in size, and microzooplankters such as rotifers and tintinnids can ingest even smaller forms (Richman et al. 1977). However, larger species of phytoplankton can be used by zooplankton and juveniles of planktivorous fish. Benthic suspension feeders also graze phytoplankton heavily. Oysters feed upon smaller species, primarily nannoplankton (Haven and Morales-Alamo 1970). Not all species of phytoplankton are equally good as food, and some (such as toxic dinoflagellates) are detrimental. "Nuisance blooms" of algae are primarily a summer phenomena in Chesapeake Bay, but blooms of cold water dinoflagellates such as Katodinium rotundatum have also been observed. Eutrophication of many Bay tributaries has contributed to these phenomena.

#### Sources:

Dahlberg <u>et al.</u> 1973	Morse 1947
Ecological Analysts 1974	Mountford 1977
Haven and Morales-Alamo 1970	Mulford 1972
Heinle <u>et al.</u> 1970	Patten <u>et al.</u> 1963
Johns Hopkins U. 1972	Richman <u>et al.</u> 1977
Lear and Smith 1976	Seliger <u>et al.</u> 1975
Mackiernan 1968 unpubl.	Van Valkenburg and Flemer 1974
Marshall 1966, 1967	Van Valkenburg <u>et al.</u> 1978
McCarthy <u>et al.</u> 1974	

## Summer/Fall Phytoplankton Associations

### Description:

Phytoplankton species which occur from early May through November constitute the Chesapeake Bay summer/fall associations or floras.

### Composition:

Species which occur in Chesapeake Bay during warmer months for each of the four associations are:

#### Tidal Freshwater:

<i>Anacystis cyanea</i>	{ blue-green algae (most important in eutrophied areas)
<i>Microceptus aeruginosa</i>	
<i>Anabaena flos-aquae</i>	
<i>Skeletonema potamos</i>	- diatom
<i>Melosira granulata</i>	- diatom
<i>Cyclotella meneghiniana</i>	- diatom
<i>Scenedesmus</i>	- chlorophyte
<i>Pediastrum</i>	- chlorophyte
<i>Euglena</i>	- euglenoid

#### Oligohaline/Low Mesohaline:

<i>Gymnodinium nelsoni</i>	- dinoflagellate
<i>G. splendens</i>	- dinoflagellate
<i>Prorocentrum minimum</i> ( <i>mariaeleborual</i> )	- dinoflagellate

#### Oligohaline/Low Mesohaline (cont.)

<i>Skeletonema costatum</i>	- diatom
<i>Diatoma hemale</i>	- diatom
<i>Nitzschia closterium</i>	- diatom
<i>Eutreptiella marina</i>	- euglenoid

#### High Mesohaline/Polyhaline Associations

<i>Gymnodinium splendens</i>	- dinoflagellate
<i>Cochlodinium heterolobatum</i>	- dinoflagellate
<i>Ceratium furca</i>	- dinoflagellate
<i>Skeletonema costatum</i>	- diatom
<i>Ditylum brightwelli</i>	- diatom
<i>Chaetoceros affinis</i>	- diatom
<i>C. subtilis</i>	- diatom
<i>C. compressus</i>	- diatom
<i>Thalassionema nitzschoides</i>	- diatom

As with the winter/spring associations, the exact floral composition changes from year to year. The above are typical species for summer and fall.

#### Salinity Relationships:

The remarks for winter/spring generally apply here, although the salinity ranges are somewhat different.

Tidal Fresh Water	0 - 5 ‰
Oligohaline/Low Mesohaline	3 -13 ‰
High Mesohaline/ Polyhaline	10‰ - Bay mouth

#### Other Sensitivities:

The general remarks for winter/spring apply here. Increasing turbidity in warmer months (due to runoff as well as increased phytoplankton biomass) decreases the depth of the euphotic zone. Warmer temperatures and greater insolation contributes to strat-

ification, reducing nutrient input from bottom waters. The major source of nutrients to phytoplankton in warm months is from autochthonous regeneration within the euphotic zone. The situation of low nutrient availability, organic nutrient sources, and shallow euphotic zone tends to favor species with rapid uptake rates, small cell size, many flagellated. The summer/fall associations occur in Chesapeake Bay generally when temperature exceeds 15°C.

#### Trophic Importance:

General remarks for winter/spring apply here. Summer months are the primary period of phytoplankton blooms, "red water", and noxious blue-green water bloom. There is evidence that the frequency of such blooms is increasing in some Bay areas with increasing eutrophication (Heinle et al. 1980); however, improvement in water treatment has caused reduction in frequency of summer blue-green blooms in many rivers.

#### Sources:

Dahlberg et al. 1973  
Ecological Analysts 1974  
Heinle et al. 1980  
Johns Hopkins U. 1972  
Lear and Smity 1976  
Mackiernan 1968 Unpubl.  
Marshall 1966, 1967  
Morse 1947  
Mountford 1972  
Nulford 1972  
Patten et al. 1963  
Seliger et al. 1975  
Van Valkenburg et al. 1978

*Prorocentrum minimum* (*P. mariaelibourae*) - Dinoflagellate

Description:

Prorocentrum minimum (Also referred to as P. Mariaelebourae, based on work by M. Faust (1974)) is a small dinoflagellate of the family Prorocentraceae. It is oval in shape, flattened, about 15 - 20  $\mu$  in length and somewhat less in width, with two anterior flagellae. Color is a golden or reddish brown.

Range:

P. minimum occurs in the east coast of North America and in European Atlantic waters, generally in estuarine or neritic waters. In Chesapeake Bay it has virtually cosmopolitan, but seasonal distribution. Densities are normally less than 1000 cells/ml, but during blooms of this species, over 10,000 cells/ml have been recorded. In addition, in areas of accumulation (due to circulation patterns coupled with positive phototaxis of the dinoflagellate) densities may reach 1,000,000 cells/ml.

The seasonal distribution of P. minimum is complex, and closely linked to estuarine circulation patterns. A complete and detailed discussion is included in Tyler and Seliger (1978), but a brief synopsis follows: In late winter, Prorocentrum populations are entrained into northward flowing saline water below the strong pycnocline. It is transported up estuary, reaching the vicinity of the Bay Bridge by late spring. The

decreasing depth of the upper Bay causes the pycnocline to rise, and mixes the dinoflagellate and nutrient rich deep water into the euphotic zone. Rapid growth and physical accumulation causes the formation of extensive "red water" patches. Prorocentrum carried down-estuary in surface waters sequentially inoculates tributary estuaries; these populations exchange slowly with the Bay mainstem. By mid-winter, the dinoflagellate reaches the Bay mouth, where the cycle repeats (Refer to Figure III-8, Volume 1). Timing of the entrainment and arrival in the bloom area is highly correlated with meteorological events, runoff, and circulation velocities (Seliger et al. 1979, Tyler and Seliger 1979).

#### Salinity Relationships:

The salinity tolerance of this species is closely tied to temperature (Mackiernan unpubl., Tyler and Seliger 1980). In general, at temperatures below 5°C, little or no cell division takes place if salinities are below 15‰. As temperatures increase, division rates also increase: at 10°C and 5‰, rates are approximately one half the maximum (Mackiernan, unpubl., Tyler and Seliger 1980). Near-maximum growth rates occur over a wide range of salinities (5-30‰) at summer temperatures (approximately 22-25°C).

This has implication for the distribution and survival of P. minimum in the Bay. Physiologically, the species' growth response enables it to survive winter in the lower Bay region. However, if the upestuary transport is too early, and the dinoflagellate arrives in the upper Bay while ambient water temperatures are still low, the summer bloom may never develop. Timing of transport is related to streamflow, particularly from southern tributaries (entrainment) and the Susquehanna (transport). This is more fully discussed in Seliger et al. (1979) and Tyler and Seliger (1980).

#### Other Sensitivities:

The relationship of Prorocentrum to temperature is discussed above.

In general, temperatures from 20-30°C support maximum growth rates at or near one doubling day<sup>-1</sup> (Mackiernan unpubl.).

Prorocentrum minimum is able to maintain the appropriate division rate for the temperature over a wide range of light levels from 0.2 to 0.02 langleys min<sup>-1</sup> (Mackiernan unpubl.). Tyler and Seliger (1980) report that the species is able to photosynthesize at very low light levels typical of the pycnocline region in winter. This adaption to low light levels is important in allowing survival of the cells during upestuary transport.

Occasionally, upstream transport of the dinoflagellate is delayed, and mortality occurs because of anoxia developing below the pycnocline (Seliger et al. 1979).

#### Potential Habitat:

In summer, potential habitat are areas above 5‰ salinity, in the euphotic zone. There is no real physiological downstream boundary, but in the Bay mainstem, populations generally occur only through the mesohaline zone. Populations also occur in warm months at the mouths of tributary rivers. The flushing rate of the lower Bay is such that Prorocentrum populations rarely build up in the surface waters of the mainstem. The species may occur along the western shore in summer, originating from populations in the lower rivers (Tyler, personal communication).

In winter, populations occur downstream of 15-18‰, usually below the pycnocline. Both winter and summer distribution varies greatly with hydrological conditions.

#### Trophic Importance:

As a dominant phytoplankton species, particularly in summer, P. minimum contributes to the productivity of the estuary. In nutrient-poor water, it exhibits a nocturnal migration to the

higher nutrient pycnocline region. This not only conveys a selective advantage upon P. minimum, but it also enhances transport of nutrients into the euphotic zone, as cells die and are remineralized.

P. minimum is fed upon by a wide variety of zooplankton, including copepods, cladocerans, and rotifers, as well as larvae of numerous invertebrates. In addition, it has been observed that juvenile menhaden being transported up estuary in deep layers, concurrent with the P. minimum transport, were apparently feeding heavily on the dinoflagellate (Tyler pers. comm.).

#### Selection Factors:

- Dependence of species' occurrence, in much of range, upon streamflow, estuarine circulation, salinity, and flushing rates of subestuaries, as factors potentially impacted by low flow.
- Importance as a major bloom organism in summer in Chesapeake Bay.
- Role as indicator or "model" for numerous species which utilize estuarine circulation for part of their lifecycle.

#### Sources:

Allison 1980  
Faust 1974  
Jordan et al. 1975  
Lippson et al. 1979  
Mackiernan unpubl. 1968  
Mountford 1977  
Mulford 1972  
Seliger et al. 1975, 1979  
Stophan 1974  
Tyler and Seliger 1978, 1979, 1980  
Zubkoff and Warinner 1975

*Ceratophyllum demersum* - coontail

Description:

Ceratophyllum demersum is a submerged angiosperm. It is considered to be primarily a freshwater species although it apparently can tolerate salinities in the Oligohaline range (Bourn 1932).

Range:

In Virginia, Orth et al. (1979) found Ceratophyllum in 35% of the vegetated samples taken. While in Maryland, the 1978 and 1979 MBHRL survey found little or no Ceratophyllum. However, Ceratophyllum was found in pervious MBHRL surveys on the Susquehanna flats, Magothy, Severn and Chester Rivers. Frequency of occurrence was less than 1 %.

Salinity Relationships and Potential Habitat:

Although Ceratophyllum demersum is generally restricted to tidal freshwater areas (0 - 0.5‰), the species does occur in oligohaline environments as well. Potential habitat for the species has been defined as shallow (<3 meters) non-turbid areas with salinities less than 7‰ (Bourn 1932).

Trophic Importance:

The importance of Ceratophyllum, as a food for waterfowl may be limited in the Chesapeake Bay. Rawls (in press) reported a frequency of occurrence of .42% in the 1,179 waterfowl stomachs

he examined. Ceratophyllum comprised .33% of the total volume of food in these stomachs.

In Virginia, Ceratophyllum was found to be an important member of a submerged aquatic vegetation community consisting of the following species (Orth et al. 1979):

Najas minor

Najas guadalupensis

Elodea canadensis

Nitella sp.

Callitriche verna

Potamogeton foliosus

Najas flexilis

Potamogeton filiformis

Potamogeton nodosus

Elodea nuttalli

Sources:

Bourn 1932

Orth et al. 1979

Rawls (in press)

*Potamogeton pectinatus* - Sago Pondweed

Description:

Potamogeton pectinatus is a submerged aquatic angiosperm. It grows in shallow waters (<3 meters) and generally requires fresh or low salinity waters.

Range:

Potamogeton pectinatus is found throughout the Chesapeake Bay. In Maryland, this species was found in approximately 15% of the vegetated samples during the 1978 MBHRL survey. In Virginia, Orth et al. (1979) found P. pectinatus in 6% of the vegetated samples. It commonly occurred with the following species:

Potamogeton crispus

Callitriche verna

Potamogeton perfoliatus

Chara

Vallisneria americana

Myriophyllum spicatum

Salinity Relationships and Potential Habitats:

Although the species in this association were commonly found in waters with a salinity equal to or less than 15 parts per thousand, P. pectinatus apparently does not do well in salinities greater than 12-13 parts per thousand (Jetter 1965). Potential habitat for this species is defined as areas less than 3 m depth, soft substrate, salinities less than 12‰.

In Maryland, past MBHRL surveys found P. pectinatus in a survey of areas (Steverson and Confer 1978). They were:

Easter Bay	Patapsco River
Choptank River	Big and Little Annamessex Rivers
Little Choptank River	Magothy River
James Island and Horga River	Severn River
Bloodsworth Island	Chester River
Manokin River	Smith Island (Maryland)

Trophic Importance:

P. pectinatus is an important waterfowl food. Rawls (in press) found this species in 2.3% of the 1,179 waterfowl stomachs he examined, while Stewart (1962) found it often in waterfowl stomachs.

Sources:

Jeeter 1965  
Stevenson and Confer 1978  
Rawls (in press)  
Stewart (1962)

*Potamogeton perfoliatus* - Red head grass

Description:

Potamogeton perfoliatus is a submerged aquatic macrophytic angiosperm. It is slightly more salt tolerant than Potamogeton pectinatus and is frequently associated with brackish waters.

Range:

Potamogeton perfoliatus was the second most abundant species found in the 1978 Maryland MBHRL survey, occurring in approximately 27% of the vegetated samples. Only Ruppia maritima was more abundant. In Virginia waters, Orth et al. (1979) found P. perfoliatus in 6% of their vegetated samples. It commonly occurred with the following species:

Potamogeton crispus  
Potamogeton pectinatus  
Vallisneria americana  
Zannichellia palustris  
Callitriche verna  
Chara  
Myriophyllum spicatum

Salinity Relationships:

P. perfoliatus is found in freshwater and in estuaries with up to about 12 parts per thousand salt (Stevenson and Confer 1978). Potential habitat for this species is defined as areas less than 3 m deep, soft substrates, over 10‰ salinity.

The distribution of P. perfoliatus in Maryland as found in past MBHRL vegetation surveys is listed below:

Eastern Bay  
Choptank River  
Patapsco River  
Magothy River  
Severn River  
Chester River

Trophic Importance:

P. perfoliatus is an important source of food to water fowl. Rawls (in press) found this species in 29.6% of the 1,179 water-fowl stomachs he examined. This frequency of occurrence was second only to Ruppia maritima. Ten percent of the total volume of vegetation found in these stomachs was the remains of P. perfoliatus.

Sources:

Orth et al. 1979  
Stevenson and Confer 1978

*Zostera marina* - eelgrass

Description:

Zostera marina is a grasslike submerged aquatic angiosperm. Where salinity conditions are correct for its growth, it is often locally abundant growing in extensive submerged beds in waters 1-6 meters deep.

Range:

Zostera marina is found primarily in the Virginia portion of the Chesapeake Bay, in salinities above than 8-10 parts per thousand. Zostera above ground biomass is present throughout the year, but with reduced growth during the winter months.

In Maryland waters the 1978 MBHRL survey found Zostera in 5% of the vegetated samples. In Virginia, Orth et al. found more than 84,000 hectares of submerged aquatic vegetation beds, with Zostera and Zostera/Ruppia being the dominant vegetation. The only species found in abundance with Zostera is Ruppia maritima.

Salinity Relationships and Potential Habitat:

Zostera is a species with salinity tolerances usually limited to above 18‰. The species is found from mesohaline to marine salinities, primarily in the lower bay.

### Trophic Importance:

In the Chesapeake Bay the importance of Zostera as a direct food source is overshadowed by other factors. Zostera is important as a stabilizer of sediments, being able to trap and bind sediment particles. Zostera is probably also important as a nutrient pump, whereby nitrogen and phosphorus are released from the sediments. Probably the most important role of Zostera in the Chesapeake Bay is as a habitat for other species. A great number of organisms live on the leaves of Zostera, as well as in and on the substrate found in the beds. Many organisms use the beds for feeding and protection.

In terms of Zostera as a direct source of food for waterfowl, Rawls (in press) found this species in .34% of the 1,179 waterfowl stomachs he examined. Stewart (1962) reported considerably higher values for a number of waterfowl species. However, these results depend upon where in the Bay the birds were collected since birds feeding in the upper portion would not have access to Zostera.

### Sources:

Rawls (in press)  
Stewart 1962

*Ruppia maritima* - widgeon grass

Description:

Ruppia maritima is a submerged aquatic macrophyte, often found associated with Zostera marina. It grows in brackish and marine waters of Chesapeake Bay.

Range:

Ruppia is found throughout the Chesapeake Bay in salinities ranging from the mesohaline range to the salinity of seawater. It occurs in association with Zostera marina in the shallower portions of that species range and alone or with other submerged aquatic vegetation in areas of lesser salinities.

Ruppia is relatively abundant in the Chesapeake Bay. The MBHRL submerged aquatic survey found Ruppia in approximately 70% of their vegetated samples. Orth, Moore and Gordon (1979) found Ruppia in approximately 12% of their vegetated samples in Virginia waters.

In Maryland, past MBHRL surveys have found Ruppia in the following areas:

Eastern Bay  
Choptank River

Little Choptank  
James Island & Honga River

Honga River  
Bloodworth Island  
Fishing Bay  
Manokin River  
Big & Little Annamessex  
Rivers  
Pocomoke Sound (Maryland)  
Magothy River

Severn River  
Patuxent River  
Back, Middle & Gunpowder Rivers  
Chester River  
Love and Kent Points  
Smith Island (Maryland)

#### Salinity Relationships and Potential Habitat:

Ruppia maritima is found in salinities greater than 5 ppt. It is found in shallow water areas from this salinity to salinities of full seawater.

As Ruppia reaches its greatest growth in warm months, it is mapped against summer salinities. Potential habitat is defined as areas less than 2 m deep, over 5 salinity (Anderson and Macomber, unpublished).

#### Trophic Importance:

Ruppia is an important waterfowl food in the Chesapeake Bay. Rawls (in press) found this species in approximately 30% of the 1,179 waterfowl stomachs he examined. Ruppia comprised about 11% of the total volume of all food found in these stomachs. Seeds, leaves, stems and rhizomes are eaten by waterfowl. Ruppia is also used as a habitat for many aquatic organisms.

In Virginia, Orth et al. (1979) found Ruppia to be associated with Zostera marina in large beds, although little Ruppia was found in areas without Zostera.

#### Sources:

Orth et al. 1979

*Zannichellia palustris* - Horned pondweed

Description:

Zannichellia palustris is a submerged aquatic angiosperm. It is usually found in non-stagnant fresh or brackish waters.

Range:

Zannichellia palustris was the most frequent SAV species found in vegetated samples in Virginia waters of the Chesapeake Bay (Orth et al. 1979). In Maryland Zannichellia was found in 17% of the vegetated samples in the 1978 MBHRL survey. In the past, Zannichellia frequency and distribution has been found to be erratic (Stevenson and Confer 1978). Zannichellia is a species which is able to colonize habitats as they become available. It also declines relatively early in the summer, a factor which perhaps accounts for its erratic distribution when mapped later in the summer. Past Maryland MBHRL surveys have found Zannichellia in Eastern Bay, and the Choptank, Little Choptank, Severn, and Chester Rivers.

In Virginia, Zannichellia has been found in association with the following species (Orth et al. 1978):

Potamogeton crispus

Callitriche verna

Potamogeton perfoliatus

Chara

Potamogeton pectinatus

Myriophyllum spicatum

Vallisneria spiralis

### Salinity Relationships and Potential Habitat:

This association is commonly found in waters with a salinity equal to or less than 15 parts per thousand. Although commonly found in association with the above species, Zannichellia also occurs in monospecific beds. Potential habitat for this species is defined as areas less than 3 m deep, under 15‰ salinity.

### Trophic Importance:

Zannichellia is probably not as important as some other species of submerged aquatic vegetation or food for waterfowl. Rawls (in press) found remains of Zannichellia in only .34% of the 1,179 stomachs he examined. However, Zannichellia is likely to be important as a habitat to aquatic organisms.

### Sources:

Orth et al. 1979

Sevenson and Confer 1978

## Coastal Fresh Marsh Association

### Description:

The species that comprise this category of marsh are for the most part restricted to fresh water areas. These marshes typically have a very high diversity of species, and can be dominated by a number of different forms. However, it is probably more common for fresh water marshes to have a mixture of abundant species. This marsh category was formed from the following Maryland and Virginia marsh categories.

#### A Maryland

- Type 12, coastal shallow fresh marsh
- Type 13, coastal deep fresh marsh
- Type 14, coastal open fresh marsh

#### B Virginia

- Type 6, Typha community (T. latifolia and T. angustifolia)
- Type 7, Peltandra virginica/Pontederia cordata community
- Type 8, Phragmites australis community
- Type 9, Nuphar luteum community
- Type 11, freshwater mixed community

Although many emergent plant species are found in coastal fresh marshes, the following species are very common:

Acorus calamus

Hibiscus palustris

Leersia spp.

Nuphar leiteum

Peltandra virginica

Phragmites australis

Polygonum spp.

Pontederia cordata

Sagittaria latifolia

Typha angustifolia

Typha latifolia

Zizania aquatica

#### Range and Salinity Relationships:

Period of inundation is as important as salinity in determining species present (Boone 1977). Changes in tidal amplitude or current structure due to low flow could affect the distribution of these marshes, as could salinity changes per se. Most of the above species are found in fresh water and oligohaline areas, although some (eg. Hibiscus) penetrate to mesohaline salinities. In general, the fresh water marsh associations are limited to areas upstream of 3 - 5‰ salinity. However, localized fresh water inputs allow occurrence of this marsh type in other parts of the Bay, or occasionally within brackish or salt marsh stands.

#### Trophic Importance:

The leaves, stalks, rhizomes, and seeds of the vegetation in these marshes are important to waterfowl and animals such as muskrats. Freshwater marshes also serve as nursery grounds for fish. The marshes serve as sources of detritus to the vast coastal detrital food web, and nutrients are released upon decomposition.

#### Selection Factors:

- Importance as direct source of food for birds and other wildlife
- Importance of this marsh type to detrital supply in fresh and oligohaline areas, and thus to fish nursery grounds
- Role in nutrient recycling
- Habitat for larval and juvenile fish, crabs, and other wildlife
- Potential vulnerability to effects of low flow

## Coastal Brackish Marsh

### Description:

Most of the species found in coastal brackish marshes are restricted to brackish areas by competition, and not because of intolerance to fresh water. Plant species diversity in brackish marshes is usually lower than in fresh water marshes, with species often occurring in large monospecific stands. This marsh category is formed from the following Maryland and Virginia marsh categories:

#### A Maryland

- Type 16 coastal salt meadow
- Type 18 coastal regularly flooded salt marsh

#### B Virginia

- Type 1 Spartina alterniflora community
- Type 2 Spartina patens/Distichlis spicata community
- Type 4 Baccharis halimifolia/Iva frutescens community
- Type 5 Spartina cynosuroides community
- \* • Type 6 Typha ( Angustifolia or T. latifolia ) community
- Type 10 Salicornia sp. community
- Type 12 Brackish water mixed community

Emergent plant species which are common in coastal brackish marshes include the following:

Baccharis halimifolia

Distichlis spicata

Iva frutescens

Limonium carolinianum

Salicornia spp.

Scirpus spp.

Spartina alterniflora

Typha spp.

\*Virginia marshes dominated by these species were classified as coastal brackish depending upon the associated species present.

#### Range and Salinity Relationships:

Again, duration and extent of tidal inundation is a primary factor controlling distribution of species within the marsh. Most are restricted to more saline environments by competition, and not by effects of reduced salinity. Many of these species are found from low mesohaline to polyhaline regions. Again, changes in tidal amplitude, drainage patterns, or salinity due to low flow could affect the species composition and abundance of this marsh type. In general, these marsh types occur above 5‰ salinity in both Bay mainstem and tributaries.

#### Trophic Importance:

The emergent vegetation in brackish marshes is generally of lesser direct value as food for waterfowl than is the emergent vegetation of freshwater marshes. Coastal marshes contribute much detritus to the nutrient cycle and food web of the estuary, however. They are also extremely important as a permanent or temporary habitat for waterfowl, other birds, animals such as muskrats, and fish.

#### Selection Factors:

- Importance to nutrient cycling and detritus based food webs
- Importance as habitat for wildlife, as well as fish and crabs
- Potential vulnerability to changes produced by low flow conditions

## Brackish Irregularly Flooded Marsh

### Description:

These brackish marshes, dominated by Juncus roemerianus, are very prevalent in both Maryland and Virginia. Plant species diversity is usually extremely low in this type of marsh because Juncus typically occurs in large, monospecific stands. Other species, such as Spartina alterniflora, S. patens, and Distichlis spicata may be present near the margins of the Juncus marsh.

This marsh category was formed from the following Maryland and Virginia marsh categories:

#### A Maryland

- Type 17 Irregularly flooded salt marsh

#### B Virginia

- Type 3 Juncus roemerianus community

### Range and Salinity Relationships:

As with the preceding marsh types, extent and duration of inundation affects the occurrence of this marsh type; Juncus stands occur in portions of the marsh subject to less tidal inundation than do the Spartina alterniflora stands. The species found in this marsh type tolerate salinities from low mesohaline (or even oligohaline) to euhaline, and are apparently confined to more saline areas by competition. Again, tidal or drainage fluctuations, as well as salinity changes, due to low flow could affect the distribution and abundance of this marsh type. As with the preceding marsh type, brackish irregularly flooded marsh occurs generally in areas above 5‰ salinity.

Trophic Importance:

Juncus is little used as a direct food source by animals, and is used relatively less as habitat due to its density and sharp tipped structure. However, its productivity and abundance make it important in the detrital food webs and in nutrient cycling. Its dense rhizome structure also makes Juncus effective in preventing erosion, especially on sandy substrates.

Selection Factors:

- Importance to detrital food webs and nutrient cycles in higher salinity areas
- Importance to erosion control
- Potential vulnerability to low flow effects

*Mnemiopsis leidyi* - Ctenophore (Sea Walnut)

Description:

*Mnemiopsis leidyi* is a lobate ctenophore of the family Mnemiidae. It is a transparent, gelatinous animal, roughly pear-shaped, with four oral lobes. Adults have no tentacles. The organism swims by means of its 8 rows of comb-like plates. *Mnemiopsis* uses its body lobes and comb plates to capture the zooplankton on which it primarily feeds. Maximum size is approximately 75 mm. *Mnemiopsis* exhibits bioluminescence, flashing if touched or disturbed at night.

Range:

*M. leidyi* is found in estuarine and near-shore areas in cool and warm temperate waters of the Atlantic. In tropical and subtropical areas it is replaced by the slightly larger *M. mcradyi*. In Chesapeake Bay, *Mnemiopsis leidyi* is found from upper oligohaline to the polyhaline zone, primarily in warm months. Its abundance may be reduced in polyhaline waters due to predation by the tentaculate ctenophore *Beroe ovata*.

Salinity Relationships:

*Mnemiopsis* is most abundant in the mesohaline and polyhaline zones, and is rarely found below 4-5‰. In summer it is most numerous, and its range extends to the oligohaline region (4-5‰). In winter and early spring it is restricted to salinities of 11‰ or above. An important late summer and fall predator, *Beroe ovata*, is itself found only down to 16‰. Extension of the polyhaline zone up estuary due to flow reductions would allow

*Beroe* to extend its range in the Bay. During the 1964-65 drought, *Beroe* was collected in the lower Patuxent River (Herman et al. 1968). Other predators, notably the butterflyfish *Peprilis triacanthus* and the harvestfish *P. alepidotus* are again inhabitants of the more saline Bay areas. *Mnemiopsis* is also eaten by the sea nettle *Chrysaora*, although such predation has only moderate effects on *Mnemiopsis* numbers (Burrell and Van Engel 1976).

#### Other Sensitivities:

*Mnemiopsis* is also affected by temperature. Lower temperatures reduce fecundity, and below 10°C, no eggs are laid (Kremer 1975).

#### Trophic Importance:

While *Mnemiopsis* is itself a relatively minor source of food for other organisms, it is a voracious predator on zooplankton. Presence of large numbers of *Mnemiopsis* can virtually eliminate copepods from the same area (Burrell 1972). The cydippid larvae of *Mnemiopsis* has tenacles, and feeds by capture. The adult ctenophore feeds by impinging prey on the oral lobes by use of ciliary currents, and entangling it in mucous strands. The feeding rate of the adults is linearly proportional to the concentration of prey. Food ingested beyond the needs of the organism are ejected in a mucous bolus, thus also killed. *Mnemiopsis* may also take some detritus and large phytoplankton, but needs animal food for long term survival (Baker & Reeve 1974). *Mnemiopsis* excretes a large proportion of its ingested organic N & P, and is thus also important to nutrient cycling.

#### Selection Factors:

- Importance as a predator on zooplankton.
- Importance to nutrient cycling.

- Sensitivity to higher salinity predators whose range could be extended by low freshwater inflow.

Sources:

Baker and Reeve 1974  
Bishop 1967  
Burrell 1972  
Burrell and Van Engel 1976  
Cargo and Schultz 1967  
Herman et al. 1968  
Kremer 1975, 1976, 1979  
Lippson 1973  
Lippson et al. 1979  
Mihursky and Boynton 1978  
Miller 1970, 1974  
Reeve and Walter 1978  
Swanberg 1974

*Chrysaora quinquecirrha* - Sea nettle Jellyfish

Description:

The sea nettle is a moderately large jellyfish of the family Pelagiidae. Like all of this group it exhibits alternation of generation between the pelagic medusa form (the familiar sea nettle) and the small sessile epibenthic polyp. The medusa ranges up to 200 mm in bell diameter, with 24-72 trailing tentacles well-armed with nematocysts, and four frilled trailing oral lobes. The usual color is white, but pink or red individuals occur, particularly in the lower Bay. The cryptic polyp is only about 4 mm high, with 16-20 tentacles, found attached to hard substrates.

Range:

*Chrysaora quinquecirrha* is found in warm temperate areas worldwide. It apparently reaches its maximum abundance in estuaries such as Chesapeake Bay. In the Chesapeake it occupies differing areas depending on life stage and season. The medusa is found during the warmer months, (particularly July and August) in mesohaline and polyhaline areas. It reaches highest numbers in the mesohaline tributaries, rather than the Bay mainstem. Interestingly enough, despite the economic effect of this species in restricting recreation, good biomass and abundance data is lacking for virtually every area of the Bay. The year-to-year abundance seems extremely variable.

Eggs and sperm released by the medusae produce ciliated planula larvae, which settle on appropriate hard surfaces and give rise

to the sessile polyp stage. Polyps form resting cysts in cold months, or when conditions are unfavorable. One polyp may form numerous cysts. Through asexual reproduction the polyps produce ephyrae, which are released in early summer when water temperatures reach 20°C. These ephyrae grow and mature into medusae, completing the cycle. Medusae first appear in numbers in Bay tributaries, eventually occurring in the mainstem.

#### Salinity Relationships:

The medusae are rarely found at salinities below 5‰. Polyps have an even more restricted salinity range, and occur generally between 7-20‰ where suitable habitat exists.

Freshets which reduce salinities over a relatively long time span can kill the polyps, thus reducing later medusa abundance, as in 1972 after Tropical Storm Agnes.

#### Other Sensitivities:

The medusae are also limited by temperature, and are generally found above 20°C. Polyps encyst at temperatures below 4°C, and produce ephyrae above 20°C. Polyps are also limited by their need for hard substrates, and are thus additionally affected by sedimentation. Anoxic or hypoxic conditions in summer in deep water, as well as preponderance of soft substrate, tends to limit polyps to less than 10 m depth. However, they can occur more deeply in areas of high dissolved oxygen and good circulation.

#### Trophic Importance:

Both polyps and medusae feed upon zooplankton, with the powerfully armed medusae also able to capture small fish, worms, and

crustaceans. When abundant, *Chrysaora* medusa can probably exert significant grazing pressure on zooplankton populations. Clifford and Cargo (1978), estimate that a moderate sized medusa can consume approximately 18,800 copepods per day in summer. *Chrysaora* medusae also feed upon the ctenophore *Mnemiopsis*, reducing its numbers.

Few organisms eat the *Chrysaora* medusae, but among them are the butterfish, *Peprilis triacanthus*, and the harvestfish *P. alepidotus*. These fish also have a commensal relationship with *Chrysaora*, as the juvenile fish shelter within the medusa's tentacles (Mansueti 1963).

The polyp is preyed upon by various species which feed upon hydroids, particularly nudibranchs such as *Cratena* sp.. Barnacles and other planktivores have been shown to capture and ingest the ephyrae (Cones and Haven 1969).

#### Selection Factors:

- Economic importance of the medusae in restricting recreational use of Bay waters in summer.
- Potential of extension of range upstream in Bay and tributaries due to low flow conditions.
- Trophic importance of species as a predator of zooplankton and small fish.

#### Sources:

Burrell 1972

Cargo and Schultz 1966, 1967

Clifford and Cargo 1978

Cones and Haven 1969

Lippson 1973

Lippson et al. 1979

Gatz et al. 1973

Littleford 1937

Loeb 1972

Mansueti 1963

Mihursky and Boynton 1978

Miller 1970, 1974

Schultz and Cargo 1971

*Brachionis calyciflorus* - Rotifer

Description:

Brachionis calyciflorus is a small (less than 0.5 mm) planktonic rotifer of the family Brachionidae.

Range:

Brachionis calyciflorus is found worldwide in temperate fresh and oligohaline areas. In Chesapeake Bay, it is most abundant in tidal freshwater, although it may extend into oligohaline salinities, particularly in spring. Numbers may reach 200,000 individuals or more per m<sup>3</sup> in late spring.

Brachionis exhibits parthenogenetic reproduction, as do most rotifers. Females produce unfertilized diploid amiotic eggs which hatch into females. Miotic eggs can be produced under unfavorable conditions. They are haploid; if unfertilized, they produce males; if fertilized, they become heavy-walled dormant eggs, from which females hatch. This species has a short maturation period and potential for rapid population growth, and this probably is of considerable importance in the ecosystem.

Salinity Relationships:

B. calyciflorus is found from the head of tide to low oligohaline areas. In Chesapeake Bay, it is densest at salinities less than

0.5‰, but can be found up to 5‰ or so. In the laboratory, maximum growth of cultures occurs below 4‰, and reproduction is retarded at 6‰; salinities of 8‰ are lethal (Spektorova et al. 1975).

#### Other Sensitivities:

*B. calyciflorus* is probably sensitive to temperature changes, but its ideal range is not known. A closely related species, *B. plicatilis*, shows an optimum range of about 16 - 27 ° C. Spektorova et al. emphasize that the concentration of suitable food was most important for maintenance of populations of *B. calyciflorus*.

#### Potential Habitat:

For this species is defined as areas 5‰ salinity or less.

#### Trophic Importance:

*B. calyciflorus* feeds upon small phytoplankters (usually less than 10 $\mu$  in diameter), bacteria, and suspended detritus. Rotifers and other microzooplankton are the primary grazers on nanoplankton, and represent a key link in converting nanoplankton productivity to food for higher trophic levels.

This rotifer is an important food for larval fishes, particularly the smaller species. *B. calyciflorus* was found to represent 42.6% of food in the stomachs of striped bass yolk sac larvae (Beaven and Mihursky 1980). Its abundance in the major spawning and nursery areas makes *Brachionis* a particularly important organism in the trophic system.

In general, the importance of rotifers to aquatic food chains is recognized, but not well quantified. The abundance and rapid turnover times of such organisms indicate that they play a major role in nutrient recycling, as well as energy transfer.

Selection Criteria:

- Sensitivity to salinity, and potential restriction of range due to low flow conditions.
- Abundance and trophic importance, particularly to larval fish.

Sources:

Beaven and Mihursky 1980  
Burbidge 1974  
Chotiyaputta and Hirayama 1978  
Dahlberg et al. 1973  
Goodwin 1970  
Grant and Berkowitz 1979  
Hirayama and Kusano 1972  
Johns Hopkins Univ. 1972  
King 1967  
Sage et al. 1976  
Spektorova et al. 1975

*Acartia clausi* - Copepod

Description:

Acartia clausi is a small ( $\sim 1$  mm) calanoid copepod of the family Acartiidae. It is extremely abundant seasonally in Chesapeake Bay.

Range:

A. clausi is an estuarine and neritic species of cool temperate/boreal affinities, typically most abundant in near-shore areas. In Chesapeake Bay, the species occurs only during the winter/early spring months when water temperatures are suitable for its reproduction. It is generally more important numerically, and more persistent in the higher salinity areas of the estuary. In Chesapeake Bay it is a winter-spring codominant with its congeneric A. tonsa. In mesohaline regions, A. clausi first appears in late November or December, reaches maximum abundance ( $\sim 5-10,000$  individuals  $m^3$ ) in March, and is gone from the plankton by May. In the polyhaline lower Bay, the species can reach densities of over 20,000 organisms per  $m^3$  and constitute over 99% of the total zooplankton in March and April. It generally persists until June in these areas.

Salinity Relationships:

A. clausi is not as tolerant of reduced salinities as is A. tonsa and reaches its maximum abundance in the Bay at salinities greater than 10‰. However, it can be found down to 3‰ in the upper Bay

and tributaries. Above ~ 18‰ it is sometimes reduced in numbers by influx of neretic carnivorous zooplankton from the shelf (Grant and Olney 1979), although polyhaline salinities do not limit its distribution.

#### Sensitivity and Potential Habitat:

A. clausi is limited by temperature in Chesapeake Bay. In general, temperatures above 20°C are not favorable to reproduction and survival. Between 11°C and 18°C, A. clausi appears to be at a competitive disadvantage in relation to A. tonsa in lower salinity water. For this reason, the observed succession of tonsa over clausi in spring occurs first in the upper Bay and tributaries and proceeds downbay. A. clausi filters more efficiently and respire less than A. tonsa at low temperatures (Anraku 1964). It can reproduce at temperatures as low as 4°C.

#### Trophic Importance:

A. clausi is a selective filter feeder on phytoplankton and detritus and also exhibits a certain amount of selective raptorial feeding on small zooplankton (including nauplii of various copepods). It can adjust its feeding strategy to take advantage of the most numerous size class of phytoplankton available, and can "track" the various biomass peaks so as to maximize feeding efficiency. There is also a tendency to select for the larger particles. Adults feed less efficiently on particles smaller than 6-8 µ. When abundant, A. clausi can exert a significant grazing pressure on the phytoplankton populations.

The two Acartia spp. are important contributors to the estuarine food web. Although A. clausi is not found in the major fish nursery areas, it nevertheless is used as food by juvenile fish, and carnivorous zooplankton such as jellyfish and ctenophores.

A. clausi also acts as a source of regenerated nutrients (primarily N & P), as do other zooplankton.

Selection Factors:

- Trophic importance, both as a grazer and as a source of food for other organisms.
- Potential expansion of range due to increased salinity up-Bay.

Sources:

Acad. Nat. Sci. Phila. 1977, 1978

Anraku 1964

Burrell 1972

Goodwyn 1970

Grant and Olney 1979

Heinle 1966, 1967

Herman et al. 1968

Jacobs 1978

Richman et al. 1977

Rupp 1969

Sage and Olson 1976

Storms 1975

*Acartia tonsa* - Copepod

Description:

Acartia tonsa is a small (~ 1 mm) calanoid copepod of the family Acartiidae. This is one of the most abundant and widespread zooplankton found in Chesapeake Bay.

Range:

Acartia tonsa is a eurytopic species, occurring worldwide in temperate areas. It is most abundant in estuarine nearshore areas, and also occurs in hypersaline lagoons. In Chesapeake Bay, A. tonsa is found year round, although it is typically most abundant in summer, and is by far the dominant copepod in Chesapeake Bay. While the species is found from tidal freshwater to the polyhaline Bay mouth, it occurs in greatest numbers in salinities over 5‰

In summer, high densities may extend upstream to 1 or 2‰. Maximum numbers of adult copepods per m<sup>3</sup> may reach 100,000, but more typical values range between 5,000 and 20,000. Numbers of copepodites and nauplii can be considerably greater. A. tonsa often constitutes 90% or more of the total zooplankton biomass. Acartia can be severely reduced in number in summer by the predaceous ctenophore Mnemiopsis, found between 5 and 20‰ salinity. The extent of Acartia tonsa penetration into low oligohaline areas and tidal freshwater is not thoroughly known, but 0.5‰ is close to the lower limit for this species. Acartia is less numerous

and a less important zooplankton constituent at the Bay mouth, where a number of neritic copepod species occur with it.

#### Salinity Relationships:

Acartia tonsa is a euryhaline species, although physiologically it may be more efficient at salinities of around 15 ‰ (Heinle, pers. comm.). Minimum salinities in warm months are near 0.5 ‰; in winter, the species is more restricted and the minimum is closer to 2-3 ‰. The species is found in hypersaline lagoons along the Gulf coast, where it may benefit from lack of competitors and predators.

#### Sensitivity and Potential Habitat:

Reproduction by A. tonsa is limited by temperature, below 10°C, production of young is minimal. A. tonsa filters less efficiently and respire more at low temperatures than does A. clausi. The upper temperature limits for reproduction and survival of A. tonsa (about 30-35°C) are rarely reached in the Bay, except near thermal outfalls.

#### Trophic Importance:

As the single most abundant and widespread zooplankton in Chesapeake Bay, Acartia tonsa must be considered a key link in many Bay food webs. As a grazer-predator, it can exert tremendous pressure on phytoplankton stocks; at times of peak abundance, 50% of the daily primary production can be consumed by this species (Heinle 1966). In addition, it may enhance itself competitively by feeding selectively on nauplii of other copepod species. It also influences the regeneration of nutrients, both through direct excretion or release of N and P, and by production of fecal pellets which are sources of food for bacteria and meiofauna.

A. tonsa is a major source of food for planktivorous organisms (especially larval and juvenile fish and invertebrates), suspension-feeders, carnivorous zooplankton (such as jellyfish, ctenophores, or chaetognaths), and plantivorous fish such as menhaden or anchovies.

Selection Factors:

- Trophic importance as a key link in most phytoplankton based food webs in Chesapeake Bay.
- Abundance and dominant biomass position in zooplankton community.

Sources:

Acad. Nat. Sci. Phila. 1977, 1978

Allan et al. 1976

Anraku 1964

Burrell 1972

Ecological Analysts 1974

Goodwyn 1970

Grant and Olney 1979

Grant and Berkowitz 1979

Heinle 1966, 1969, unpubl.

Herman et al. 1968

Jacobs 1978

J.H.U. 1972

Lonsdale et al. 1979

Olson and Sage 1978

Rupp 1969

Sage and Olson 1976

Sage et al. 1977

Storms 1975

*Eurytemora affinis* - Copepod

Description:

Eurytemora affinis is a small ( $\sim 1$  mm) calanoid copepod of the family Temoridae. It is an abundant organism in the tidal freshwater and oligohaline zones of the Chesapeake Bay.

Range:

Eurytemora affinis is an estuarine endemic found in temperate areas. In Chesapeake Bay, Eurytemora is found throughout the year, although it is more abundant and has the greatest range in spring. In summer months, this species is restricted to oligohaline and tidal freshwater areas. Lack of zooplankton information from most of the eastern shore tributaries necessitates defining these areas as potential habitat for Eurytemora affinis.

Salinity Relationships:

In spring months, Eurytemora occupies a salinity range from 0 to about 12‰. Maximum abundance, about 50 to 100,000 individuals per  $m^3$ , occurs in the area where salinities are less than 10‰. As temperatures rise in late spring, the numbers of this species decline, and it disappears from the higher salinity areas. At this time, maximum abundance (about 1000 - 5000 individuals/ $m^3$ ) is found below 4‰.

### Sensitivity and Potential Habitat:

Eurytemora affinis is a species with north temperate origins (Jeffries 1962), and this is reflected in its reduced range and abundance in summer. Competition with Acartia tonsa was once proposed as the mechanism restricting E. affinis to low salinity regions in warmer months. However, the observed decline in abundance of Eurytemora begins before A. tonsa numbers increase dramatically (Sage, pers. comm.). Competition could still be a factor, however, since A. tonsa has been shown to feed upon the nauplii of E. affinis (Lonsdale et al. 1979).

### Trophic Importance:

Eurytemora affinis is probably the single most important zooplankter in the oligohaline and tidal fresh nursery grounds of many fish. It has been shown to be particularly important to alosids (Burbidge 1972) as well as moronids (Polgar et al. 1976, Setzler et al. 1979, Beaven and Mihursky 1980). Abundance of Eurytemora is important for survival of striped bass larvae (Setzler et al. 1979), as it can constitute 72% of their food (Beaven and Mihursky 1980).

Eurytemora is a selective filter feeder, and feeds upon algae and detritus. Like Acartia, it "tracks" biomass peaks to maximize feeding efficiency, but does not show raptorial feeding on larger particles. When algal production is insufficient to meet carbon requirement for this species, it utilizes detritus (Allan et al. 1977). Delivery of marsh detritus to the lower estuary by spring runoff is important to Eurytemora biomass in this time period.

### Selection Factors:

- Trophic importance to larval fish survival.
- Restricted salinity range, and vulnerability to low flow salinity increases.

- Importance of runoff to detrital input.

Sources:

Acad. Nat. Sci. Phila. 1977, 1978  
Allan et al. 1977  
Beaven and Mihursky 1980  
Burbidge 1972  
Burrell 1972  
Conte and Otto 1980  
Ecological Analysts 1974  
Goodwyn 1970  
Grant and Berkowitz 1979  
Herman et al. 1968

Jefferies 1962  
J.H.U. 1972  
Lippson et al. 1979  
Lonsdale et al. 1979  
Olson and Sage 1978  
Polgar et al. 1976  
Sage and Olson 1977  
Sage et al. 1976  
Setzler et al. 1979  
Storms 1975

*Scottolana canadensis* - Copepod

Description:

Scottolana canadensis is a harpacticoid copepod of the family Canuellidae. It is an elongate form about 1.5 - 2.0 mm long, typically epi-benthic, but seasonally abundant in the zooplankton. In many collections it has been confused with the much smaller Halectinosoma curticorne, also an abundant species in the Bay (Sage, pers. comm.). For this reason, there is a certain amount of conjecture regarding some of its distribution records.

Range:

Scottolana is an estuarine endemic species, reaching its greatest abundance in the oligohaline portions of temperate-zone estuaries. In the Chesapeake, Scottolana is most abundant in late spring and summer, and extends its range furthest downstream at this time, into low mesohaline regions. Collection records tend to show a much greater abundance of copepodites, than adults in the plankton; this is probably an artifact due to net evasion by the adult animals (Gauzens, pers. comm.). Collection information for this species is lacking in many of the eastern shore tributaries. It is probable that it exists in all suitable habitats within the Bay.

Although considered a benthic species, and a member of the meio-fauna, there is a great paucity of information on Scottolana's

benthic role. It is probable that it overwinters and spends part of its life cycle on the bottom but there is apparently no information as to depth and sediment preferences, if any. This reflects the general lack of knowledge about meiofaunal composition and distribution in Chesapeake Bay.

#### Salinity Relationships and Potential Habitat:

Scottolana reaches its greatest abundance (up to 100,000 individuals  $m^3$ , but usually an order of magnitude less) between the salinities of 1.0 to 5.0‰ or so. It is found in salinities up to 10‰ or slightly more, and also in tidal freshwater, but at reduced densities. The extent of this species' range into lowest salinities is uncertain, but it is not a characteristic member of the freshwater zooplankton.

#### Trophic Importance:

Scottolana and other harpacticoids are considered one of the major foods for juvenile sciaenid fishes, as well as other benthic feeders. For example, Stickney et al. (1975) found harpacticoides in 88% of spot stomachs examined, the single most numerous item. The coincidence of Scottolana's range with major nursery areas is of particular importance.

#### Selection Factors:

- Restricted salinity tolerance of this species, and potential reduction of range under low flow conditions.
- Importance as food for demersal feeding juvenile fish, particularly Sciaenids.

#### Sources:

Acad. Nat. Sci. Phil. 1977, 1978  
Burrell 1972  
Heinle et al. 1975  
Lippson 1973

Lippson et al. 1979  
Sage and Olson 1976  
Stickney et al. 1975

*Bosmina longirostris* - Cladoceran

Description:

Bosmina is a small, primarily freshwater cladoceran of the family Bosminidae. This species has a rounded body, and appendages adapted for swimming and filtering food. The head is extended forward and down into a pointed horn, hence "longirostris."

Range:

This species is widespread in temperate rivers and lakes. In Chesapeake Bay, it is restricted to freshwater and oligohaline reaches of tributary rivers and the Bay mainstem. Bosmina occurs throughout the year, but is most abundant in spring and summer. At that time it achieves its maximum extension downstream. Densities may often exceed 100,000 or more individuals per m<sup>3</sup>, particularly in lowest salinities.

Like all cladocerans, Bosmina exhibits parthenogenic reproduction for most of the year.

Salinity Relationships and Potential Habitat:

Bosmina reaches its greatest abundance in freshwater, and is reduced in number when salinities exceed 0.5 to 1.0‰. It generally does not occur in salinities over 5‰.

### Trophic Importance:

Bosmina is a filter feeder, ingesting algae, bacteria, and detritus. This species is an important source of food for larval fish, as it is one of the most numerous zooplankters in the freshwater nursery areas. It was found to comprise up to 65% of food in the stomachs of larval striped bass from the Potomac River (Beaven and Mihursky 1980). It is also an important item of food for larval and juvenile alosids, such as the blue-back herring (Burbidge 1972) when it is abundant.

### Selection Factors:

- Importance as food for larval and juvenile fish in tidal freshwater nursery areas.
- Sensitivity to potential increases in salinity, due to low flow conditions, with corresponding reduction of range.

### Sources:

Beaven and Mihursky 1980  
Burbidge 1972  
Ecological Analysts 1974  
Goodwyn 1970  
Herman et al. 1968  
Lippon et al. 1979  
Sage et al. 1976  
Zhdanova and Frinooskaya 1975

*Evadne tergestina* - Cladoceran

Description:

Evadne tergestina is a marine cladoceran, of the family Podonidae (Polyphenoidea). It has an angular, pointed body with a single large eye and appendages adapted for seizing the large dinoflagellates, and small zooplankton (ciliates, rotifers, and copepod nauplii) upon which it feeds.

Range:

E. tergestina is a neretic species found worldwide in warm temperate seas. In Chesapeake Bay, E. tergestina occurs only in the lower Bay, and is most abundant in summer months. At these times, it can represent a major fraction of the zooplankton biomass, with densities often exceeding 100,000 individuals per m<sup>3</sup>. During the 1960's drought, Evadne was recorded as far north in the Bay as Calvert Cliffs; typically, however, it is restricted to Virginian waters (Bosch & Taylor 1968).

Salinity Relationships:

Evadne tergestina is a relatively stenohaline species, and is not found at salinities much below 16‰. Maximum densities occur at 20‰ salinity and above.

Sensitivity and Potential Habitat:

Evadne tergestina enters the Bay only when temperatures are near the summer maximum. They disappear rapidly in early fall, at least partially due to predation by Chaetognaths, as well as falling water temperatures.

### Trophic Importance:

During its period of maximum abundance, E. tergistina could exert a significant feeding pressure on microzooplankton, as well as copepod nauplii and copepodites, and large dinoflagellates. In turn, they represent an important source of food for larger predacious plankton, larval and juvenile fish, and planktivorous adult fish.

### Selection Factors:

- Restricted salinity range, and demonstrated increased penetration into the Bay during periods of low flow.
- Trophic importance.

### Sources:

Bosch and Taylor 1968

Bryan 1977

Jacobs 1978

*Podon polyphemoides* - Cladoceran

Description:

Podon is one of the few marine cladocera, and is a member of the family Podonidae. It is characterized by a rounded body, large single eye, and appendages adapted for swimming and grasping prey (it feeds upon large phytoplankton and small zooplankters such as rotifers and naupleii).

Range:

Podon is an estuarine endemic species, found worldwide where environmental conditions are suitable. In Chesapeake Bay it is most abundant in the mesohaline regions of the estuary. Podon first appears in tributaries when spring water temperatures reach 6°C, hatching from overwintering eggs. Numbers increase through parthenogenetic reproduction, although sexual forms appear as temperatures reach 11°C (rarely amounting to more than 10% of the population). Highest densities of Podon occur in the Bay mainstem, during the time when water temperatures remain below 27°C. The species disappears when temperatures exceed this value, only to reappear in fall as the water cools. Eggs produced by sexual forms in the autumn overwinter to produce the next year's spring animals.

Maximum densities may reach 100,000 individuals per m<sup>3</sup>, although densities an order of magnitude smaller are more usual.

Salinity Relationships:

Parthenogenetic females are most abundant between the salinities of 8 and 18‰ with a maximum tolerance of 31.5‰. Males and sexual females are found between the salinities of 4 and 20‰.

### Sensitivity and Potential Habitat:

Podon is, as was discussed above, also limited by low temperatures in winter (rare at temperatures below 6°C) and high temperatures in summer months (over 27°C). Sexual forms have an even more restricted tolerance, and are found generally when water temperatures are between 11 and 23°C.

This species exhibits diurnal vertical migration, and apparently uses the upstream flow of water at depth to maintain itself within the estuary. Low flow could alter this circulation pattern.

### Trophic Importance:

Podon may reach densities in June and October of over 100,000 individuals per m<sup>3</sup>. When this abundant, Podon can exert a significant grazing effect on the phytoplankton and microzooplankton on which it feeds. Also, it can represent a major source of food for larval fish and crabs, as well as planktivorous fish. It is also preyed upon by ctenophores and coelenterates, such as Mnemiopsis.

### Selection Factors:

- Sensitivity to salinity and circulation, both potentially affected by low flow.
- Trophic importance, both as source of food for larval fish, and as grazer/predator on large phytoplankton and microzooplankton.

### Sources:

Bosch and Taylor 1968, 1973a, 1973b

Bryan 1977

Goodwyn 1970

Herman et al. 1968

Jacobs 1968

JHU 1972

Lippson et al. 1979

*Limnodrilus hoffmeisteri* - Oligochaete worm

Limnodrilus hoffmeisteri is an oligochaete worm of the family Tubificidae. It is a long slender worm about 0.5 - 2.5 cm in length, often occurring in high densities in Chesapeake Bay.

Range:

L. hoffmeisteri is found worldwide in fresh and oligohaline temperate areas. In Chesapeake Bay it is restricted to the fresher parts of the tributaries and main Bay. Numbers are often very high, particularly in areas of organic enrichment, to 15,000 individuals/m<sup>2</sup> or more. Although 100 - 2000/m<sup>2</sup> is more typical. In some polluted areas, L. hoffmeisteri and its congenics are the only abundant benthic fauna (Pfitzenmeyer 1975).

L. hoffmeisteri reproduces twice a year in European waters, from May - June and from late September to early October (Poddubnaya 1973). Eggs are brooded for a time in a cocoon, which is later deposited on the bottom by the adults. The young worms hatch, grow rapidly, and spring young may reach sexual maturity by fall in warmer areas. Adult worms apparently die after reproduction, accounting for a decrease in adult abundance in summer and winter (Poddubnaya 1973). It is not known if the same pattern is found in Chesapeake Bay. Crumb (1977) found L. hoffmeisteri population to increase in spring, with peak numbers of juveniles by June. Densities decreased in August, possibly due to high temperatures, and these lower densities persisted throughout winter.

### Salinity Relationships:

Laboratory experiments have shown L. hoffmeisteri to withstand salinities from 0 - 10.7‰, with the 168 hr LC<sub>50</sub> being 14.7‰ (Birtwell and Arthur 1979). In the Thames it was found downstream to areas which experienced salinity variations up to 13.5 although the mean salinity where it was the dominant species was 3.9‰. However, in Chesapeake Bay, L. hoffmeisteri is rarely found above 5‰, and generally occurs at salinities below 1.0‰ (Diaz 1977, 1979, Cory and Dresler unpubl.). In the Patuxent River it occurs further downstream, and shows a bimodal distribution, with maximum abundance below 1‰ and then again near the discharge from Chalk Point S.E.S., at around 5‰ (Holland et al. 1980). Thus, under suitable conditions, L. hoffmeisteri can be found in salinities well above its usual range.

### Other Sensitivities:

Limnodrius hoffmeisteri is a very tolerant organism and is considered an indication of organic enrichment (Brinkhurst 1970). Birtwell and Arthur (1979) found it able to withstand temperatures up to 37.5°C, and predicted that it could exploit habitats adjacent to thermal outfalls, as Holland et al. (1980) observed. However, temperatures of 20 - 25°C are more optimal for the species (Appleby and Brinkhurst 1970). In fact, Crumb (1977) reported a steep decline in Limnodrilus numbers as bottom temperatures in the Delaware River reached the 28 - 32°C range. He proposed that high temperatures may limit its populations in the river.

Although L. hoffmeisteri is found in all sediments, including gravel and pebbles, it is much more abundant in soft organic rich muds (Crumb 1977, Birtwell and Arthur 1979, Diaz 1979).

The species is also tolerant of considerable anoxia (Crumb 1977, Birtwell and Arthur 1979), and would thus be able to exploit the normally hypoxic summer conditions in many Bay tributaries.

Limnodrilus hoffmeisteri is thus an opportunistic species, able to colonize and exploit stressful habitats. When possible competitors or predators are absent (due to unfavorable conditions), it may occur well outside its expected range.

#### Potential Habitat:

Potential habitat for this species is defined as areas from freshwater to 1.0‰, up to 5 ‰ under certain conditions, all depths and all sediments, but most abundant in mud.

#### Trophic Importance:

L. hoffmeisteri is a deposit feeder, ingesting detritus and its associated bacteria and microfauna. It feeds head down in its burrow, with the caudal end projecting (and undulating) above the sediment surface. In fresh water areas, where they are the dominant infauna, L. hoffmeisteri and other oligochaetes, are probably most important in the transfer of detrital and bacterial energy to higher trophic levels (Diaz 1979). They are used as food by birds, fish, and numerous smaller predators such as insect larvae, which are in turn food for fish. In estuarine areas where smaller oligochaete species are found, and polychaetes become numerous, the trophic importance of the group declines (Diaz 1977). However, in polluted or disturbed areas, they again may represent a key trophic link.

Limnodrilus is also important in its effect on sediment structure. Sediment is ingested in subsurface layers, and egested on the surface. Sediments may be turned over to a depth of 4 - 6 cm up to a dozen times annually (Appleby and Brinkhurst 1970). The activities of oligochaetes also has implications for the regeneration or release of nutrients from the sediments to the water column (Diaz 1979). Lastly, burrowing activity may increase oxygenation of the upper centimeters of sediment.

Selection Factors:

- Abundance and faunal dominance in tidal freshwater and oligohaline areas.
- Importance to bioturbation of sediments in these waters.
- Key link in detrital/bacterial food web in these areas.

Sources:

Appleby and Brinkhurst 1970  
Birtwell and Arthur 1979  
Brinkhurst 1970  
Cory and Dresler unpubl.  
Crumb 1977  
Diaz 1977, 1979  
Ecological Analysts 1974  
Holland et al. 1980  
Lippson et al. 1979  
Pfitzenmeyer 1973, 1975, 1976  
Poddubnaya 1973  
Reinharz et al. unpubl.

*Heteromastus filiformis* - Polychaete Worm

Description:

Heteromastus filiformis is a long, slender burrowing polychaete of the family Capitellidae. It is a narrow worm about 40 - 70 mm long, with few obvious polychaete-like appendages, a pointed head-region (superficially resembling an oligochaete), and is purplish-red in color. H. filiformis inhabits a mucous-lined burrow in intertidal or subtidal areas.

Range:

H. filiformis is found from New England south to Florida, and also occurs in Europe. In Chesapeake Bay, it occurs from the oligohaline zone to the Bay mouth, and may be very abundant: densities are usually around 500/m<sup>2</sup> or less, but numbers of 2000 adults per square meter have been recorded. Recruitment of over 50,000 juveniles/m<sup>2</sup> into enclosure cages was reported by Virnstein (1979). The species is tolerant of eutrophication and thermal discharges, which, coupled with its planktonic larvae and rapid growth rate, mark it as a euryhaline opportunist (Wass et al. 1972, Grassle & Grassle 1974).

H. filiformis begins breeding in early spring in Chesapeake Bay. Loi and Wilson (1979) record sexually mature adults containing gametes in March. The species has a planktonic larvae, and

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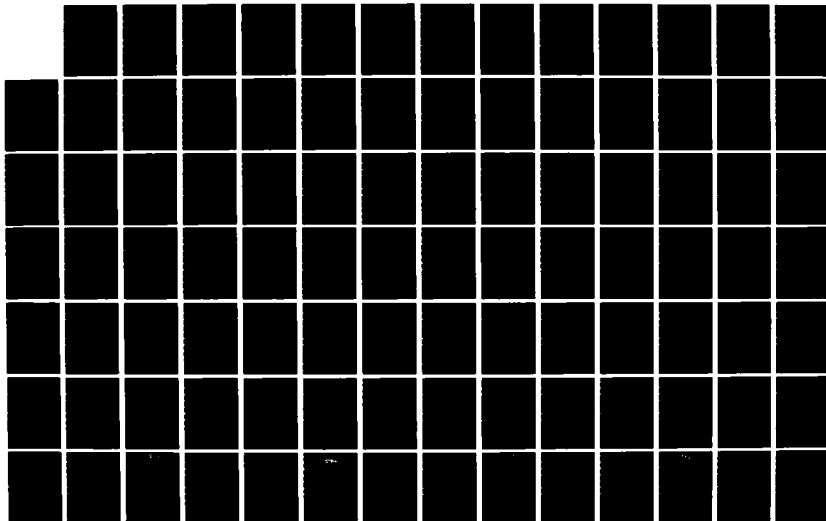
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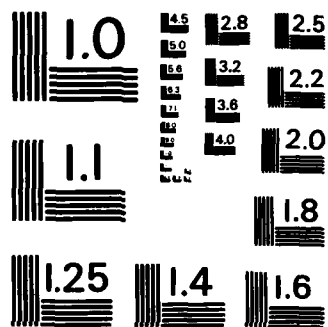
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recruitment is at a peak in June and July. H. filiformis is probably reproductively active for much of the year. Typically the species shows considerable temporal and spatial variability in its distribution (Watling 1975, Loi and Wilson 1979, Virnstein 1979), although there appears to be little seasonal variation in Patuxent River populations (Holland et al. 1980).

#### Salinity Relationships:

H. filiformis is a euryhaline species and collection records show it occurs in salinities as low as 2 ‰ in Chesapeake Bay. However, densities decrease rapidly below 5 ‰. It occurs in full oceanic salinities, as well.

#### Other Sensitivities:

Heteromastus filiformis is found in a variety of substrates from sand to mud, although many authors report that it occurs with greatest frequency in muddy sediments (Watting 1975, Kinner and Maurer 1978, Maurer et al. 1978). This may reflect its deposit-feeding mode of life (and need for organic-rich sediments), rather than any strict substrate requirement. Tenore (1970) reported that H. filiformis occurred only in sand substrates in Pamlico Sound. Dauer et al. (1979) also found H. filiformis more abundant in sand in the Lynnhaven River.

The species occurs with greatest frequency in shallow areas, although it has been reported at great depths offshore (Kinner and Maurer 1978, Holland et al. 1979, Loi and Wilson 1978). The depth limitation in Chesapeake Bay is probably related to summer anoxia (Holland et al. 1977).

H. filiformis is eurytopic in regard to temperature. Mature gametes occur in worms in March at Calvert Cliffs, when ambient

water temperatures is about 7 - 8°C, and the species breeds for much of the year. Although Wass et al. (1972) indicate that the species is quite tolerant to thermal pollution, Holland et al. (1980) do show a reduction in numbers at stations affected by discharge from Chalk Pt. S.E.S. relative to control stations. However, no information on exact physiological temperature limits appears available for this species.

#### Potential Habitat:

Potential habitat for this species is defined as areas greater than 2‰ salinity, to 10 meters, most abundant above 5‰ and in less than 6 - 7 meters depth.

#### Trophic Importance:

Heteromastus filiformis is a deposit feeder, ingesting detritus, algae, microorganisms, and decaying matter from below the surface. It is found oriented vertically, head-down, in its tube; waste material and sediment are deposited on the substrate surface as a small cone.

H. filiformis is fed upon by fish and crabs, although it is able to avoid some predation by deep burrowing (Virnstein 1979). Densities of H. filiformis in enclosure cages were significantly higher than controls at many stations (Virnstein 1979, Holland et al. 1979).

Heteromastus filiformis is an opportunistic species, and might be expected to increase in abundance quickly up estuary if salinities increase due to low flow. Dean and Haskin (1964) reported it as a pioneer species in recolonization of a previously polluted area; however, it was replaced within a year in many areas by other species.

The deep burrowing and tube building of this species contributes to sediment reworking, sorting, nutrient regeneration and release.

Selection Factors:

- Abundance of species, and dominant position in many areas.
- Importance of predators, sediment reworking and detrital breakdown.
- Potential colonizer of disturbed areas.

Sources:

Boesch 1971, 1977 unpubl.  
Cory and Dresler unpubl.  
Dauer et al. 1979  
Dean and Haskin 1964  
Diaz 1977  
Grassle and Grassle 1974  
Harman unpubl.  
Hartman 1945  
Holland et al. 1977, 1979, 1980  
Kinner and Maurer 1978  
Loi and Wilson 1979  
Maurer et al. 1978  
Pfitzinmeyer 1970, 1975  
Reinharz et al. unpubl.  
Tenore 1970  
Virnstein 1979  
Wass et al. 1972  
Watling 1975

*Pectinaria gouldii* - Polychaete worm

Description:

Pectinaria gouldii\* is a large tube-building polychaete of the family Amphictenidae; popularly known as the trumpet worm because of its long conical-shaped tube. The tube is about 2 - 5 cm in length, depending on the size of the animal, and constructed of a single layer of sand grains firmly cemented together. The most notable feature of the animal are the two sets of long golden paleae or setae on the head, which are used for digging or as an operculum for the tube. The head is also equipped with numerous tentacles which are used in feeding and tube building.

Range:

Pectinaria gouldii is found from New England to North Carolina in inter- or subtidal areas. In Chesapeake Bay, it is confined to high mesohaline and polyhaline regions. Its distribution is spotty and variable within its range, and densities are usually less than 500/m<sup>2</sup>, although numbers of 4000/m<sup>2</sup> or more have been recorded (chiefly young worms).

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\* Note: Because of confusion about the type specimen for the genus, the name Pectinaria has been recently replaced by Cistena. However, as this change has been appealed to the International Commission on Zoological Nomenclature, the more familiar name is retained for this report.

The tube of P. gouldii is permanent, and the animal will not leave it.; Watson (1927) characterized it as the organism's "life work". The animal is typically found buried in an oblique position below the substrate surface, with the tapered end of the tube projecting for a centimeter or so above the surface. The animal digs with its paleae, and sediment is conveyed to the mouth by the tentacles. The activities of the worm form small collapsing caverns or channels which fill in with surface sediment (Watson 1927, Gordon 1966), thus constantly reworking the substrate.

P. gouldii appears to spawn once a year in Chesapeake Bay, probably in late spring (Virnstein 1979). Larvae are pelagic; they first settle to the bottom and build a small chitinous tube (Watson 1927). This forms the base of the later adult tube. Recruitment is irregular, but several thousand young worms per square meter may in late May or June settle. Growth is relatively rapid, the worms reaching adult size by autumn (Virnstein 1979). Loss to predation is high, however, and few worms live to two years of age (Peer 1970).

#### Salinity Relationships:

There are apparently no laboratory studies of the exact physiologically tolerances of P. gouldii, at least in regard to salinity. However, collection information from Chesapeake Bay indicates that it is not found in salinities much below 10‰, and is most abundant at 15‰ or above. This is the expected range of a eurytolerant marine species such as Pectinaria gouldii.

#### Other Sensitivities:

Like all organisms, P. gouldii is affected by temperature. Optimal

and lethal temperatures for this species have apparently not been determined, but spawning appears initiated when spring temperatures reach 15°C or so. Rate of sediment working (feeding) and respiration are also temperature-dependent, and reach very low levels in winter (Gordon 1966, Nichols 1975).

P. gouldii is also somewhat sensitive to sediment type. Adult worms cannot work particles larger than 1 mm (Gordon 1966). Also, Watson (1927) reports the death of young worms of the congeneric P. koreni resulting from clogging of the small end of the tube by passage of too-large-sized particles. P. gouldii is generally more abundant in fine sands, muddy sands, and sandy muds (Pfitzenmeyer 1961, Boesch 1973).

Anoxic conditions may limit Pectinaria. In Kiel Bay, W. Germany, years in which summer anoxia developed had greatly reduced recruitment of young P. koreni, and near total destruction of standing stock (Nichols 1976). Wass et al. (1972) report P. gouldii to about 30 meters in Chesapeake Bay, but summer hypoxia in many areas could be expected to reduce or eliminate populations below 15 - 20 meters (Holland et al. 1979).

#### Potential Habitat:

Potential habitat for this species is defined as those areas where salinity is greater than 10‰, with greatest abundance over 15‰ and from 0 to about 10 meters.

#### Trophic Importance:

Pectinaria gouldii is a deposit feeder, ingesting detritus and its associated microorganisms, algae, and decaying animal and vegetable matter. Gordon (1966) found that this species removed almost half of the organic matter from each gram of sediment

worked (laboratory results). The animal digs vigorously with its paleae, and the loosened sediment is conveyed to its mouth by the ciliated tentacles. Some sediment is rejected, some ingested, while some is worked and then passed through the tube by a vigorous "pumping" action of the worm's body (Watson 1927). The ejected material is deposited as a small mound at the posterior of the tube.

P. gouldii is a major prey item for bottom feeding fish and crabs and mortality due to predation is heavy. Peer (1970) estimated that 80% of the annual mortality of P. hyperborea was due to predation, and that 70% of a cohort was lost to predation during its first year of life. Virnstein (1979) noted that P. gouldii is usually not abundant in the natural environment, but that it increased several orders of magnitude in enclosure cages. He hypothesized that fish and crab predation are major factors regulating the numbers of this species.

Pectinaria is also an important bioturbator of sediments where it is abundant. In the laboratory, Gordon (1966) determined that each worm works about 6 grams of sediment per day at 18 - 19°C, with the rate decreasing with temperature. At the latitude of Cape Cod, he estimates that one worm would rework 600 grams of sediment annually (in Chesapeake Bay this rate would probably be higher). He finally concludes that at densities of 40 worms/m<sup>2</sup>, the sediment would be completely turned over to a depth of 6 cm in four years. Also, where larger particles are mixed with finer sediment, the finer material is carried to the surface and deposited, leaving the coarser material at depth (Gordon 1966). Thus P. gouldii can also exert a sorting effect on natural substrates.

#### Selection Factors:

- Potential for range extension under low flow conditions.
- Importance as food for demersal fish and crabs.
- Importance as a bioturbator of sediments.

Sources:

Boesch 1971, 1973, unpubl.

Cory and Dresler, unpubl.

Diaz 1977

Harman, unpubl.

Holland et al. 1979

Kaufman et al. 1980

Nichols 1975, 1976

Peer 1970

Pfitzenmeyer 1961

Virnsetein 1979

Watson 1927

Wass et al. 1972

*Scolecoides viridis* - Polychaete worm

Description:

Scolecoides viridis is a burrowing polychaete worm of the family Spionidae. Adult worms are about 4 - 10 cm long, green or brownish green in color, with prominent red branchiae, and two stout tentacular palps. It inhabits a mucous-lined burrow, generally in intertidal or subtidal areas.

Range:

Scolecoides viridis is found from Newfoundland to Georgia, in areas of reduced salinity. In Chesapeake Bay, it is confined to the oligohaline through mesohaline regions, chiefly in intertidal or shallow subtidal areas. Densities are generally less than 2000/m<sup>2</sup>, but numbers of 10,000 individuals/m<sup>2</sup> have been recorded.

S. viridis breeds in early spring in Chesapeake Bay, and juvenile worms appear in May through July (Pfitzenmeyer 1970, Dauer et al. 1980). Eggs and sperm are released from ripe individuals, and planktonic larvae result. George (1966) reported that eggs cannot be fertilized, nor will they develop, at salinities under 5‰. This has implications for the species in Chesapeake Bay, as a large proportion of the population is found below these salinities, and Pfitzenmeyer (1970) considers it one of the

three characteristic oligohaline species in the upper estuary. Dauer et al. (1980) observed numerous ripe worms swimming at the surface at night on an ebb tide, which they consider a mechanism for dispersing breeding individuals into higher salinity areas. The resulting larvae may then be transported up estuary by bottom currents to recolonize the oligohaline zone. Larvae metamorphose at about 30 - 40 days of age, becoming negatively phototactic and testing the substrate. They eventually construct a small vertical burrow and begin a benthic existence (George 1966).

#### Salinity Relationships:

Scolecoides viridis is a characteristic species of the upper Bay, although it has been found regularly in upper mesohaline areas, and even occasionally in the polyhaline zone (Dauer et al. 1980). Salinity per se is probably not the adult downstream limit, as much as predation or competition. Adults have been collected in salinities as low as 0.5‰, and occur with frequency up to 15‰ or so. Maximum densities occur generally between 1 - 5‰ in the Bay.

Larvae, as was discussed above, have definite minimum salinity limits. Eggs cannot be fertilized or early egg cleavage takes place below 5‰, although older larvae can survive 2.5‰. Eggs develop normally up to 30‰.

If adults inhabiting oligohaline areas do migrate down estuary at time of spawning, and if the resulting larvae utilize the upstream flow of water at depth to repopulate the oligohaline zone, then low flow alterations of estuarine circulation may affect the occurrence of this species in the Bay.

#### Other Sensitivities:

S. viridis is affected by temperature both in regard to spawning and development, and probably summer survival. It is a boreal/north temperate species, and may be limited by summer temperatures at the latitude of Chesapeake Bay. Holland et al. (1980) record that its abundance is at a minimum in summer. George (1966) found that larvae need temperatures of at least 2°C to begin development, and of 10°C to reach metamorphosis. Upper temperature limits for both adults and larvae appear to be between 34 - 35°C.

S. viridis is most numerous in firm substrates which allow tube-building, although it has been recorded from virtually all sediment types. Pearson et al. (1975) found that it was more tolerant of excess siltation than some other upper Bay species.

#### Potential Habitat:

Potential habitat for this species is defined as areas between 0.5‰ and 15‰, most abundant in 1‰ to 5‰, in sand and muddy sand, to 10 meters depth.

#### Trophic Importance:

Scolecoides viridis is an infaunal deposit feeder, ingesting detritus, algae, microorganisms, small meiofauna, and decaying animal and vegetable matter. The worm inhabits a vertical mucous-lined burrow in firm substrates, and feeds upon the surface deposits surrounding its tube. The ciliated tentacles carry food to the pharynx, where it is ingested. The animal was abundant in organically-enriched substrates in Baltimore Harbor, including mud, so it should be considered a relatively pollution-tolerant species (Pfitzenmeyer 1975).

S. viridis is fed upon by fish, crabs and benthic invertebrates predators such as Nereis. Holland et al. (1980) suggest that the temporal pattern of the species at Chalk Pt. indicates its standing stock is controlled by predation; numbers are lowest when predators are most abundant. Caging experiments at Calvert Cliffs show that numbers inside the enclosure are significantly higher than controls only in summer (Holland et al. 1979). The lower numbers observed inside the cages at other times may reflect "internal" predation by species such as Eteone or Nereis. Homer and Boynton (1978) found that S. viridis is an important item in the diet of sport and winter flounder, and is eaten by other bottom feeding species.

As with all tube-building species, S. viridis contributes to sediment stabilization, sorting, and aeration.

#### Selection Factors:

- Sensitivity of reproductive cycle to salinity, and importance of estuarine circulation patterns to distribution of the species in the oligohaline zone.
- Abundance of the species in low salinity areas, and food potential for fish, crabs, birds and other predators.

#### Sources:

Boesch 1971 unpubl.  
Cory and Dresler unpubl.  
Dauer et al. 1980  
Diaz 1977  
George 1966  
Holland et al. 1979, 1980

Homer and Boynton 1978  
Lippson, A.J. et al. 1979  
Lippson, R.L. unpubl.  
Pearson et al. 1975  
Pfitzenmeyer 1970, 1975  
Reinharz et al. unpubl

*Streblospio benedicti* - Polychaete Worm

Description:

Streblospio benedicti is a small burrowing polychaete of the family Spionidae. Adult worms are only 5 - 12 mm long, reddish brown in color, with a pair of prominent ciliated tentacular palps. It inhabits a small, soft tube constructed of mucous and debris, slightly buried into the sediment.

Range:

Streblospio benedicti is found on both the west and east coast of North America; on the east coast it occurs from New England to North Carolina. In Chesapeake Bay, it is found throughout the mesohaline and polyhaline zones. Densities are normally less than  $100/\text{m}^2$ , but numbers up to 5000 per square meter or more have been recorded. Extremely large numbers have set into enclosure cages, exhibiting the response pattern of an opportunistic species to available open habitat.

S. benedicti breeds primarily from April through October in the Chesapeake; the peak period of recruitment is spring (Virnstein 1979). The species is larviparous; females brood the developing embryos until approximately the ninesetiger stage. The released larvae metamorphose within 24 hours if suitable substrate is available, although this can be delayed as much as two weeks (Dean 1965). The recently metamorphosed larvae forms a small tube; maturity is reached in about a month after setting.

There is a decline in number of adults after breeding, unrelated to predation (Vernstein 1979). Brood protection, metamorphosis delay, year-round breeding, and rapid maturity are characteristics of one type of benthic opportunist, according to Grassle and Grassle (1974). The S. benedicti population fluctuates both in space and time in response to changes in environmental conditions, and predation or competition.

#### Salinity Relationships:

Streblospio benedicti is a euryhaline species, and is found from 5‰ (or even less) to full oceanic salinities. It is a characteristic species of the mesohaline and polyhaline Chesapeake Bay.

#### Other Sensitivities:

S. benedicti builds fragile tubes out of fine sediment and mucous, which lay along the substrate or are buried to a depth of 1 - 2 cm. The species is most abundant in silts and clays, detritus, and similar substrates (Hartman 1945, Dean 1965, Maurer et al. 1978). However, it does occur in sand (Holland et al. 1979).

S. benedicti is eurytopic as regards temperature, and although the peak breeding season occurs when water temperature exceeds 10°C, some reproduction takes place year round (Vernstein 1979).

The species is very vulnerable to predation, as will be discussed in a following section.

#### Potential Habitat:

Potential habitat for this species is defined as areas above 5‰ salinity, to 20 m depth; highest abundance in muddy sand, sandy mud, and mud.

### Trophic Importance:

Streblospio benedicti is a surface deposit feeder, ingesting detritus, microorganisms, algae, and decaying material. Food is carried to its mouth by the ciliated palps; rejected and fecal material is deposited around the tubes.

S. benedicti is a very small worm, and is fed upon by both larger predators such as fish or crabs, and smaller invertebrates such as shrimp. Caging experiments have shown that extremely high densities can develop in areas free of predators (to 140,000/m<sup>2</sup>) (Virnstein 1977, 1979, Holland et al. 1979). Virnstein (1979) reported that crab predation was a much more significant factor than fish predation.

The tubes of this worm serve to stabilize and bind the substrate, allowing colonization by other species such as Mya (Virnstein 1979). Biodeposition by this worm also increased the proportion of silts and clays in exclosure cages dense with S. benedicti (Virnstein 1979).

Although intra- and interspecific competition generally appear to have little effect on populations of this species (Virnstein 1977, Holland et al. 1979), Mills (1967) regards Ampelisca abdita as a direct competitor. The two species tend to occupy similar habitats, where the feeding behavior and tubes of the amphipod interfere with the polychaete. Areas with and without Ampelisca had significantly different numbers of Streblospio.

### Selection Factors:

- Abundance, and importance in soft sediment communities, and as a potential colonizer.
- Importance in detrital based food webs, and as prey for various species.
- Importance to substrate stability, biodeposition, and sorting of sediment.

Sources:

Boesch 1971, 1973 unpubl.

Cory and Dresler unpubl.

Dauer et al. 1979

Dean 1965

Diaz 1977

Grassle and Grassle 1974

Harman unpubl.

Hartman 1945

Holland et al. 1979, 1980

Maurer et al. 1978

Mills 1967

Pfitzenmeyer 1975

Reinharz et al. unpubl.

Virnstein 1977, 1979

*Urosalpinx cinerea* - Oyster drill

Description:

Urosalpinx cinerea is a small snail of the family Muricidae. It is about 1.5 - 2.5 cm long, fusiform in shape, with a moderately high-spired shell crossed by numerous rounded folds. The shell is greyish, brown, or yellowish in color, with a white, brown or purple aperture.

Range:

U. cinerea is found from the Maritime provinces to Florida along the western side of the Atlantic. It has also been introduced to (and occurs locally) on the west coast of North America and Great Britain. In Chesapeake Bay the oyster drill is confined to the highest mesohaline and the polyhaline zone. Urosalpinx occurs from the intertidal zone to deep water, limited chiefly by availability of appropriate substrate and prey. It is found most abundantly on pilings, rocks, reefs, and on shells of oyster beds: numbers may rarely reach 200 individuals or more per square meter, but 2 - 20 is a more typical range.

Urosalpinx spawns in the warmer months, from about May through October in Chesapeake Bay. Sexes are separate in this species, and they have internal fertilization. Sperm from a single copulation can remain viable for extended periods (Stauber 1943). About 5 - 20 eggs are laid at a time, enclosed in characteristic whitish to yellow-brown urn-shaped egg capsules about 5 - 10

mm long. Several egg cases may be deposited at once, on hard substrates. The incubation period varies with water temperature, but ranges from 25 - 45 days or more (Carriker 1955). Small protoconches (about 1 mm high) emerge and begin to feed on small bivalves or barnacles. Sexual maturity is reached in about 15 - 25 months, and individuals may live 10 years or more. Because of the non-planktonic larvae and relatively slow rate of reproduction, drills are slow to recolonize areas from which they have been eliminated (by freshets, for example).

#### Salinity Relationships:

Salinity has a critical influence on the distribution of Urosalpinx. Minimum salinity for survival appears to be near 11‰; and feeding is greatly reduced below 12.5‰ (Manzi 1970). Optimum salinities are about 15 - 35 ‰ (Carriker 1955). Because of the low mobility of this species, the minimum salinity at any particular spot during the year determines Urosalpinx's presence or absence. Thus in nature, relatively stable "drill lines" existed in the main Bay and tributaries: Towles Point on the Rappahannock, Claybank on the York, Brown Shoals on the James, and Tangier Sound on the eastern shore. After tropical storm Agnes, however, the species was eliminated from much of its range (Andrews 1973), and has not yet recovered (Haven pers. comm.). Low salinities at time of egg-laying have the greatest effect on distribution (Haskin 1974).

#### Other Sensitivities:

Temperature also has an effect on the distribution of Urosalpinx. Drills become inactive, and may burrow into the bottom, when water temperatures drop below 8 - 10°C. (There is considerable geographic and individual variation in this response). Oviposition begins at around 15°C; although again, there is considerable variation. There is a synergistic effect of temperature and

salinity observed by several investigators: mortality decreases at low salinities when water temperatures are also low (Stauber 1943, Manzi 1970). This enhances Urosalpinx survival during spring months when runoff is highest, and water temperatures still are low.

Urosalpinx is found chiefly on hard substrates, and oviposition can only take place in such areas.

#### Potential Habitat:

Potential habitat for this species is mapped as areas of former distribution to a depth of 10 m, where suitable substrate exists. The area of present distribution, as well as is known from recent surveys, is also mapped.

#### Trophic Importance:

Urosalpinx cinerea is a carnivorous snail, and preys upon shelled invertebrates, especially small bivalves and barnacles. Shell of the prey is penetrated by mechanical action of the radula, aided by secretions of the accessory gland, and the flesh of the prey rasped out. Urosalpinx in Chesapeake Bay appears to feed primarily on barnacles, oyster spat, and the smaller stages of other bivalves such as Mya, although it has been shown to prey upon other Urosalpinx, mussels, bryozoans, crabs, and carrion.

Urosalpinx represents one of the principle predators of young oysters and spat. In high salinity areas they can cause serious destruction of planted seed, up to 60 - 70% (Galtsoff 1964).

#### Selection Criteria:

- Possible range extension resulting from low flow conditions.

- Importance as a predator of small oysters and planted seed.
- Importance of freshets in establishing upstream limits of distribution.

Sources:

Allen 1958

Andrews 1973

Carriker 1955

Galtsoff 1964

Haven et al. 1975, 1977, 1979

Lippson 1973

Lippson et al. 1979

Manzi 1980

Stauber 1943

*Crassostrea virginica* - American oyster

Description:

Crassostrea virginica is a large epifaunal bivalve mollusk of the family Ostreidae. Adults range from 75 - 150 mm or more in length, irregularly elongate, with a somewhat cupped lower valve cemented to the substrate. The shape and size of this species varies greatly with growing conditions.

Range:

The American oyster ranges from New England through the Gulf Coast states, in both estuarine and marine waters. It is found attached to a variety of hard substrates (pilings, rocks, oyster shell, firm sand, mud, etc.) in the intertidal to subtidal zones; in many areas extensive reefs or beds are formed. In higher salinity water, predators may eliminate subtidal populations. In Chesapeake Bay, Crassostrea virginica is found from the low mesohaline through the polyhaline zone, primarily in shallow water (less than 8 - 10 meters deep). Densities vary, depending on the type of substrate, from 10 - 100 or more individuals per m<sup>2</sup>. Numbers of oysters reaching 1000 or more per m<sup>2</sup> have been recorded in dense intertidal beds along the Gulf coast (Dame 1972).

Oysters spawn during warmer months, when water temperatures are over 15°C. The peak period is typically from mid-July to August (Galtsoff 1964). The exact time of peak spawning and setting can vary from area to area and from year to year, depending on hydro-

graphic conditions. Sperm and eggs are released into the surrounding water, and free-swimming planktonic larvae result. Time to setting of the larvae varies with temperature, and may be as short as 7 - 10 days under optimal conditions. Spat set is highest on clean, sediment-free surfaces, while survival is best in areas with low numbers of predators (such as Urosalpinx, Rhithropanopeus, or Callinectes). Oysters reach harvestable size in 2 - 3 years, and may live 10 years or more.

Crasostrea is limited in higher salinity Chesapeake Bay areas by predators to a certain extent, and by two protozoan parasites, Minchinia nelsoni ("MSX") and Perkinsus marinus ("dermo").

The American oyster is one of the most important and valuable shellfish in Chesapeake Bay and the subject of numerous studies and investigations.

#### Salinity Relationships:

Crassostrea virginica is an euryhaline species, tolerant of a wide range of salinities from ~ 6 - 7‰ to 35‰. Minimum salinity for survival is 5‰ in the laboratory, although it can withstand lower salinities for short time periods (Castagna and Chanley 1973). Survival is normal at 7.5‰ or higher (Loosanoff 1952). Acclimation may play an important role in response to salinity stress. Chaley (1958) found optimum growth of larvae between 12.5 and 25‰. However, reproduction occurs at different salinities depending upon the acclimation of the adult animals: Davis (1958) found eggs spawned at low salinities (7.5 - 10‰) to develop normally, while eggs from adults held at higher salinities had higher development optima. Lower salinities reduce the range of temperature tolerance for development (Davis and Calabrese 1964). Increase of salinity due to low flow may enhance setting and survival in upstream oyster bars (Kranz, pers. comm.), although new predators may be introduced.

### Other Sensitivities:

In its normal estuarine environment, Crassostrea tolerates a wide range of temperatures. Adult oysters can withstand temperatures as low as  $1^{\circ}\text{C}$  and in excess of  $35^{\circ}\text{C}$ . However, below  $6 - 7^{\circ}\text{C}$ , Crassostrea ceases feeding (Galtsoff 1964). Developmental stages have more restrictive requirements. Gametogenesis is initiated at  $15^{\circ}\text{C}$ , and peak spawning occurs above  $20^{\circ}\text{C}$  in Chesapeake Bay. Normal development of eggs and larvae occurs between  $20 - 32^{\circ}\text{C}$ , with fastest growth at higher temperatures (Davis and Calabrese 1964). Low salinities narrow this tolerance range.

Oysters are also sensitive to turbidity and sedimentation. Excessive sediment smothers adult oysters and prevents setting of spat. Deposition of sediment within historic times has shifted the upstream limit of oyster distribution downstream several miles (Alford 1968). Areas of good circulation, therefore, are best for oyster setting and survival. Low flow conditions may reduce sediment runoff and deposition in some areas.

Oyster larvae have been shown to utilize the upstream flow of higher salinity water at depth to maintain themselves within the estuary, and to reach upstream oyster beds (Hargis and Wood 1971). In addition, shear zones at frontal areas may be sites of accumulation (and recruitment) of bivalve larvae (Hartwell and Savage 1980). Circulation changes brought about by low flow may reduce the impact of these mechanisms, possibly affecting recruitment.

Like most benthic species, oysters are limited in depth by dissolved oxygen concentrations. In the Chesapeake, most oysters are found in less than 10 meters depth, where circulation is good, distribution may extend to much greater depths (Merrill and Boss 1966).

A major factor affecting density and abundance of oysters in Chesapeake Bay are predation and disease (actually, protozoan parasites). Minchinia nelsoni ("MSX") was introduced to the Bay in the late 1950's - early 1960's, and caused extensive mortality

in higher salinity areas. This sporozoan is most important in salinities over 14 - 15‰, and remains a major limit to oysters in these waters. Perkinsus marinus (formerly Dermocystidium or "dermo") occurs into lower salinities than MSX, and is infective during warmer months (when salinities tend to be high). Kranz (pers. comm.) has found active "dermo" infections in oysters at 10 - 11‰. Several major predators, in particular the drills Urosalpinx and Eupleura, are also restricted to higher salinities.

#### Potential Habitat:

Potential habitat for this species is based both on known areas of distribution (oyster ground surveys) and general restrictions of 10 meter depth.

#### Trophic Importance:

Crassostrea virginica is an epibenthic suspension feeder, ingesting algae, bacteria, and small detrital particles. The majority of particles ingested are in the 1 - 12  $\mu$  range, with 1 - 3  $\mu$  the largest single size fraction (Haven and Morales - Alamo 1970); this is in the range of nanoplankton and bacteria. An oyster weighing one gram (dry weight) will pump and clear approximately 6 liters per hour, although rate depends on temperature. Particles filtered but not ingested are eliminated as pseudofeces. Fecal and pseudofecal material is important in sediment production and deposition, provides sites for remineralizing bacteria action, and represents a source of food for deposit feeders. In warmer months, an oyster may deposit 1.5 grams or more of feces and pseudofeces per week (Haven and Morales - Alamo 1967).

Oysters are a major commercial species in Chesapeake Bay, and although harvests are reduced compared to historical levels, they still represent a significant economic contribution. Transportation of seed from areas of good recruitment to areas where growth is good and loss to predation and disease reduced is widely

practiced, and in recent years the use of hatchery-produced spat has increased. In the future, oyster culture and harvest will probably become even more managed, with less reliance on natural recruitment.

#### Selection Factors:

- Sensitivity to circulation freshets, stratification, and sedimentation, all of which could be altered by low flow scenarios.
- Effects of higher-salinity disease and predation.
- Commercial importance.

#### Sources:

Alford 1968	Larsen 1974
Andrews 1967	Lippson 1973
Castagna and Chanley 1972	Lippson <u>et al.</u> 1979
Chanley 1958	Loosanoff 1952
Dame 1972	Merrill and Boss 1966
Davis 1958	Yates 1913
Davis & Calabrese 1964	
Galtsoff 1964	
Hargis and Wood 1971	
Hartwell and Savage 1980	
Haven & Morales-Alamo 1967, 1970	
Haven <u>et al.</u> 1977, 1978, 1979	

*Macoma balthica* - Baltic macoma

Description:

*Macoma balthica* is a small clam of the family Tellinidae. It is usually less than 3.0 cm in length, with a thin oval shell of white or pinkish exterior and rose-red interior.

Range:

This species is circumboreal in distribution, and is found from the arctic to approximately Georgia on the west coast of the Atlantic. M. balthica is most abundant in estuaries, sheltered bays, and similar brackish environments, and may be replaced in higher salinity areas by the congeneric M. tenta (south of Cape Cod). M. balthica is one of the major mollusks in Chesapeake Bay, and may reach densities of 2000 individuals per m<sup>2</sup> or more although numbers an order of magnitude smaller are more usual. It lives as an infaunal species in muddy sands and softer substrate, and feeds upon detritus. M. balthica exhibits two periods of recruitment each year, corresponding to April - mid June and August - November spawning seasons, a pattern typical of species of boreal affinities.

This species is long-lived and in cold waters may live 10 years or more. Longevity in the Bay is probably half that.

### Salinity Relationships:

Macoma balthica can tolerate salinities from 2.5‰ to full oceanic values in the laboratory; however, in nature it is most abundant below 25‰ (Castagna and Chanley 1973). In Chesapeake Bay, M. balthica is generally found below 18-19‰. Its distribution may be mediated by competition with M. tenta (Boesch 1971).

### Other Sensitivities:

M. balthica appears relatively tolerant of sediment type, being found from mud to fine sand, although most abundant in softer substrates. Spawning periods are mediated by water temperature; in Chesapeake Bay the period of spawning corresponds to water temperatures between 15 - 22°C. Like all Chesapeake Bay benthic species, M. balthica is sensitive to the typical summer hypoxia in deep waters, and for this reason is generally found in less than 12 - 15 meters depth. However, in areas with good circulation and high dissolved oxygen, it may be found at greater depths.

### Potential Habitat:

This species' potential habitat is defined as areas less than 19‰ salinity and less than 12.5 meters deep. Mapping is for fall distribution, after the autumnal recruitment period.

### Trophic Importance:

Macoma balthica is an infaunal deposit feeder, ingesting material through use of its long active incurrent siphon. It also ingests a certain percentage of suspended material near the sediment-water interface. Productivity of M. balthica is usually highest where bacterial productivity on detrital particles is also high (Tunnicliffe and Pesk 1977).

Because of its abundance, M. balthica is an important source of food for demersal fish, crabs, and waterfowl (Homer and Boynton 1978,

Holland et al. 1979). Perry and Uhler (1976) found that M. balthica now represents about 95% of the food of canvasback ducks, probably due to the great reduction in submerged aquatic vegetation in recent years. The great differences in density of M. balthica between caged and uncaged bottom areas ( $31,000 \text{ m}^{-2}$  vs.  $733.6 \text{ m}^{-2}$  in July) shows the effects of predation on this important species.

#### Selection Factors:

- Trophic importance as source of food for variety of organisms.
- Potential reduction of range due to increased salinity downstream.

#### Sources:

Boesch 1971, unpubl.  
Castoagna and Chanley 1973  
Cory and Dresler, unpubl.  
Davies 1972  
Diaz 1977  
Ecological Analysts 1974  
Harman unpubl.  
Holland et al. 1979, 1980  
Homer and Boynton 1978  
Johns Hopkins U. 1972  
Kaufman et al. unpubl.  
Lippson et al. 1979  
Lippson, R.L., unpubl.  
McErlean 1964  
Perry and Uhler 1976  
Pfitzenmeyer 1961, 1970, 1975  
Reinnarz et al. unpubl.  
Tunncliffe and Risk 1976

*Mercenaria mercenaria* - Hard clam, Quahog

Description:

Mercenaria mercenaria is a large bivalve of the family Veneridae. It is about 10 cm or less in length, with oval somewhat arched valves, strong umbones, short siphons, and a wedge-shaped foot. The shell is grey, white, or cream exteriorly, with a white interior and rich purple markings near the posterior and ventral margins.

Range:

The hard clam is abundant near shore from the Gulf of St. Lawrence to the Gulf of Mexico, and in European waters. In Chesapeake Bay it is found in the lower Bay, from the upper mesohaline through the polyhaline zones. Although found in a wide variety of sediment types, Mercenaria is most abundant in firm substrates.

Mercenaria spawns when water temperatures reach 22 - 24°C, and larvae set in the summer months. The species is long-lived, and recruitment to some populations (especially those existing near the lower limits of salinity tolerance) may be infrequent.

Salinity Relationships:

M. mercenaria is a euryhaline marine species and is limited by salinity. Adult clams cannot survive salinities much below 12-12.5‰,

and growth of juveniles ceases below 17.5‰ (Castagna and Chanley 1973). Larvae fail to metamorphose below 17.5‰, and the range of salinity for normal egg development was 20 - 35‰ (Davis 1958).

#### Other Sensitivities:

Wells (1957) found that the abundance of hard clams was correlated with substrate, and that sediment preference followed this order: shell, sand, sand/mud, mud. Abundance in shell may be related to larval setting behavior, as the larvae prefer to attach their byssus to a firm substrate lightly covered by sediment.

Temperature also affects this species. The minimum temperature necessary for spawning (22 - 24°C) may limit Mercenaria in the northern part of its range. Davis and Calabrese (1964) found the optimum temperature for growth of clam larvae was 25 - 30°C.

Freshets occurring during spawning periods could affect larvae both through direct salinity stress and by flushing them from the estuary.

#### Potential Habitat:

Potential habitat for this species is defined as areas in greater than 12‰ salinity, in depths between 1 - 10 meters. Highest abundance is in sand and muddy sand. The species is mapped in its summer distribution pattern.

#### Trophic Importance:

Mercenaria mercenaria is a shallow-burrowing infaunal suspension feeder, ingesting detritus and phytoplankton. In turn, it is food for a number of fish, crabs, and waterfowl, although the large size and solid shell of the fully adult clam afford it a measure of protection. Gulls and rays feed upon the adult clams, the former

dropping them from height to crack the shell; the latter relying on their powerful dental pavement to crush the clam (Hibbert 1977, Orth 1975). Juveniles and newly set spat are preyed upon by crabs, demersal fish, and waterfowl.

The hard clam is also a commercially important species, although harvests in the Bay are limited by irregular recruitment (itself due to low salinities). Areas which support harvests include the lower York River, Tangier and Pocomoke Sounds. Transfer of young clams from areas of good recruitment (or from hatcheries) to regions suitable for growth has potential to increase the fishery. Higher salinities resulting from low flow might produce a larger and more stable population of M. mercenaria in the Bay, although increase of certain predators such as Busycon could also result.

#### Selection Factors:

- Distribution limited upestuary by salinity and potential for range increase due to low flow.
- Narrow salinity tolerance of larvae, and sensitivity to freshets.
- Commercial importance, and potential for fishery increase.

#### Sources:

Allen 1954  
Boesch et al. 1973  
Castagna and Chanley 1973  
Davis 1958  
Davis and Calabrese 1964  
Haven et al. 1975, 1977, 1979

Hibbert 1977  
Lippson 1973  
Orth 1975  
Pfitzenmeyer 1961  
Wells 1957

*Mulinia lateralis* - Coot clam

Description:

Mulinia lateralis is a small clam of the family Mactridae. It is approximately 2.0 cm in length, wedge-shaped, with arched valves, white in color.

Range:

Mulinia lateralis is found nearshore in estuaries, bays, and shallow areas from Canada to the eastern Gulf of Mexico. In Chesapeake Bay it is most abundant in shallow, nearshore environments in the upper mesohaline and polyhaline zones, in a variety of sediment types. Abundance of Mulinia varies greatly from year to year and place to place; it is a fugitive, eruptive species with an opportunistic life history. Densities may reach 5000 m<sup>-2</sup> or more, but 200-600 individuals per m<sup>2</sup> are far more common. Typical of opportunistic forms, it is short-lived, usually less than one year, and there may be 2 - 3 generations a year in Chesapeake Bay (Boesch et al. 1973). M. lateralis grows quickly, and can reach 13 mm length and be sexually mature in two months or less from setting (Virnstein 1979). Predation plays an extremely important role in the distribution and abundance of this species (Virnstein 1977).

Mulinia recruitment is at a maximum in late fall and early spring, and the species typically suffers heavy summer mortalities due to predation, turbidity, anoxia, or competition. M. lateralis begins

spawning in spring when temperatures reach 15°C, usually mid-May, and continues until mid-November in Chesapeake Bay.

#### Salinity Relationships:

In the laboratory, M. lateralis can survive salinities down to 2.5‰, but 100% survival of adults occurs only above 10‰ (Castagna and Chanley 1973). It tolerates full oceanic salinities as well. In nature, the species is not found below about 10‰. This probably reflects the greater salinity sensitivity of the embryos and larvae: Calabrese (1969) found optimum salinity for embryos to be 20 - 27.5‰, and for larvae, 20 - 30‰, with no development occurring below 15‰. Spawning cannot occur below 7.5‰ (Castagna and Chanley 1973).

During the mid-1960's drought, M. lateralis extended its range up estuary to the mouth of Romney Creek.

#### Other Sensitivities:

M. lateralis occurs in a wide variety of sediment types, but is somewhat more abundant in muddy sand and mud. Like many infaunal benthic species in Chesapeake Bay, it can be limited by summer anoxia in deep water. In addition, high turbidity near the sediment/water interface can be limiting to this suspension feeder (Boesch et al. 1976).

Temperature affects M. lateralis primarily through its effect on spawning and development. The LC<sub>50</sub> for temperature for adult Mulinia is approximately 30 - 33°C, which can be approached in nearshore areas in summer. The optimum temperature range for embryos is 15 - 20°C, and for larvae, 20 - 30°C (Calabrese 1969).

### Potential Habitats:

Potential habitat for this species is defined as areas in greater than 10‰ salinity, depths less than 12.5 meters. Mapping is done for late fall and winter, a period of maximum distribution due to higher salinities and fall recruitment.

### Trophic Importance:

M. lateralis is an infaunal suspension feeder, ingesting fine particles, bacteria, phytoplankton, and microzooplankton near the sediment/water interface. The major importance of Mulinia is as prey for numerous species of fish, crabs, and waterfowl. Virnstein (1977, 1979) found both spot and crabs to feed on Mulinia, and to have severe effects on density; numbers in exclosures may reach 8000 m<sup>-2</sup> or more, versus trace populations in cages subject to crab predation. Heavy predation on this species in warmer months may reduce summer populations to small reservoirs in shallow nearshore areas (Wass et al. 1972).

### Selection Factors:

- Trophic importance for demersal fish and crabs, as well as productivity and turn-over time.
- Potential for range extension up estuary if salinities increase due to low flow.
- Sensitivity to turbidity and anoxia, both affected by flow regimes.

### Sources:

Boesch 1971, 1973 unpubl.  
Boesch et al. 1973, 1976  
Calabrese 1969  
Castagna and Chanley 1973  
Cory and Dresler unpubl.

Holland et al. 1979, 1980  
Lippson, R.L. unpubl.  
Pfitzenmeyer 1970, 1975  
Reinharz et al. unpubl.  
Virnstein 1977, 1979

Sources (cont.)

Diaz 1977

Harman, unpubl.

Wass et al. 1972

*Mya arenaria* - Soft clam

Description:

Mya arenaria, the soft-shell clam or mannose, is a relatively large bivalve, belonging to the family Myacidae. It is a relatively elongate oval form, with gaping valves, large fused siphons, the shell dull white in color. Adult Mya inhabit permanent burrows in shallow water.

Range:

M. arenaria is found from Labrador to approximately Cape Hatteras on the east coast of North America and also is found in European waters. In northern latitudes it is more often found in areas at or near full oceanic salinities, whereas at the southern part of its range it is primarily an estuarine inhabitat (Pfitzenmeyer 1965). In Chesapeake Bay, Mya is found in shallow intertidal and subtidal areas in a variety of substrates, from the oligohaline through the polyhaline zones. Abundance varies widely: numbers may reach  $1000\text{ m}^{-2}$  or more, but generally are less than 200 per  $\text{m}^2$ . M. arenaria is commercially harvested in Chesapeake Bay, often by use of the hydraulic escalator dredge which can reach the subtidal populations.

Mya exhibits the bimodal spawning pattern typical of mean boreal species in Chesapeake Bay. Spawning starts in May and continues through June, ceases during the warmest months, resumes in late August and continues until November. Recruitment (setting) occurs in both late spring and fall, but the spring recruitment is often unsuccessful. This is probably due to predation on the young clams,

particularly by blue crabs. Mya arenaria is a long-lived species, and may reach 10 years or more in age. Recruitment into many populations may occur at widely-spaced intervals (Haven 1976).

#### Salinity Relationships:

In the laboratory, M. arenaria has been able to survive salinities as low as 2.5 ‰ indefinitely. In nature, however, it is generally found above 3 - 3.5 ‰, and not numerous until salinities are above 5 ‰. Greatest abundance occurs in water over 8 ‰, which may reflect the observed minimum for larval survival, 8 ‰ (Castagna and Chanley 1973). It occurs in Eastern shore bays at salinities of 35 ‰ or so, but not at high densities.

M. arenaria is also sensitive to freshets which not only can kill adult clams up estuary, but can eliminate larvae from tributaries by flushing or by salinity stress. After Tropical Storm Agnes, soft clams were eliminated over much of the Bay. A successful spawning in fall restored numbers to a great extent baywide.

#### Other Sensitivities:

Mya is tolerant of a wide variety of substrates from sand to mud and peat, but unstable substrates support lowest densities. Adult Mya live in permanent burrows, and are slow reburrowers, thus vulnerable to sediment disturbance by waves, currents, or bioturbation. They are also quite susceptible to anoxia in deeper regions in summer; young clams may recruit into deep water in spring, but suffer high mortalities during warm months (Boesch, unpubl.). Adult clams are thus most abundant in stable substrates less than 6 - 10 meters depth. Because of the low tidal amplitude in Chesapeake Bay, most of these are subtidal.

Temperature also affects Mya arenaria: spawning occurs mostly between 15 and 22°C; unspawned gametes are resorbed in warmer waters,

and the clam's gonads are inactive until temperatures drop in early fall (Pfitzenmeyer 1962, 1965). The lethal temperature for Mya arenaria is 32.5°C (adults), which can limit intertidal distribution in the southern part of the species range (Kennedy and Mihursky 1971).

#### Potential Habitat:

Potential habitat for this species is defined as areas greater than 3.5‰ and shallower than 10 meters. The species distribution is mapped in spring.

#### Trophic Importance:

Mya arenaria is an infaunal suspension feeder, ingesting small detrital particles, phytoplankton, bacteria, and microzooplankton through its long extensible siphon. Adult clams burrow deeply, while juveniles live closer to the surface and are more vulnerable to predation (Virnstein 1979).

Mya represents a major prey organism for numerous fish, crabs, and waterfowl when it is abundant. It is a favored prey of the blue crab (and green crab, Carcinus maenas, in northern waters) and these organisms are major factors controlling Mya's abundance. Set of spat into predator exclusion cages can be exceedingly heavy: Virnstein (1979) counted in excess of 65,000 per m<sup>2</sup>, while areas outside the enclosure had only trace populations.

Commercial harvesting can also reduce populations, both through direct harvest and by disruption of sediment and removal of sub-adult from their burrows (making them vulnerable to predation during the relatively long reburrowing process).

### Selection Factors:

- Trophic importance to fish and crabs.
- Commercial importance of species.
- Potential upstream expansion of range under low flow conditions, due to salinity increase, and reduction of freshets and turbidity.

### Sources:

Boesch 1973, unpubl.  
Castagna and Chanley 1973  
Cory and Dresler unpubl.  
Diaz 1977  
Ecological Analysts 1974  
Harman unpubl.  
Haven 1976  
Holland et al. 1979, 1980  
Kaufman et al. unpubl.  
Kennedy and Mihursky 1971  
Lippson, R.L. unpubl.  
Pfitzenmeyer 1961, 1962, 1965, 1970, 1975  
Virnstein 1979

*Rangia cuneata* - Brackish-Water Clam

Description:

Rangia cuneata is a medium-sized clam of the family Mactridae. It is about 3.5 cm (maximum 7.0 cm) in length, wedge-shaped, with arched valves, white in color with a dark periostracum. Rangia is not native to Chesapeake Bay, but was introduced there around 1960.

Range:

R. cuneata was found from New Jersey to Mexico during the Pleistocene, but in the Recent period was restricted to the Gulf coast. However, it has extended its distribution within the last 25 years to include east coast waters from Florida to Delaware Bay (Hopkins and Andrews 1970, Maurer et al. 1974), essentially reoccupying its old range. The clam was probably carried in seed oysters from the Gulf of Mexico to the east coast. In Chesapeake Bay, Rangia was first discovered in 1960 in the James River, and by 1968 was found in the upper Bay (Gallagher and Wells 1969). It is restricted to the tidal freshwater, oligohaline, and low mesohaline zones of the Bay mainstem and most tributaries, except the York River. Populations are variable in numbers and range, due both to year-to-year differences in recruitment and to winter mortalities caused by low temperatures and ice scour. Densities may reach 5000 clams or more per m<sup>2</sup> in favorable areas, but numbers an order of magnitude smaller are more typical.

Rangia may spawn in early summer (a minor peak), but the major period of reproduction begins in autumn and continues to early winter (Cain 1975). Spawning is highly correlated to ambient salinity and temperature, and ripe clams need certain salinity stimuli to initiate spawning. The fall and winter recruitment of larvae is usually most successful. R. cuneata is long-lived (up to 10 years), and reaches sexual maturity at about one year of age (Cain 1975). Because of the spawning requirements and salinity sensitivity of the larvae, recruitment to some areas may be sporadic, and the Rangia population consist entirely of individuals of one or two year classes.

#### Salinity Relationships:

Rangia cuneata is an estuarine endemic, extremely eurytopic as to salinity as an adult. In the laboratory, Rangia could survive freshwater, and after acclimation, 30‰ indefinitely. In nature, however, adult clams are found mostly below 10‰, extending nearly to (or into) tidal freshwater.

The explanation for this range restriction appears due to the reproductive physiology of the organism. Ripe Rangia require some stimulus of salinity or temperature change to induce release of gametes. Cain (1975) found that a change in salinity up from 0‰ or down from 10‰ or 15‰ to be necessary, with a change from near 0‰ to 5‰ best. Early larvae require salinities from 2 - 10‰ to develop, although older larvae are more tolerant, surviving up to 20‰ (Hopkins et al. 1973). After setting, salinity per se has little effect on Rangia.

#### Other Sensitivities:

In Chesapeake Bay, R. cuneata is near the northern limit of its range. For this reason, temperature can play an important role

in the distribution and survival of the organism. Prolonged temperature at or near  $0^{\circ}\text{C}$  can cause massive mortalities; in addition, clams in the shallowest subtidal regions can be seriously affected by ice scour. The severe winter of 1976-1977 eliminated Rangia from much of its range within Chesapeake Bay, and the species has not yet fully recovered.

Temperature also controls reproduction: gametogenesis occurs between  $10 - 16^{\circ}\text{C}$ , and spawning between  $12 - 22^{\circ}\text{C}$  (however, dependent on salinity stimulus). Larval survival is best at  $24^{\circ}\text{C}$ , and growth slows or stops below  $16^{\circ}\text{C}$  (Cain 1975).

Rangia cuneata is found in a variety of substrates from fine sand to mud. Several investigators have found specimens in sand to have better survival and growth than individuals in mud (Tenore et al. 1968, Peddicord 1977). This may be due to higher suspended solids in waters immediately over mud sediments, which reduces pumping rate and increases pseudofeces production (Peddicord 1977).

Depth per se does not affect Rangia but summer anoxia below 10 meters (particularly in the turbid oligohaline transition region) limits its distribution. Ice scouring and winter cold impacts populations in very shallow water, and most clams are found in 1 meter depth or more.

#### Potential Habitat:

Potential habitat for this species is defined as areas less than  $10\text{‰}$  to about  $0.1\text{‰}$  salinity, between 1 and 10 meters depth. The species is mapped in summer, the time spawning is initiated.

#### Trophic Importance:

Rangia is an infaunal suspension feeder, ingesting detritus, phytoplankton, and bacteria. It has also been shown to take up amino acids from the ambient medium (Hopkins et al. 1973).

This species is of particular interest because it is a new addition to the Bay fauna, and occurs in the oligohaline zone where benthic faunal diversity is lowest (Diaz 1977). Its biomass and wide distribution indicate that it might represent a new food source for fish, crabs, and waterfowl. Waterfowl have been shown to utilize the smaller sized clams, although the larger individuals are difficult to crack to extract meat (Perry and Uhler 1976). Mammals also use this clam as food; raccoons have been observed digging the clams at low tide in shallow water, and opening them with their teeth. In all, Hopkins (1973) lists 20 or more species which feed on Rangia throughout its range; many of these are important in Chesapeake Bay.

Rangia also has commercial importance, not yet exploited in Chesapeake Bay. On the Gulf Coast its shells are used for road material (hence its common name, Southern Road Clam), and the meats packed and sold for food. Many people harvest this species in a non-commercial basis, but the small size of Rangia in the Bay region reduces its potential as a commercial species.

#### Selection Factors:

- Sensitivity of reproductive cycle to salinity changes, and restricted tolerance of larvae.
- Trophic importance, and biomass dominance in many oligohaline areas.
- Potential decrease of range due to low flow.
- Potential commercial importance.

#### Sources:

Boesch 1972

Cain 1975

Castagna and Chanley 1973

Hopkins and Andrews 1970

Hopkins et al. 1973

Johns Hopkins U. 1972

Sources (cont.):

Cory and Dresler, unpubl.

Davies 1972

Diaz 1977

Ecological Analysts 1974

Gallagher and Wells 1969

Harman, unpubl.

Holland et al. 1979, 1980

Lippson, 1973

Lippson et al. 1979

Maurer et al. 1979

Peddicord 1977

Perry and Uhler 1976

Pfitzenmeyer 1968, 1970, 1975

Tenore et al. 1968

*Ampelisca abdita* - Amphipod

Description:

Ampelisca abdita is a burrowing amphipod of the family Ampeliscidae. The body is of generally typical amphipod shape, about 5 - 8 mm in length, with females somewhat smaller. The antennae and peraeopods are modified for feeding. This is a fairly recently described species (Mills 1964), and in many earlier collections it was confused with its sibling species A. vadorum or other congeners.

Range:

A. abdita is found from the boreal region of Maine at least to the western Gulf coast, excepting southern Florida. In Chesapeake Bay, it is found in the high mesohaline through the polyhaline zones. Densities typically are less than 2000 per square meter, but accumulations of 30,000/m<sup>2</sup> or more have been recorded. Mills (1967) characterizes this species as successful in crowded conditions because it grows rapidly, and breeds early.

Ampelisca abdita inhabits a tube for the greater portion of its life, save for a brief free-swimming period during reproduction. The tube is constructed of fine sand grains glued together with a secretion from the first two pairs of pereopods, which hardens to a parchment-like material. The tube is about 3 - 4 cm long,

flattened laterally, and rather flexible.

Reproduction is linked to water temperature, and 8 - 10°C seems to be the initiating temperature. Overwintering animals reaching sexual maturity in spring leave their tubes and swim about, particularly at times of spring tides and full moon. Mature males grasp mature females and carry them about; the female then molts and copulation occurs. Mature males die soon after mating, but females return to the substrate to brood their eggs. Females produce only one brood in their lifetime. Young animals disperse and build small tubes. They grow rapidly, building larger and larger tubes, and reach sexual maturity by mid-summer. Their offspring overwinter, growing more slowly, and breed the following spring.

#### Salinity Relationships:

There are apparently no laboratory studies delineating the exact physiological salinity tolerances of A. abdita. However, field collections in Chesapeake Bay indicate that the species is confined generally to areas above 12‰ (e.g. Boesch 1971, unpubl., Wass 1972).

#### Other Sensitivities:

Temperature affects A. abdita in regard to both growth rate and reproduction. As previously mentioned, 10°C appears to be the initiating temperature for reproduction. South of Cape Hatteras, where winter temperatures remain high, breeding occurs throughout the year (Mills 1967). Growth, however, can occur in temperatures as low as 3 - 4°C. Thus overwintering individuals may attain much greater size than summer broods.

The distribution of A. abdita is influenced by sediment type. In general, it is most numerous in fine sediments, including fine

sand, silts, and clays. It's sibling species, A. vadorum, is considerably larger and better adapted to coarse substrates (Mills 1967, Watling and Maurer 1972). The two species may occur together, but generally densities are then low, suggesting competition (Mills 1967).

A. abdita has been recorded from the intertidal to depth, in Chesapeake Bay; however, it appears to occur primarily subtidally. This probably reflects sediment preferences. Feeley and Wass (1967) record it as the most numerous ampeliscid in lower Chesapeake Bay. It occurs seasonally in submerged aquatic vegetation beds, primarily during reproductive periods (Marsh 1970, Orth 1973).

#### Potential Habitat:

Potential habitat for this species is defined as areas above 12‰ salinity, from 3 - 15 m in depth, most abundant in muddy sands, sandy mud, and mud.

#### Trophic Importance:

A. abdita is considered a suspension feeder, ingesting suspended detritus, algae, and algae attached to sand grains, although it also resuspends sediment from the bottom, and thus ingests deposited material. The animal feeds at the top of its tube, ventral surface uppermost. The pleopods and second antennae beat and whirl rapidly, setting up feeding currents over the mouth parts.

A. abdita is in turn fed upon by various birds, fish, and other predators. It is sometimes extremely dense, and its tubes constitute a major feature of its habitat. The tubes not only help bind the substrate, they provide shelter and attachment for numerous other species. Mills (1967) noted that fine sediments accumulated around the tubes, providing food for deposit feeding

species. In addition, the animal's activity keeps the sediment oxygenated to the depth of the tube. Chlorophyll values were also about two times greater than in a nearby tubeless area (Mills 1967).

Selection Factors:

- Potential for range increase under low flow conditions.
- Abundance, and importance in binding soft sediments, providing shelter for other species, and oxygenation of substrate.

Sources:

Boesch 1971, 1972, 1973, 1977, unpubl.

Bousfield 1972

Diaz 1977

Feeley 1967

Marsh 1970

Mills 1964, 1967

Orth 1973

Reinharz et al. unpubl.

Watling and Maurer 1972

Wass et al. 1972

*Balanus improvisus* - Acorn barnacle

Description:

Balanus improvisus is a small barnacle of the family Balanidae. It is about 0.5 to 1.5 cm in diameter; its shell a low cone formed of six overlapping somewhat triangular plates, and the shell orifice closed by four triangular opercular valve plates.

Range:

Balanus improvisus is common in the low intertidal and subtidal zones, primarily in lower salinity water, in temperate and subtropical areas worldwide. In Chesapeake Bay it is most abundant in the oligohaline and low mesohaline areas, but can occur into the polyhaline zone. Densities can reach 50,000 individuals per m<sup>2</sup> or more under favorable conditions.

Acorn barnacles exhibit two periods of setting in many Chesapeake Bay areas. Calder and Brehmer (1967) found a heavy set at Hampton Roads in May, with another recruitment in October. However, Branscomb (1976) reports only a spring set in 1972, the year of Tropical Storm Agnes.

Barnacles are hermaphroditic, but cross-fertilization is the rule. B. improvisus spawns in spring and fall in Chesapeake Bay. The eggs are brooded in the mantle cavity, and the larvae released as nauplii which have a characteristic horned, triangular cara-

pace. The nauplii metamorphose into the bivalve cyprid larvae, which seek out and attach themselves to hard substrates by a short stalk. Further metamorphosis occurs, to produce the typical adult shape. Barnacles reach adult size in approximately four to six months, depending on water temperature, availability of food, and crowding effects. There is often heavy mortality due to predation, spatial competition, and in winter, effects of cold and dessication (Branscomb 1976).

Barnacles are principle fouling organisms in marine areas. B. improvisus, one of the dominant species in Chesapeake Bay, is important in bio-fouling of ships, pilings and other structures, water intake and condensor tubes, as well as oyster beds. For this reason, considerable effort has been devoted to study and control of barnacles and other fouling species.

#### Salinity Relationships:

B. improvisus is a relatively eurytopic species in respect to salinity. It occurs in nature in salinities as low as 2‰, and up to 20 to 24‰ (Gordon 1969). Turpaeva and Simkina (1961) found optimum growth of this species in the Black Sea occurred at 5 to 11‰, which corresponds generally to its major abundance in Chesapeake Bay. It is able to withstand lower salinities for short periods, as Larsen (1974) reported it year round at a station where salinities dropped in spring to 0.7‰.

B. improvisus is, however, seriously impacted by predators — some of which are limited to higher salinities. The flatworm Stylochus ellipticus is a major cause of summer barnacle mortality (Branscomb 1976); it is rarely found below 9 - 10‰ in nature (Larsen 1974). In the laboratory, Landers and Rhodes (1970) found Stylochus to be able to survive and feed at salinities of 5‰ or above, so the apparent salinity limit of its realized range may reflect reproductive stress.

#### Other Sensitivities:

B. improvisus are sensitive to low winter temperatures, particularly when in conjunction with high winds. The combination of these two factors accounts for a major part of intertidal barnacle mortality in Chesapeake Bay (Branscomb 1976). Recolonization of the intertidal apparently results from surviving subtidal populations.

In addition to predators such as Stylochus, Urosalpinx, and crabs, barnacles are affected by competition for space. The bryozoan Victorella pavidia is a major spatial competitor, smothering the barnacles (Branscomb 1976).

Balanus is restricted to hard substrates, and occurs on rocks, pilings, bivalve and crustacean shells, and so forth. Anoxia in summer may reduce or eliminate individuals in depths greater than 10 m, although the species can be found to 15 m or so.

#### Potential Habitat:

Potential habitat for this species is defined as areas between 2 - 24‰, to 15 m, when hard substrate exists. Over 10‰, the species is reduced by predation.

#### Trophic Importance:

B. improvisus is an epibenthic suspension feeder, and ingests bacteria detritus, algae, and small zooplankters. They are capable of selective feeding, and show a preference for animal food (Kuznetson 1972, 1979). They may also ingest the larvae of invertebrates, including barnacle nauplii.

Barnacle nauplii may constitute a significant portion of the zooplankton at some times of the year or in certain areas (Herman

et al. 1968). At such times they can become a source of food for planktivorous fish, larvae, and suspension feeding invertebrates.

Selection Criteria:

- Sensitivity to predation, in higher salinities.
- Biomass and economic importance as a fouling organism.

Sources:

Branscomb 1976  
Calder and Brehmer 1967  
Diaz 1977  
Gordon 1969  
Harman unpubl.  
Herman et al. 1968  
Kuznetsova 1972, 1979  
Landers and Rhodes 1970  
Larsen 1974  
Lippson et al. 1979  
Lippson, R.L. unpubl.  
Turpaeva and Simkina 1961

*Callinectes sapidus* - Blue crab

Description:

Callinectes sapidus is a swimming crab of the family Portunidae. Adult crabs are 120 mm or larger across the body (point to point), and have the last pair of walking legs expanded and flattened for use in swimming. Males ("jimmies") are typically larger than females, have larger claws, and a T-shaped abdominal apron, while that of the mature female ("sook") is broadly rounded. The general body color is bluish green or brownish-green, with a white underside, bright blue markings on the first pair of legs, and in the female, red tips on the claws. This is one of the most important commercial and recreational species in Chesapeake Bay.

Range:

Blue crabs are found inshore from New England to Mexico, and have recently colonized the Mediterranean Sea (probably transported in water ballast). In Chesapeake Bay, they are found from freshwater to the Bay mouth, but there are distinct differences in the ranges of males and females. In summer, adult males range from freshwater into the polyhaline zone, with maximum concentrations from about 3‰ to 15‰. Females are found in maximum numbers from 10‰ to the Bay mouth, reflecting their orientation to the high salinity spawning areas. Where the two sexes overlap in abundance delineates the major areas of mating, which in the mainstem occupies Tangier Sound and the lower portion of the

Maryland Bay. Mating occurs in summer, and is at a peak in August and early September. A male locates a suitable mate, "cradle-carries" her until she molts, and then mates while she is in the soft crab stage. After her shell hardens, she is released and begins her migration to the spawning grounds at the Bay mouth. Eggs may be laid in late summer, or the sperm stored and used in the next year. Sponge crabs (females carrying eggs) are first seen in late May. Zoea are released in water over 25‰ salinity in the lower Bay or on the shelf, usually nearshore. The zoea tend to be carried out of the Bay in surface waters. After metamorphosis to megalops, the young crab settles towards the bottom, and can be transported back into the Bay by bottom currents.

Newly metamorphosed true crabs begin their up-Bay migration in about August, which (interrupted by winter) can continue until the next spring. Adult size is reached one to one and a half years after hatching.

In colder months, the crabs leave the shallow inshore areas, and seek depths greater than 10 - 15 meters. There they bury in the sediments to overwinter in a state of semihibernation. Most of the females are, by that time, in the lower Bay; this concentration of overwintering females supports a winter dredge fishery in Virginia.

#### Salinity Relationships:

Physiologically, adult crabs can tolerate salinities from fresh-water to oceanic levels (Tagatz 1971). The observed differences in range of males and females reflects for the most part life history and breeding requirements. This spatial separation of the sexes apparently occurs at an early stage (Miller et al. 1975).

The spawning and development stages are, however, restricted by salinity. Spawning success is greatest and zoeal survival best at salinities between 23 - 30‰. If salinities are below about 18‰, eggs hatch in the abnormal "prezoea" stage, which dies. Optimal salinity range for development is about 21 - 28‰. The megalops is somewhat more tolerant of salinity, although the optimum range is between 20 - 35‰ at 20 - 25°C (Costlow 1967). Higher salinities and lower temperatures delay metamorphosis to the crab stage, which has implications for the offshore transport of megalops between estuaries.

#### Other Sensitivities:

Blue crabs are affected by temperature, both as adults and as larvae. The range of temperature necessary for hatching is 19 - 29°C. Temperatures above 20°C produce the most rapid development of the megalops; below this, development is delayed by a factor of 2 to 4 times.

Adult crabs are more active in warm water, and in fall as temperatures fall below 10°C, they move to deeper water to overwinter. Lower temperatures affects the crabs' ability to osmoregulate, and may prompt this migration (Amende 1974).

Because of the blue crab's life history, maintenance of the species within the estuary depends upon the two-layered circulation pattern typical of Chesapeake Bay. As the megalops metamorphose over the continental shelf, they migrate towards the bottom, and re-enter the Bay in bottom currents. The northward-flowing deep water assists the upestuary migration of the newly developed true crabs, as well. In addition, freshets tend to carry zoea out over the shelf, reducing the chance that the megalops will return into Chesapeake Bay (Van Engel, pers. comm.). Both circulation and freshets will be affected by low flow conditions.

### Potential Habitat:

The species is mapped at two seasons, because of its widely different winter and summer distributions. Potential habitat in summer for males are areas from the head of tide to approximately 15‰, while that of females is from 10‰ to the Bay mouth. Spawning areas are nearshore waters where salinities exceed 25‰. Potential habitat in winter for males are regions deeper than 12.5 meters, over 5‰ salinity to about 20‰; for females it is areas deeper than 30 feet in the lower Bay.

### Trophic Importance:

Callinectes is an active swimming and crawling scavenger and predator. The zoea prey upon zooplankton, and adults are major predators of benthic organisms. Crabs can dig and crack the shells of mollusks such as Macoma, Mulinia, Mya, Rangia and Mercenaria, as well as feeding upon oyster spat and young oysters. They are important predators on numerous polychaete worms, as well, such as Streblospio, Nereis, and Polydora (Virnstein 1977, 1979). Only deep or rapidly burrowing forms can escape this active animal. Callinectes is probably a major factor controlling populations of many benthic invertebrates (Virnstein 1979). Other food includes roots and stems of seaweeds and SAV, including Zostera, smaller crustacea, and fish (Van Engel 1958, Tagatz 1968). Blue crabs are occasionally destructive to newly set oysters or clam.

The blue crab is itself used as food by a large number of species including man. Many fish, such as the striped bass, feed upon young crabs, as do waterfowl and mammals such as raccoons. The species is one of the most important commercial and recreational organisms in Chesapeake Bay. About 50,000,000 pounds are harvested annually by commercial crabbers, and the sports fishery is probably equally large. Thus any effect on this species resulting from low flow would have wide repercussions both environmentally and economically.

### Selection Factors:

- Trophic importance, particularly as a predator on benthic invertebrates.
- Sensitivity of reproduction to salinity, circulation, and freshets.
- Major commercial and recreational importance

### Sources:

Amende 1974  
Costlow 1967  
Graham and Beaven 1942  
Holland et al. 1979, 1980  
Lippson 1973  
Lippson et al. 1979  
Lippson, R.L. 1971, unpubl.  
Miller et al. 1975

Miller et al. 1975  
Pearson 1948  
Sandifer 1973, 1975  
Sandoz and Rogers 1944  
Tagaty 1968, 1971  
Van Engel 1958  
Virnstein 1977, 1979

*Cyathura polita* - Isopod

Description:

Cyathura polita is a moderate sized isopod of the family Anthuridae. It is about 12 - 20 cm in length, with a narrow elongate body, the first pair of legs subchelate and are modified for grasping, the other six pairs similar and used for walking and burrowing. Color varies with substrate, but is typically greyish-brown.

Range:

C. polita is found along the Atlantic and Gulf coasts, chiefly in estuarine waters, from Maine to Louisiana. In Chesapeake Bay it is found from oligohaline to mid-mesohaline areas, although in other parts of its range it has been found under hypersaline conditions (Burbanck 1967). The species builds tubes in stable substrates. Numbers may reach 1000/m<sup>2</sup> or more under favorable conditions, although less than 500/m<sup>2</sup> is a more typical density.

C. polita broods its young in a marsupium, and fertilization is internal. Gravid females are found only in warmer months in the northern part of the species' range, while reproduction is year-round in subtropical areas (Burbanck 1967). Juvenile animals live interstitially in the substrate. Animals are believed to live about three years. There is evidence that protogynic hermaphroditism is common in C. polita; that is, the animal functions as a female its second year, and a male in the third (Burbanck and Burbanck 1974). In Florida, Kruczynski and Subrahmanyam (1978)

found juveniles maturing sexually in one year, and living only two years. Cyathura do not range widely, and most individuals spend their life within a few square meter's area.

#### Salinity Relationships:

C. polita adults are found in a wide range of salinity from fresh or near fresh water, to full salinity, and even (for part of the year) hypersaline conditions. In the northern part of its range, it is more common at full salinity. However, in Chesapeake Bay, the species occurs mainly below 12‰. Laboratory experiments have shown adults can survive a range of 0 - 40‰ or more for several hours (Kelley and Burbanck 1972).

In the laboratory, embryos of C. polita develop normally only between 0.5 - 20‰, while at 30‰, larvae develop normally but embryos die (Kelley and Burbanck 1976). The distribution of this species thus probably reflects the sensitivity of the embryo. However, competition or predation may also affect the species' occurrence in Chesapeake Bay.

#### Other Sensitivities:

C. polita constructs tubes in stable substrates to a depth of 7 cm or so. It is most numerous in sand, shell, firm clays, and silty sand sediments; less numerous or absent in soft muds (Kruczynski and Subrahmanyam 1978). The species is sensitive to low dissolved oxygen, which further limits its distribution in unstable muds and in deep water (Burbanck 1967). C. polita is found in salt marshes, intertidally, and subtidally to depth, until restricted by summer anoxia or hypoxia.

Adult C. polita are tolerant of a wide range of temperatures, reflected in their boreal-subtropical distribution. Reproduction, however, occurs in warmer months, generally April - August in most of its range. There is evidence that extremes of temperature

limit osmoregulatory ability, and that this is most pronounced in southern populations (Burbanck 1967).

#### Potential Habitat:

Potential habitat for this species is defined as areas between 0.5 - 12‰ salinity, with highest densities occurring between 1 and 7‰, in sand, muddy sand, and sandy mud, down to approximately 6 meters depth.

#### Trophic Importance:

Cyathura polita is an omnivorous feeder, ingesting detritus, algae, dead animal matter, and small organisms. Since in some habitats it represents the most numerous benthic species, it probably contributes significantly to transfer of material and energy from detritus to other food webs. C. polita has been shown to be used as food by numerous species of fish throughout its range (Burbanck 1963), and it is probably also preyed upon by crabs. Predation by fish has been cited as one cause of the species summer decline in many areas (Burbanck 1967).

Holland et al. (1980) found C. polita populations to increase inside predator exclusion cages during summer months. C. polita appeared as an important item in the diet of juvenile weakfish and other bottom feeding species collected near Calvert Cliffs, although the isopod is not an abundant member of the benthos there (Homer and Boynton 1978, Holland et al. 1979).

#### Selection Factors:

- Abundance in oligohaline areas, where the major effects of low flow are expected.
- Importance to detrital food web and as food for fish.
- Sensitivity of embryonic stages to higher salinities.

Sources:

Boesch 1971  
Boesch et al. 1976  
Burbanck 1963, 1967  
Burbanck and Burbanck 1974  
Cory and Dresler unpubl.  
Diaz 1977  
Harman unpubl.  
Holland et al. 1979, 1980  
Homer and Boynton 1978  
Kelley and Burbanck 1972, 1976  
Krucynski and Subrahmanyam 1978  
Lippson, R.L. unpubl.  
Pfitzenmeyer 1970, 1975  
Reinharz et al. unpubl.

*Gammarus daiberi* - Amphipod

Description:

Gammarus daiberi is a small epibenthic amphipod of the family Gammaridae. It is about 6 - 12 mm in length, of typical amphipod shape, and with banded coloration. G. daiber was only recently described (Bousfield 1969), and the species was (and continues to be) confused with the freshwater G. fasciatus, or a sibling species G. tigrinus (e.g., in Cory 1967).

Range:

G. daiberi ranges along the mid-Atlantic states from New York at least to South Carolina, in oligohaline and low mesohaline environments. In Chesapeake Bay, it is restricted to the upper third of the Bay mainstem and to the lower salinity areas of tributaries. Densities are typically less than  $500/\text{m}^2$ , and most commonly under  $100/\text{m}^2$ ; however, more than 4000 individuals per  $\text{m}^2$  have been recorded under exceptional conditions. There is some problem in delineating the range of this species within Chesapeake Bay, because of the taxonomic problem. Diaz (1977) found G. fasciatus and G. daiberi to have disjunct occurrence in the James River: G. fasciatus was found from approximately river mile 50 upstream, in less than 0.1‰ salinity, while G. daiberi was collected from river mile 25 (between 1 - 5‰) upstream to mile 35 or 40 (over 0.1‰). Possibly many records of "G. fasciatus" in oligohaline areas are actually G. daiberi.

G. daiberi may occur pelagically within its range; Ginn et al. (1976) found it to be the most abundant planktonic macroinvertebrate in the Hudson River near Indian Point. Bousfield (1969) notes that planktonic populations are most numerous during spring and summer. It has been recorded from floating objects in salinities up to 14 ‰ (Bousfield 1969).

Female G. daiberi are smaller than the male (6 - 8 mm). Eggs are fertilized in the females' brood chamber, where they are held until hatching. There are no planktonic stages, and development is direct.

#### Salinity Relationships:

From collection information, G. daiberi is found with greatest frequency between the salinities of 1 - 5 ‰, although it occurs from 0.5 - 7 ‰. Bousfield (1969) also reports it from higher salinity areas, taken in plankton or floating material.

#### Other Sensitivities:

G. daiberi appears relatively tolerant of temperature extremes, surviving temperature increases to approximately 34°C with no loss of reproductive ability (Ginn et al. 1976). Reproduction occurs mostly at warmer temperatures, but oviparous females have been recorded virtually year-round (Bousfield 1969).

G. daiberi is most numerous on substrates which provide some shelter or cover. Larsen (1974) recorded up to 3200 individuals per m<sup>2</sup> on oyster bars, while Diaz (1977) records maxima of less than 1/10 this value in soft substates.

#### Potential Habitat:

Areas from about 0.5 to 7 ‰, most abundant between 1 - 7 ‰ on all

types of sediment where suitable cover exists, to about 6 - 7 m depth. It may also occur pelagically at certain times of year within its range or somewhat downstream.

#### Trophic Importance:

Gammarus daiberi feeds upon a variety of material, including detritus, algae, fresh and decaying vegetation and animal matter, and small organisms.

Amphipods themselves are prey for a number of pelagic and demersal fish, shore birds, and a host of smaller invertebrate predators. Thomas (1971) found Gammarus (including fasciatus and daiberi) to comprise a high proportion of the food in young spot, silver perch, black drum, and weakfish in Delaware Bay. Thus G. daiberi, because of its abundance in the low salinity nursery areas of these and other species, is undoubtedly an important food resource and a key link in detritus-based food webs.

#### Selection Factors:

- Importance as a food for juvenile and adult fish, as well as its abundance in the low salinity nursery areas.
- Vulnerability to range reduction due to low flow conditions.

#### Sources:

Boesch 1971  
Bousfield 1969  
Cory 1967  
Cory and Dresler, unpubl.  
Diaz 1977  
Ginn et al. 1976  
Holland et al. 1980

Larsen 1974  
Pfitzenmeyer 1976  
Thomas 1971

*Leptocheirus plumulosus* - Amphipod

Description:

Leptocheirus plumulosus is a moderate-sized burrowing amphipod of the family Photidae. It is about 10 - 13 mm in length, and of typical amphipod outline, with heavily plumose setae on the gnathopods and pereopods. It inhabits a tube constructed of sand grains and debris.

Range:

Leptocheirus plumulosus has been reported from Cape Cod to northern Florida, chiefly in estuaries and tidal ponds. In Chesapeake Bay, it is found from oligohaline waters to the upper mesohaline zone, primarily in shallower areas. It is often quite abundant, and densities of 3000 - 4000/m<sup>2</sup> are not uncommon, while 10,000 or more individuals per square meter have been recorded. Pfitzenmeyer (1970) characterized L. plumulosus as one of three permanent dominant upper Bay species (the others being Cyathura polita and Scolecoplepides viridis).

L. plumulosus breeds in the warmer months, mostly during the period May through September, although Pfitzenmeyer (1970) found ovigerous females in October. Adults leave their burrows and a male grasps the female, which may be carried for a while before mating. The female broods the eggs, there are no planktonic stages, and development is direct. Each female produces two broods a year (Bousfield 1972). The young of the year overwinter, to breed the following spring. Densities of L. plumulo-

sus are generally highest in winter and early spring, and lowest during summer and fall (Holland et al. 1980). This may reflect both the action of predators, and the death of adults after breeding.

#### Salinity Relationships:

There apparently exists no laboratory information on the exact physiological tolerances of L. plumulosus. However, collection information indicates that it is generally restricted to areas where salinity is less than 15‰, and reaches greatest abundance from about 1 to 10‰.

#### Other Sensitivities:

No information is available on the exact temperature tolerances of L. plumulosus. Breeding, however, is apparently initiated in spring when water temperatures exceed 15°C or so.

L. plumulosus is found in all soft sediments: fine sand, muddy sand, sandy mud, and mud, as well as debris. Boesch et al. (1975) say that its preferred habitat is in shallow sand bottoms in oligohaline areas, but collection records report it in other sediments as well (Pfitzenmeyer 1970, Ecolog. Analysts 1974, Holland et al. 1979, 1980, and others). In hard substrates (firm sands, gravel, shell) it is replaced by another tube-building amphipod, Corophium lacustre. The species is adversely affected by sedimentation, which interferes with feeding. Gareth et al. (1975) noted that excess siltation following Tropical Storm Agnes limited L. plumulosus populations, and Bousfield (1972) notes that it occurs in areas with good circulation.

The species is definitely more abundant in shallow areas, which may reflect sediment preference, or sensitivity to summer hypoxia in deeper waters. Although recorded to depths of 15 m, it is most abundant in areas less than 10 meters.

### Potential Habitat:

Potential habitat for this species is defined as areas 0.5 - 15‰ salinity, with highest populations between 1 - 10‰, all soft sediments, to 15 meters depth but most abundant in less than 10 meters.

### Trophic Importance:

Leptocheirus plumulosus is a mixed deposit/suspension feeder, ingesting detritus, algae, microorganisms, and some animal and vegetable debris. It inhabits a relatively shallow tube, in which it lies oriented ventral side uppermost. Food is collected by action of the setose appendages and transferred to the mouth.

L. plumulosus represents a major source of food for benthic feeding predators, particularly fish, because of its abundance and wide distribution. Holland et al. (1980) suggest that the temporal distribution of the species indicates that its standing stock is controlled by predation. It showed one of the largest increases in enclosure cages, and Holland et al. (1980) cite Hixon (1978, 1979) that the species is frequently observed as a food item of bottom feeding fish.

Like all tube-building species, L. plumulosus contributes to sediment stabilization, sorting, and oxygenation.

### Selection Factors:

- Dominance in oligohaline and low mesohaline areas, and possibility of range reduction due to low flow.
- Importance as a food item to bottom-feeding predators.

Sources:

Boesch, inpubl.

Boesch et al. 1975

Bousfield 1972

Cory and Dresler, unpubl.

Diaz 1977

Ecological Analysts 1974

Harman unpubl.

Hixon 1978, 1979

Holland et al. 1979, 1980

Pfitzenmeyer 1970, 1973, 1975

Pearson et al. 1975

*Palaemonetes pugio* - Grass shrimp

Description:

Palaemonetes pugio is a small (~3 - 4 cm) decapod of the family Palaemonetidae. It is of typical shrimp form, transparent greenish-grey in color; the first two pairs of legs are chelate and longer than the six walking legs, the rostrum is long, laterally compressed, with stout spines. Females tend to be larger than males.

Range:

Palaemonetes pugio is abundant in nearshore habitats along the Atlantic and Gulf coasts of North America. In many of these areas it occurs with its congeners P. vulgaris and P. intermedius, which has raised interesting questions as to habitat partitioning among these sympatric species. Palaemonetes typically inhabit areas which provide shelter, such as eel grass or other SAV beds, pilings, brush, cobbles, etc. and are less abundant along exposed shores. At high tide, they may enter marshes and feed upon detritus, algae, and small organisms.

In Chesapeake Bay, P. pugio is most abundant in oligohaline to polyhaline waters, although it has been found occasionally in tidal freshwater. In high mesohaline polyhaline areas it co-occurs with P. vulgaris, the importance of which increases seaward.

P. Pugio zoea are released into the plankton starting in early summer, and continue to be found until September. The larvae are most abundant in the bottom water layers where the net transport is upstream, and apparently utilize the characteristic two-layered estuarine circulation to retain themselves within the estuary.

Palaemonetes is abundant in its nearshore habitat until the coldest months, where it apparently retreats to deeper waters to overwinter.

#### Salinity Relationships:

In Chesapeake Bay, P. pugio is found from 0 - 1‰ to approximately 20‰ salinity. P. vulgaris is of increasing importance above 15‰ at this point, the two species tend to occur in approximately equal numbers (Bowler and Seidenberg 1971).

Because of the differences observed in the distributions of P. pugio and P. vulgaris, numerous laboratory investigations have been made in an attempt to elucidate the habitat partitioning between the two species. In general, the larvae of both species appear to develop best at higher salinities; P. pugio larvae have an optimum range of 15-35‰ with development significantly retarded below 10‰ (Broad and Hubschman 1962, Sandifer 1973, McKenney and Neff 1979). Some laboratory studies have shown adults of P. pugio to be tolerant of low salinities, with several investigators citing 3‰ as the lethal lower limit for P. vulgaris (Nagabhushanam 1961, Wood 1967, Knowlton and Williams 1970, Bowles and Seidenberg 1971, Thorp and Hoss 1975). However, the latter authors found that, above 3‰, both species were equally tolerant to salinity, and that salinity per se does not mediate habitat partitioning.

Welsh (1975) found P. pugio to be far more tolerant of low dissolved oxygen, high detritus, and poor circulation environ-

ments than is P. vulgaris, and that these are probably the major environmental variables affecting the two species distributions.

#### Other Sensitivities:

P. pugio is also affected by temperature. Reproduction occurs when water temperatures warm in spring, with larvae released at about 18-20°C. Optimum survival and development occurs at 20-25°C. Juveniles are stressed at temperatures below 11°C, and survival is best at 18-25°C (Wood 1967). The increase of proportion of P. pugio to P. vulgaris in high salinity areas in winter reported by Thorp and Hoss (1975) for Rhode Island may reflect downstream migration of the former species (as does Crangon in winter). P. pugio is restricted by availability of shelter, and has thus been affected by the recent bay-wide decline in SAV's.

#### Potential Habitat:

Potential habitat for this species is defined as areas between 1-20‰ salinity, where suitable cover exists; it is generally found in less than 3-4 meters water.

#### Trophic Importance:

Palaemonetes pugio is an important food organism for fish, particularly those species inhabiting nearshore areas (eg. Fundulus).

P. pugio is particularly important, however, as a detritivore and nutrient recycler (Welsh 1975). The shrimp ingests detritus from marshes, as well as attached algae such as Ulva and diatoms, and assimilates the detritus and associated bacteria. The mechanics of feeding also tend to "mill" or reduce the detritus particle

size enhancing decomposition. P. pugio thus represents a major pathway for transfer of energy and material from tidal marshes to higher trophic levels.

Selection Factors:

- Importance of estuarine circulation to maintenance of species within the estuary, and in transport of larvae from higher salinity areas where development is maximal to low salinity parts of range.
- Potential reduction of range downstream due to salinity increase.

Source:

Bowles and Seidenberg 1971  
Broad and Hubschman 1962  
Cargo 1977  
Knowlton and Williams 1970  
Lippson et al. 1979  
McKenney and Neff 1979  
Nagabhushanam 1961  
Sandifer 1973, 1975  
Thorp and Hoss 1975  
Wass et al. 1972  
Welsh 1975  
Wood 1967

*Alosa pseudoharengus* - alewife

Description:

The alewife is a member of the herring family, Clupeidae. The species of the genus Alosa are collectively known as river herring. The river herrings are marine fish making spawning migrations into rivers well into freshwater. The color of the alewife is gray-green on the back, silvery on the sides. The alewife grows to 38 cm.

Range:

The alewife enters Chesapeake Bay and migrates up the major tributaries in late March when the water temperature reaches 10.5°C. The alewife migrates to freshwater. It spawns in slower, shallower reaches of creeks and rivers, never spawning in turbulence and fast water. Migration may continue through mid-May or until the water temperature reaches 28°C. During the spawning runs the alewife does not eat. The eggs are adhesive and tend to remain in the vicinity of spawning. The eggs hatch in one week at 15°C. The larvae are usually found within five miles of where the eggs were spawned.

After spawning the adults move downstream where they begin feeding. Depending on conditions they may move toward the ocean or remain in Chesapeake Bay until fall. Juveniles move down stream after a month. They reach the sea during the autumn at an average length of 10 cm.

### Salinity Relationships:

- Eggs are found in freshwater  $< 0.5\text{‰}$ .
- Larvae are found in freshwater and into the oligohaline region (0-3‰).
- Juveniles are found in the oligohaline region through early fall.
- Adults - marine to freshwater. Landlocked freshwater populations exist outside Chesapeake Estuary.

### Low Flow Sensitivities:

Spawning habitat is critically sensitive to the effects of low freshwater flows. Higher temperatures, lower dissolved oxygen levels and reduced water quality are all areas of concern. Movement of the 0.5‰ isohaline upstream in rivers where the fish's passage is restricted by falls, dams or obstructions a reduction in size of spawning habitat will result. This may result in overcrowding on the spawning grounds or increased spawning in marginal habitat.

### Potential Habitat:

The only relevant potential habitat is spawning habitat which requires shallow slow flowing freshwater between 10.5°C and 28°C with debris in it.

### Trophic Importance:

The alewife is a seasonally abundant fish feeding chiefly on zooplankton, particularly copepods. The alewife will also take young fish when they are available. Alewives of all ages serve as food for large bluefish, striped bass and other top predators.

### Selection Factors:

The alewife is a fairly abundant river herring with sport and commercial importance. It shares many life history characteristics with the shad.

### Sources:

Annon. 1968  
Carter 1973  
Dovel 1971  
Hildebrand and Schroeder 1928  
Johnson et al. 1978  
Jones et al. 1978  
Kaufman et al. 1980  
Lippson and Moran 1974  
Lippson et al. 1979  
Lippson (unpub.)  
O'Dell et al. 1976  
Raney and Massmann 1953  
Ritchie and Koo 1973  
Wang and Kernehan 1979  
Whitney 1961

*Alosa sapidissima* - American shad

Description:

The shad is a member of the herring family, Clupeidae. The shad is the most sought after of the river herrings. Shad is an anadromous spawning marine fish. Color of the shad is dark blue to green on the back fading to silvery-white on the sides. The shad grows to 75 cm and is highly prized for its flavor and for the caviar-like shad roe.

Range:

The shad enters coastal waters as they warm in the spring. Usually in March, when the water temperature in Chesapeake Bay has reached 13°C the fish begins its spawning run up the rivers. Where the rivers are not blocked by dams or other obstructions shad will move long distances upstream (formerly as far as 480 km up the Susquehanna). Most spawning currently is located much closer to the salt water interface due to the prevalence of stream obstructions. Spawning occurs in rapidly flowing water over clean sand or gravel bottom. Eggs are nonadhesive and rolled along with the current. In larger rivers spawning tends to occur in the channels. Eggs hatch in two weeks at 11°C. Juvenile shad remain in the river until fall at which time (around October) they leave for the ocean. Adults return to sea after spawning. They have generally left the Bay by the end of June.

### Salinity Relationships:

- Eggs - freshwater <0.5‰.
- Larvae - freshwater to oligohaline <5‰.
- Juveniles - oligohaline region into low mesohaline <12‰, gradually moving into more saline regions.
- Adults - freshwater to euhaline (oceanic).

### Low Flow Sensitivities:

A. sapidissima require flowing freshwater with dissolved oxygen levels above 5 ppm and clean sand or gravel bottoms. High temperatures, above 21°C, and low D.O. levels are detrimental to hatching. Local reaches of rivers with depressed D.O. have proved to be a barrier to the downstream migration of juveniles. Physical barriers to spawning migrations are sufficiently prevalent even on minor tributaries that the population has suffered severe decline. Intrusion of salt into the remaining spawning reaches below dams and barricades may be sufficient to eliminate entire year classes.

### Potential Habitat:

The only relevant potential habitat is a spawning habitat which requires temperatures 13°C - 17°C, freshwater, current, and adequate dissolved oxygen.

### Trophic Importance:

Adult shad feed mainly on copepods in the surface layer. Other small fish and planktonic crustaceans form a small part of the diet. The trophic impact of shad on Chesapeake Bay is limited by the pattern of not eating during migration and prompt return to the ocean after spawning by the adults. Juvenile shad are planktivores and form an important prey resource for top predators.

### Selection Factors:

Offshore overfishing, water quality problems in spawning rivers and greatly restricted access to spawning habitat have contributed to a drastic population decline in the Maryland tributaries. Maryland Department of Natural Resources has closed the fishery for shad for the indefinite future. The species is already under considerable stress which has reduced the resiliency of the Chesapeake Bay populations. Additional restrictions of spawning habitat due to upstream displacement of salinity is likely to produce an immediate and abrupt result.

### Sources:

Annon 1968  
Carter 1980  
Dovel 1977  
Env. Serv. Dept. VEPCO 1976  
Hildebrand and Schroeder 1928  
Johnson et al. 1978  
Jones et al. 1978  
Lippson and Moran 1974  
Lippson et al. 1979  
Neves and Depres 1979  
Raney and Massman 1953  
Scott and Boon 1973  
Wang and Kernehan 1979  
Whitney 1961

*Brevoortia tyrannus* - Atlantic menhaden

Description:

The menhaden is a member of the herring family, Clupeidae. The adult menhaden is a marine spawner which is dependent on the estuary both as a nursery for juveniles and which use the estuary as a feeding grounds during the summer months. The adult fish is dark blue to green with a conspicuous dark spot behind the head. Menhaden grow to a length of 46 cm and is the single most important non-food fish on the east or Gulf coast.

Range:

Menhaden enter Chesapeake Bay from the ocean in April and remain until October. Post-larval menhaden enter the Bay during the winter or early spring from spawning areas on the continental shelf. Post-larvae accumulate at the fresh salt water interface. After metamorphosis the juveniles begin to move from the fresh water interface through the oligohaline zone into the mesohaline. Larger fish are found in deeper water and further down the Bay. After metamorphosis the fish become pelagic feeders. Sub-adults will leave the estuary with the adults in October.

Salinity Relationships:

- Eggs - oceanic
- Larvae - oceanic drifting to tidal fresh on the bottom current.

- Juveniles - moving generally in surface layer from oligohaline to euhaline (oceanic).
- Adults - wandering from mesohaline (5 ‰) to euhaline with areas of concentrated adults and juveniles (5-8 ‰) following plankton patches.

#### Low Flow Sensitivities:

Change in stratification and net upstream drift of bottom waters could change delivery of larvae to low salinity nursery area. Breakdown of stratification could disperse plankton concentrations and make feeding more difficult for adults.

#### Potential Habitat:

Nursery area is the only critical habitat, potential nursery area described by salinity within the 0‰ to 5‰ zone, shallow waters, with organic bottom sediments and high plankton productivity.

#### Trophic Importance:

The only forage fish feeding directly on primary producers, menhaden are a major energy pathway from plankton direct to large piscivores. Present in exceedingly dense aggregations, the filter feeding of menhaden is a primary limit to plankton abundances.

#### Selection Factors:

- Unique trophic importance.
- Dependence on estuarine circulation for reproduction
- Dependence on high primary productivity of turbidity maximum.

Sources:

Beauchamp 1974	Lippson <u>et al.</u> 1979
Colton <u>et al.</u> 1979	Massman <u>et al.</u> 1962
Dovel 1971	McHugh <u>et al.</u> 1959
Durbin 1976	Oviatt <u>et al.</u> 1972
Harrison <u>et al.</u> 1967	Ritchie and Koo 1973
Hildebrand and Schroeder 1928	Scott and Boone 1973
Jones <u>et al.</u> 1978	Wang and Kernehan 1979
Lewis 1966	Weinstein 1979



ANCHOVY

*Anchoa mitchilli* - Bay anchovy

Description:

The Bay anchovy is a delicate, soft bodied small fish with large eyes and an underslung jaw giving it a "chinless" profile. The Bay anchovy belongs to the family Engraulidae. The Bay anchovy grows to a length of 10 cm and is translucent with a narrow horizontal silvery stripe along each side. The Bay anchovy is more inshore and estuarine oriented than is Anchoa hepsetus with which it competes in the higher salinity regions.

Range:

The Bay anchovy is found in open water throughout the Bay from the freshwater zone to the euhaline zone. However, spawning is concentrated in a much narrower salinity range (5 to 15‰), with peak egg densities only in 12-13‰ salinities in Chesapeake Bay. Other estuaries to the south have different spawning salinity relationships. Spawning is pelagic. Larvae move shoreward, remain in the surface waters and appear to collect in the area of salinities between 3 and 7‰. Juveniles are pelagic, shoreward oriented and euryhaline. Juveniles have been recorded far upstream of the limit of tidal influence in Virginia rivers. The juveniles are most abundant at the salt-freshwater front.

### Salinity Relationships:

- eggs - 5-15‰, max, concentration 12-13‰.
- larvae - 3-7‰.
- juveniles - 0-35‰, max concentration 0.5 -3‰.
- adults - 0-35‰.

### Low Flow Sensitivities:

The most sensitive life stage appear to be that of the larvae which collect in the surface waters of the oligohaline salinity zone. Movement of the oligohaline region into narrower regions of the tributary extuaries will concentrate the larvae and reduce the area available for feeding and growth. Larvae and early juveniles are dependent on the density of copepod nauplii for food. Crowding may well result in food limitation and reduction in size of year class of these important forage fish.

### Potential Habitat:

Potential spawning habitat is open Chesapeake Bay water with a salinity between 5 and 15‰. Potential habitat of larvae is the shallow shore zone where the salinity is between 3 and 7‰, while the adults habitat is all open water from tidal fresh to the ocean (euhaline zone).

### Trophic Importance:

Young anchovy feed exclusively on copepods. They may compete with alosid larvae for copepods, where ranges overlap. Adult anchovy feed upon copepods and other planktonic crustaceans such as crab larvae, mysids and cladocerans. In some areas larval fish are also taken by adult anchovy, however this does not occupy a substantial portion of thier diet. In turn, the Bay anchovy is fed on quite heavily by white perch and yellow perch, young bluefish and young striped bass. Juvenile weakfish are parti-

cularly dependent on anchovies for forage fish. In addition to its high abundance the anchovy is important as a forage fish because of its presence in the Bay year round.

Selection Factors:

The sensitivity of the larval stage to salinity the importance of the anchovy as a forage fish and its high biomass and wide distribution are all factors which contributed to the selection of the Bay anchovy as a study species.

Sources:

Carter 1973  
Dovel 1971  
Homer and Boynton 1978  
Hildebrand and Schroeder 1928  
Jones et al. 1980  
Lippson and Moran 1974  
Lippson et al. 1979  
Lippson (unpubl)  
Raney and Massmann 1953  
Scott and Boone 1973  
Wang and Kernehan 1979



SPOT

*Leiostomus xanthurus* - Spot

Description:

The spot is a member of the drum family, Sciaenidae. It is a relatively small drum growing to a maximum length of 34 cm. The spot has a deep, compressed body, with inferior mouth. The color of the spot is bluish gray with a large black shoulder spot from which it gets its name. This fish is presently the most abundant sciaenid in Chesapeake Bay.

Range:

The spot is widespread in Chesapeake Bay from early April through early November. The spot spends the winter on the continental shelf where it spawns. Post-larvae enter the Bay in the spring in the net upstream flow of bottom water. Metamorphosis apparently occurs in transit or soon after the fish arrives on the nursery grounds. Newly arrived young spot congregate in the oligohaline zone although during periods of high population densities some young move into fresh water and into shallow marshes and drainage ditches. As the spot grows it tends to move toward deeper and saltier water. Adults are found in mesohaline to euhaline salinity zones. Adults and juveniles tend to prefer soft muddy bottoms. Spot leave the Bay as water temperatures cool in the fall. Fish in their second or third year of life do not penetrate very far into the estuary, being found in any numbers only in the lower Virginia position of the Bay.

### Salinity Relationships:

- juveniles - tidal fresh to oligohaline, spring through fall.
- adults - mid mesohaline to euhaline, spring through fall.

### Low Flow Sensitivities:

The transport of the larvae from ocean to the nursery grounds is dependent on the hydrology of the partially mixed estuary. Low inflow conditions may act to reduce stratification and slow the inward movement of oceanic water. A sufficient delay in the passage of young fish to the nursery grounds could result in metamorphosis occurring early before the necessary quantities of appropriate food is reached. Spot on the nursery grounds are highly dependent on harpacticoid copepods such as Scottolana which reach high densities only in the oligohaline zone.

### Potential Habitat:

Summer salinities between tidal fresh and oligohaline and depths of three meters or less are nursery habitat for juvenile spot. Adult spot habitat is defined as mid-mesohaline to euhaline in depths to six meters over bottoms of soft sediment.

### Trophic Importance:

Spot juveniles can be quite dense on the nursery areas in some years and not in other years. This has a profound effect on the numbers of benthic harpacticoid copepods. Adult spot are the most important benthic grazers on small crustaceans, annelids, small molluscs and fish. The majority of the production of the soft bottom benthic community is grazed by spot. Spot are preyed upon by large gamefish and by the sport and commercial fishery. Spot also serve as an export of energy

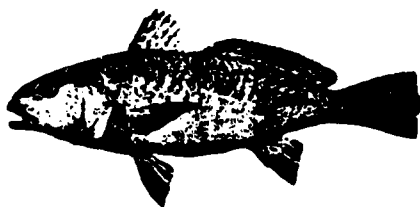
from the estuary to the shelf.

Selection Factors:

The sensitivity of juveniles to changes in Bay circulation, the requirements of juveniles for particular substrate-food combinations, the abundance of spot and its importance as a benthic grazer of invertebrates are the primary reasons for its selection as a study species.

Sources:

Chad and Musick 1977  
Environ. Serv. Dept. VEPCO 1976  
Haven 1957  
Hildebrand and Schroeder 1928  
Homer and Boynton 1978  
Johnson 1978  
Joseph 1972  
Kaufman et al. 1980  
Lippson et al. 1979  
Ritchie and Koo 1973  
Scott and Boone 1973  
Wang and Kernehan 1979  
Weinstein 1979



CROAKER  
RANGE - GULF OF MEXICO TO NEW YORK

Micropogonias\*undulatus - Atlantic croaker

Description:

The Atlantic croaker is a member of the drum family, Sciaenidae. The croaker is larger than its relative the spot, reaching a maximum length of 50 cm. The croaker is distinguished by numerous small barbels under the mandible and a wedge shaped caudal fin. The back of the fish is a greenish-silver with wavy vertical lines of dark spots. The Atlantic croaker is subject to a sport and commercial fishery throughout the southern Atlantic and Gulf coasts.

Range:

Adult Atlantic croaker enter Chesapeake Bay from the ocean in late March or early April as the water warms. Croaker are more numerous in Virginia's portion of Chesapeake Bay, however, during periods of high population densities, the fish will be found further north to salinities of 10‰. Croaker prefer deeper water than spot and are found in channels and in the vicinity of oyster reefs. Adult croaker have been reported in permanent fresh water in St. Johns River, Florida. Larger individuals tend to remain in higher salinities and spawning individuals leave sooner than juveniles. All spawning fish have left by mid-Sept. while immatures may remain as late as early December during mild winters.

Larvae enter Chesapeake Bay from the ocean beginning in September and continuing through the winter. Larvae drift with the bottom layer of inflowing sea water. Transforming larvae accumulate in fresh water just above the fresh-salt interface. As the

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\* Renamed Micropogonias by Chao. Micropogon preoccupied by a bird genus, Bore 1827.

juveniles grow they tend to move into deeper and more saline waters. Depending on growth rates juveniles may remain in the estuary one to two years before migrating to the ocean.

#### Salinity Relationships:

- Eggs - Euhaline, spawning is in the ocean
- Larvae - euhaline to fresh, semi passive movement
- Juveniles - fresh to low mesohaline during first winter moving down Bay during late summer
- Adults - euhaline to high mesohaline during March through September.

#### Low Flow Sensitivities:

Change in stratification and net upstream movement of bottom waters could change transport of larvae from ocean to nursery area. Juveniles on nursery grounds are highly dependent on harpacticoid copepods such as Scottolana. Changes in conditions in the fresh-oligohaline region which impacts Scottolana would reduce the food supply available to the transforming larvae and juveniles.

Adults would be likely to expand their range in an upBay direction if the salinity isohalines progress up the Bay.

#### Potential Habitat:

Potential nursery habitat is the 0 to 5‰ salinity zone in winter with cooccurrence of harpacticoid copepods. Potential adult habitat is hard bottom in three meters or greater water depths and a salinity between 10 and 34‰.

#### Trophic Importance:

The Atlantic croaker feeds on a wide variety of small benthic invertebrates, primarily crustaceans and molluscs. The croaker is a food fish caught in considerable numbers by recreational fishermen and commercial fishermen.

Selection Factors:

- Dependence of larvae on Bay circulation
- Requirement of early juveniles on one type of food
- Sensitivity of early life stages to substrate
- The importance of adults and juveniles as consumers of benthos
- The value of the fish to the fishery

Sources:

Chad and Musick 1977

Dovel 1968

Haven 1957

Hildebrand and Schroeder 1928

Johnson 1978

Joseph 1972

Kaufman et al. 1980

Massmann and Pacheco 1960

Wallace 1940

Weinstein 1979



SILVERSIDES

*Menidia menidia* - Atlantic silverside

Description:

The silverside family is Atherinidae. The Atlantic silverside is an inshore schooling forage fish of the tidal regions. They feed in marshes on the flood tide and are strongly oriented to estuaries. Superficially the silverside looks similar to an anchovy. The color of the live fish is pale, translucent green. The wide silver horizontal band on the fish is edged with black, the mouth is oblique and there are two well separated dorsal fins. The scales of the Atlantic silverside are smooth, which easily distinguishes it from the rough silverside which has rough scales. The Atlantic silverside grows to a maximum length of 14 cm.

Range:

The Atlantic silverside is widespread and abundant throughout the lower tributaries and main stem waters of Chesapeake Bay. Upstream penetration into freshwater is evidently limited by competition with the tidewater silverside *M. beryllina*. Feeding adults are associated with emergent vegetation and marshes. Spawning also occurs in the intertidal region and in shallow SAV beds. The eggs are provided with adhesive filaments and become attached to sedges, eelgrass, sand and beach trash. Juveniles tend to prefer vegetated bottom more than adults, which tend to be found over sand bottom when not feeding.

Salinity Relationships:

- o eggs - 3-14‰ preference, 1-34‰ range
- o larvae - 3-14‰ preference, 1-34‰ range
- o juveniles - 3-14‰ preference, 1-34‰ range
- o adults 3-14‰ preference, 1-34‰ range

This salinity distribution results from competition and possibly predation rather than physiology. Lab studies and records from locations other than Chesapeake Bay indicate survival from 0 to 34‰. In lab studies larval survival is higher at higher salinities as is egg hatching success.

#### Low Flow Sensitivities:

The upstream boundary of this species is apparently due to species competition. An expansion of this species in an upstream direction could be anticipated where wetlands border the tributaries.

#### Potential Habitat:

There is insufficient information on the distribution of the Atlantic silversides in the higher salinity regions of the lower eastern shore to determine whether the silverside is abundant there outside of its preference zone, as found in western shore tributaries. Therefore the potential habitat as mapped is from 3 to 34‰ salinity in the shallow shore regions of hard bottoms.

#### Trophic Importance:

The Atlantic silverside is abundant in the shore zone throughout much of the Bay and tributary estuaries. The shoreward orientation of the silverside in contrast to the pelagic anchovy means that the silverside is fed on by different predators than the anchovy or by different life stages of the same predator. The silverside is soft bodied and fragile. They are difficult to capture alive and to maintain in the lab. As a consequence less is known in quantitative terms about the Atlantic silverside role in the flow of energy in the estuary but it is quite

important to juvenile blue fish and juvenile striped bass. In turn the silverside preys on small crustaceans, worms, insects and epiphytic algae.

Selection Factors:

The Atlantic silverside is the most abundant of all Atherinidae in Chesapeake Bay. By grazing in the marshes it serves as a form of energy importer to the aquatic portion of the estuary. In turn the Atlantic silverside is an important item of diet for game fish species.

Sources:

Dovel 1971

Hildebrand and Schroeder 1928

Lippson 1973

Lippson et al. 1979

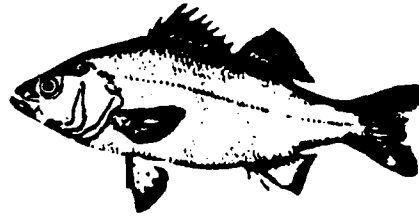
Raney and Massman 1953

Scott and Boone 1973

Wang and Kernehan 1979

Weinstein 1979

Wheeler 1975



WHITE PERCH  
RANGE - NORTH CAROLINA TO MAINE

*Morone americana* - White perch

Description:

The white perch is a member of the family Percichthyidae, the temperate basses. The white perch is an anadromous species which is occasionally has local populations confined to fresh water. The perch does not wander far from its natal river system. The white perch is a relatively deep bodied fish with separate spiny and soft dorsal fins, plain silver color without stripes or spots. The white perch grows to a maximum length of 49.5 cm.

Range:

The white perch is found throughout the Chesapeake Bay and C & D canal. They have been reported from marine areas north of Chesapeake Bay. White perch move upstream in the spring into the shore zone in tidal freshwater to spawn. Spawning occurs on shoal hard bottoms, (eg. sand or gravel) where there is current. Juveniles remain in shallow, soft bottomed nursery areas, preferably in areas of vegetation, for their first year. Juveniles larger than 25 mm total length begin inshore-offshore movements related to light levels. Cold temperatures cause white perch to move into deeper waters. Wintering populations are found in the deeper channels and holes in the Bay.

### Salinity Relationships:

- eggs are found in fresh to oligohaline waters, maximum salinities 4.2‰, mapped 0-5‰.
- larvae are found in fresh to oligohaline water, maximum salinities 8.0‰, but prefer less than 1.5‰, mapped 0-5‰.
- juveniles are found in fresh to low mesohaline waters, maximum 13‰ but prefer less than 3‰, mapped 0-5‰.
- adults range from fresh water to 30‰ but prefer salinities between 4 and 18‰, mapped 5-18‰.

Higher temperatures have the effect of reducing maximum salinities in which white perch are found.

### Low Flow Sensitivities:

Spawning habitat is the critical life history stage subject to effects of low flows. Increased salinity or increased siltation due to restricted freshwater inflow may impact the spawning area by restricting the available habitat through upstream displacement of the salinity zone and smothering of eggs adhering to the substrate, usually clean sand or gravel.

### Potential Habitat:

Mapped potential habitat shows the area of the salinity preference zones (5 to 18‰) and the spawning habitat between 0 and 5‰ in shoal areas. Although white perch will be found outside of these preference areas the metabolic cost of existence in the marginal area is greater than the preferred region.

### Trophic Importance:

White perch is the single most abundant species in many areas of the mid and upper Bay. The white perch is a generalized

feeder eating fish, crustaceans, annelids and insect larvae. In turn, small white perch are eaten by top predators such as blue fish and striped bass.

Selection Factors:

White perch are a major biomass contributor in areas of the estuary and its distribution is well documented. The location of spawning is dependent on the salinity and velocity regime of the subestuaries which will most likely be affected by consumptive water losses and drought.

Sources:

Dovel, W. 1971  
Env. Serv. Dept. VEPCO 1976  
Hardy, J. 1978  
Lippson, A.J. et al. 1979  
Lippson, R. (unpubl.)  
Loo, J. 1975  
Mansueti, R. 1961  
Mansueti, R. 1964

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CHESAPEAKE BAY LOW FRESHWATER INFLOW STUDY APPENDIX E  
BIOTR(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE  
DISTRICT SEP 84 CHB-84-L-APP-E

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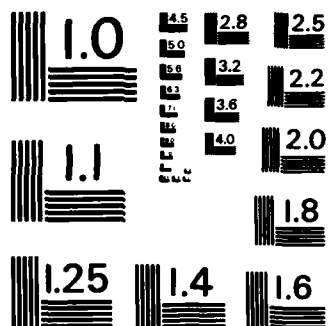
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STRIPED BASS

*Morone saxatilis* - Striped bass

Description:

The striped bass is a close relative of the white perch. A member of its family Percichthyidae, the striped bass is an anadromous marine game fish which can grow as large as 127 cm. The fish is olive green shading to white on the ventral surface. with seven dark horizontal stripes which gives the species its common name. It is highly prized as a sport fish and is also netted commercially in Chesapeake Bay. The Chesapeake provides in excess of 80% of the Atlantic coastal striped bass stock.

Range:

Within Chesapeake Bay the striped bass is found from the ocean to the fall line. Formerly striped bass ascended far up the Susquehanna River but the route is presently blocked by dams. The Chesapeake and Delaware Canal is used both for migration to and from Chesapeake Bay and as a major spawning area. Younger fish tend to be found in shallower and less saline water. During summer the striped bass is oriented to high energy shorelines, (rocky points, beaches, hard bottom where there is a current). During the winter striped bass seek out deep holes and channels where they remain relatively inactive. Larger fish are found in the high mesohaline to low polyhaline regions along the bottom. Younger fish may be found further upstream in winter,

also in deep water.

Salinity Relationships:

- eggs - tidal fresh to 1‰.
- larvae - tidal fresh to oligohaline
- juveniles - tidal fresh to mesohaline
- adults - spawning migrations to freshwater, otherwise mid-mesohaline to euhaline.

Low Flow Sensitivities:

Spawning requires turbulent water to keep the eggs in suspension. Spawning is apparently successful only in turbulent silty areas of rocky or hard bottoms and only in fresh water. Some studies have indicated that fish will not enter a river during periods of low discharge from upstream dams while restoring the reservoir water levels. This will be one of the anticipated effects of the regularizing of the river flow resulting from the construction of additional impoundments.

Potential Habitat:

Potential spawning habitat as mapped includes some areas where striped bass have been reported to have spawned in the past but which are not now used for spawning. Within the recent past spawning areas have shifted up and down rivers such as the Potomac due to hydrologic variables and chemical pollutants. Potential habitat for spawning is defined as tidal fresh water in mid-channel in regions of turbulent river flow. Habitat for juvenile striped bass is the shore zone in the oligohaline and low mesohaline salinity zones. Summer habitat for adults is the mid-mesohaline to euhaline salinity zones in water six meters or less deep while winter habitat for adults is depths greater than six meters and salinities from mid-mesohaline to

euhaline.

#### Trophic Importance:

Striped bass are large active predators feeding on a wide variety of fish and crustaceans. Larval striped bass are dependent upon the densities of copepod naupleii and other very small planktonic crustaceans. As the striped bass grow, their size of the prey increases also. Large striped bass have been accused of making severe inroads on populations of juvenile Atlantic croaker over the winter. The most significant predator on adult striped bass is man. The sport fish landings may exceed the commercial fisheries landings by approximately a factor of two.

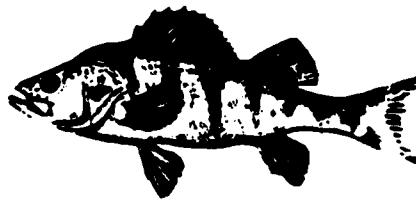
#### Selection Factors:

The large number of studies on the biology and distribution of the striped bass, the sensitivity of its egg and larval stages to the circulation and salinity changes expected to occur during low flow conditions and high trophic importance were all contributing factors in the selection of the striped bass as a study species. In addition, the fish has a high economic and social importance which, interacting with concern about the decline in fish recruited to the fishery, make this study species of considerable interest.

#### Sources:

Carter 1973  
Dovel 1971  
Environ. Serv. Dept. VEPCO 1976  
Harcy 1978  
Hildebrand and Schroeder 1928  
Kaufman et al. 1980  
Lippson and Moran 1974

Lippson et al. 1979  
Mihursky et al. 1970  
Miller 1978  
Ritchie and Koo 1973  
Scott and Boone 1973  
Talbot 1966  
Wiley et al. 1978



YELLOW PERCH

*Perca flavescens* - Yellow perch

Description:

A member of the family Percidae, the yellow perch is a native of central North America. The yellow perch requires slow flowing rivers, with vegetation, submerged trees or pilings. The yellow perch is a deep bodied green fish with broad vertical black bars on its back and distinct yellow-orange fins. Yellow perch grow to a length of 53 cm. Yellow perch are a popular sport fish of the upper reaches of the estuary.

Range:

Yellow perch are found from non-tidal fresh water to salinities of 13‰ in all coastal waters tributary to Chesapeake Bay. They are able to tolerate low oxygen levels and remain active even under winter ice. Yellow perch make vertical temperature dependent migrations and inshore, upstream spawning migrations. Spawning occurs in shallow waters often with debris or vegetation present. Eggs are adhesive and form ribbon-like clumps attached to each other and to branches, roots and gravel. Spawning occurs in March and April in both tidal and non-tidal freshwaters. Females move down river soon after spawning while males remain upstream for longer periods. Juveniles move to aquatic vegetation in the oligohaline and low mesohaline zones where they tend to form large pelagic schools. Adults become demersal with a preference for soft mud bottoms.

### Salintiy Relationships:

- eggs-0 to 0.5 ‰ freshwater
  - larvae- 0 to 0.5 ‰ shallow freshwater
  - juveniles-0.5 to 10‰ tidal fresh to mesohaline
  - adults- 0 to 13‰ , tidal fresh to mesohaline
- regions, seasonal migrations for spawning and temperature regulation.

### Low Flow Sensitivities:

Spawning very sensitive to river flow. Changes in water level strands eggs out of water or washes them off their attachments. Low flow conditions are expected to be favorable for spawning of yellow perch by reduction of current and regularization of of water levels in major tributaries. Changes in salinity zones with respect to soft mud bottom habitat could affect feeding patterns of adult.

### Potential Habitat:

Spawning habitat is defined as shallow areas in the tidal freshwater portion of the study area. Although the adult yellow perch has been recorded at depth above 27 meters, most specimens prefer shallower regions. The yellow perch is an epibenthic feeder preferring but not restricted to soft bottom. The mapped potential habitat is between the lower limits of tidal fresh water to mid-mesohaline salinity zones, oriented to the shore zone in summer and oriented to the deeper waters in winter.

### Trophic Importance:

The principal foods of the young perch in fresh water are insects and small crustaceans. The adult, in the estuarine portion of its range feeds on soft bodied fish, minnows and anchovies as well as isopods, amphipods, shrimp and snails. The yellow perch is an important competitor in the oligohaline and lower mesohaline zone where large populations can cause stunting of the adults. In the upper Bay the yellow perch is the second most numerous fish, after the white perch, and exerts considerable feeding pressure on the smaller fishes and invertebrates. The yellow perch is a popular sport fish.

### Selection Factors:

Large biomass, competition with other species and the sensitivity of the early stages to changes in hydrology due to low flows are the main reasons for the selection of this species.

### Sources:

Carter 1973  
Dovel 1971  
Hardy 1978  
Hildebrand and Schroeder 1928  
Kaufman et al. 1980  
Lippson 1973  
Lippson and L. Movan 1974  
Lippson et al. 1979  
Lippson (unpubl)  
Mansueti 1964  
Raney and Massman 1953  
Ritchie and Koo 1973  
Schwartz 1964  
Wang and Kernehan 1979

Anas platyrhynchos - Mallard

Description:

The mallard is a member of the dabbling duck subfamily Anatidae. The drake mallard is well-known, with a iridescent green head chestnut breast, white neck ring and yellow beak. The hen is mottled brown; both sexes have a iridescent blue speculum on the wing.

Range:

Mallards are very abundant migrants and winter residents in the Chesapeake Bay area, and are one of the most desirable and heavily hunted of the Bay ducks. A few birds breed in the Bay area during the summer months. In the 1980 Maryland mid-winter waterfowl survey, areas of high mallard abundance include the Chester, Wye, Manokin, and Pocomoke Rivers. Prior to 1980, the upper Patuxent and Potomac Rivers also supported high abundances of mallard. In the Virginia waters of Chesapeake Bay areas of high abundance, as reported in the 1980 Virginia mid-winter survey, include the upper Pamunkey, James and the Rappahannock Rivers.

Salinity Relationships and Sensitivities:

Mallards are most abundant in shallow fresh and brackish areas near agricultural fields, particularly in the upper tributaries. They also occur, although are usually not as abundant, in forested swamps and coastal salt marshes. Salinity will affect the bird only insofar as it affects its food and habitat.

Trophic Importance:

Mallards eat a large proportion of vegetable matter, and this diet includes a wide variety of plant material. The following

species were found to occur in more than 10% of the mallard gizzards examined by Rawls (in press):

- Nyssa silvatica
- Polygonum pennsylvanicum
- Polygonum punctatum
- Potamogeton perfoliatus
- Ruppia maritima
- Scirpus americanus
- Scirpus validus
- Zea mays

Animal remains accounted for less than 5% of the total food volume in these birds.

The mallard is one of the most desirable waterfowl for the sportsman, accounting for about 35% of the ducks harvested.

#### Other Factors:

The mallard is also of interest because of its hybridization with the black duck, an apparently increasing phenomenon on the Atlantic flyway (Morgan et al. 1976, Wass, pers. comm., Morton, pers. comm.). This hybridization may pose a threat to the survival of the black duck species in areas where the breeding zones of the two species overlap.

#### Selection Factors:

- Abundance of the species and importance to the waterfowl sport harvest
- Importance as a feeder on SAV's and EAV's
- Potential competitor with black ducks

Anas rubripes - Black Duck

Description:

The black duck is a dabbling duck, subfamily Anatinae of the family Anatidae. Male and female black ducks are similar, and in general resemble the female mallard but are darker. The body color is a dark mottled brown, and neck and head lighter brown, with an iridescent violet blue speculum on the wing.

Range:

Black ducks are present in the Chesapeake Bay area throughout the year. They migrate through the spring and fall, overwinter, and breed in the area during spring and summer. They are among the most abundant overwintering species, and are heavily hunted in the Bay area. In the 1980 Maryland mid-winter waterfowl survey, concentrations of black ducks were found in the Chester Wye, and Choptank Rivers. The Nanticoke, Wicomico, Manokin, and Pocomoke Rivers also were areas of black duck concentrations. In Virginia, the 1980 mid-winter survey found black duck concentrations in the James, Chickahoming, and Pamunkey Rivers. Pocomoke Sound and the Rappahannock also had substantial numbers of black ducks.

Salinity Relationships and sensitivities:

Black ducks are found in a wide variety of habitats during the non-breeding periods of the year, although more abundant in tributaries and near shore. They seem to prefer nesting in wooded and brushy areas near creeks and marshes, particularly estuarine coastal marshes, although they also occur in coastal salt and fresh water marshes. Salinity changes would probably only affect the black duck through affecting food or habitat.

#### Trophic Importance:

Black ducks feed on both plant and animal material. Rawls (in press), found the following plant species in 10% or more of the 131 black duck gizzards examined:

- Myriophyllum spicatum
- Polygonum spp.
- Potamogeton amplifolius
- Potamogeton perfoliatus
- Sparganium americanum
- Zea mays

Animal matter comprised approximately 6% of the total food volume in these samples.

The black duck is one of the most valuable waterfowl for the sportsman, accounting for about 20% of the total kill.

#### Other Factors:

The black duck is undergoing introgressive hybridization with the mallard in some areas, and this is apparently increasing on the Atlantic flyway (Morgan et al. 1976, Wass, pers. comm., Morton, pers. comm.). This hybridization may pose a threat to the existence of the black duck as a species in areas where the two species' breeding zones overlap.

#### Selection Factors:

- Abundance of the species and importance to the waterfowl sport harvest.
- Importance as a feeder on SAV's and EAV's
- Potential competition from mallard

## Aythya Valisineria - Canvasback

### Description:

The canvasback is a member of the diving duck subfamily Aythyinae of the Anatidae. This is a distinctive duck in appearance: the male has a chestnut head, white back and sides, and black breast and rump, while the female is duller in color. Both have a characteristic long head and sloping profile.

### Range:

The canvasback is one of the most numerous wintering and migrating ducks in the Chesapeake Bay area. Before a severe decline in numbers put it on the restricted list in Maryland and Virginia, it was also one of the most popular game ducks. The species is common in relatively open water areas, such as fresh and brackish river sites. The 1980 Maryland mid-winter waterfowl survey found large concentrations of canvasbacks in the Patuxent, Magothy, and Severn Rivers. On the eastern shore the Chester, Choptank, and Haza Rivers had higher concentrations of canvasbacks, as did Eastern and Fishing Bays, and the Nanticoke and Wicomico Rivers. In Virginia, major concentrations of canvasbacks occur in the lower Rappahannock, York River and Mobjack Bay, Pocomoke Sound, and the lower James and Nansemond River.

### Salinity Relationships and Sensitivities:

Canvasbacks would probably only be affected by salinity changes as they would affect food distribution. The current heavy reliance of this species on Macoma balthica might render it more sensitive to low flow conditions.

#### Trophic Importance:

In freshwater areas submerged aquatic vegetation was the most important food source, while animal material became important in brackish areas. The pattern has apparently been modified by the recent decline in SAV's in the Chesapeake Bay. Perry and Uhler (1976) found animal material to be the most abundant food in canvasbacks killed in 1975 and 1976; Macoma balthica, a clam, was the most numerous species eaten (90%). Although nineteen species of plants were also found in these birds, they occurred in much less abundance.

The canvasback was once one of the most important game species in this area, and if numbers were restored, could again become available to the sportsman.

#### Selection Factors:

- Potential vulnerability to changes in food; current relatively restricted diet.
- Potential value of the species to the sport harvest, and current reduced numbers and protected status

## SPECIES REFERENCES

- Academy of Natural Sciences of Philadelphia. 1977, 1978.  
Unpublished zooplankton data. Benedict Estuarine Research  
Lab., Benedict, Maryland.
- Alford, J.J. 1968. Changing Oyster Yields in the Major Admin-  
istrative Units of the Chesapeake Bay Fishery. Ph.D. U. of  
Kansas.
- Allen, J.F. 1958. "Urosalpinx cineria and Eupleura caudata  
in Chesapeake Bay, Maryland." Nautilus 72(2):49-51.
- Allison, J. 1980. Phytoplankton Sampling results, April, May,  
and June 1980. Md. Water Resources Admin., Field Service  
Division, Tech. Briefs (May, June, and July 1980) Annapolis,  
Maryland.
- Amende, L.M. 1974. Osmotic response to the blue crab, Callinectes  
sapicus, to temperature and salinity stress. pp. 139-146 IN:  
The Thermal requirements and tolerances of key estuarine  
organisms. J.A. Mihursky et al.. 146 pp.
- Annon. 1968. Suitability of the Susquehanna River for Restor-  
ation of Shad. U.S. Dept of Interior Sport Fish & Wildlife/  
Commerical Fishries. Md. Bd. Nat. Res. N.W. Conserv. Dept.  
PA Fish. Comm. USGPO, Wash. D.C. 60 pp.
- Appleby, A.G. and R.O. Brinkhurst. 1970. "Defecation rate  
of the three tubificid oligochaetes found in the sediments  
of Toronto Harbour, Ontario." J. Fish. Res. Bd. Canada  
27:1971-1982.
- Baker, L.D. and M.R. Reeve. 1974. "Laboratory culture of the  
lobate ctenophore Mnemiopsis micradyi with notes on feeding  
and fecundity." Marine Biol. 26:57-62.
- Beauchamp, R.G. (ed.). 1974. Marine Environment Planning Guide  
for the Hampton Roads/Norfolk Naval Operating Area. Naval  
Oceanographic Office. Spec. Pub. No. 250. Naval Ocn. Off.  
Washington, D.C. 262 pp.
- Birtwell, I.K. and D.R. Arthur. 1979. "The ecology of tubificids  
in the Thames Estuary with particular reference to Tubifex  
costatus (Claparede). IN: Oligochaete Biology. Brinkhurst,  
R.O. and D.G. Cook (eds.). Pellum Press, N.Y.
- Bishop, J.W. 1967. "Feeding rates of ctenophore Mnemiopsis  
leidyi." Ches. Sci. 8(4):259-261.
- Bosch, H.F. and W.R. Taylor. 1968. "Marine cladocerans in the  
Chesapeake Bay estuary." Crustaceana 15(2):161-164.
- Bosch, H.F. and W.R. Taylor. 1973. "Distribution of the Clado-  
ceran Podon polyphemoides in the Chesapeake Bay." Mar. Biol.  
19:161-171.

- Bosch, H.F. & W. R. Taylor. 1973. "Diurnal vertical migration of an estuarine cladoceran, Podon polyphemoides, in the Chesapeake Bay." Mar. Biol. 19:172-181.
- Bousfield, E.L. 1969. "New records of Gammarus (Crustacea: Amphipod) from the Middle Atlantic Region." Ches. Sci. 10(1):1-17.
- Bousefield, E. L. 1972. Shallow water gammarideai Amphipoda of New England. Cornell Press, Ithaca, N.Y. 344 pp.
- Bowler, M.W. and A.J. Seidenberg. 1971. "Salinity tolerance of the prawns, Palaemonetes vulgaris and P. pugio, and its relationship to the distribution of these species in nature." Va. J. Sci. 22:94.
- Branscomb, E.S. 1976. "Proximate causes of mortality determining the distribution and abundance of the Barnacle Balanus improvisus Darwin in Chesapeake Bay." Ches. Sci. 17(4):281-288.
- Brinkhurst, R.O. 1970. "Distribution and abundance of turbificid (Oligochaeta) species in Toronto Harbour, Lake Ontario." J. Fish. Res. Bd. Canada 27:1961-1969.
- Broad, A.C. and J.H. Hubschman. 1962. "A comparison of larvae and larval development of species of Eastern U.S. Palaemonetes with special reference to the development of Palaemonetes intermedius Holthius." Am. Zool. 2:394-395.
- Burbanck, W.D. 1963. "Some observations on the isopod, Cyathura polita, in Chesapeake Bay." Ches. Sci. 4(2):104-105.
- Burbanck, W. D. 1967. "Evolutionary and ecological implications of the zoogeography, physiology, and morphology of Cyathura (Isopod). pp 564-573 IN: G.E. Lauff (ed.). Estuaries. AAAS Publ. 83, Washington D.C. 757 pp.
- Burbanck, M.P. and W.D. Burbanck. 1974. "Sex reversal of female Cyathura polita (Stimpson 1855) (Isopoda, Anisopoda)." Crustaceana 26:110-112.
- Cain, T.D. 1974. "Combined effects of changes in temperature and salinity on early stages of Rangia cuneata." Va. J. Sci. 25(1):30-31.
- Cain, T.D. 1975. "Reproduction and recruitment of Rangia cuneata in the James River, VA" Fish. Bull. 73(2):412-413.
- Calabrese, A. 1969. "Individual and combined effects of salinity and temperature on embryos and larvae of the coot clam, Mulinia lateralis (Say)." Biol. Bull. 137(3):417-428.
- Cargo, D.G. 1977. "Biological summary of Palaemonetes pugio the grass shrimp. pp. 110-115 IN: Corps of Engineers, Balto. District, Chesapeake Bay Future Conditions Report. Vol. 11, Biota, Baltimore, Maryland. 423 pp.

- Chanley, P.E. 1958. "Survival of some juvenile bivalves in water of low salinity." Proc. Natl. Shellfish Assoc. 48:52-65.
- Chotiyaputta, C. and K. Hirayama. 1978. "Food selectivity of the rotifer Brachionus plicatilis on phytoplankton." Mar. Biol. 45(2):105-112.
- Conte, M. and R.G. Otto. 1979. Seasonal Aspects of the Species Composition and nearshore distribution of the zooplankton in the mid-Chesapeake Bay. CBI Spec. Rep. draft.
- Costlow, J.D. Jr. 1967. "The effect of salinity and temperature on survival and metamorphosis of megalops of the blue crab Callinectes sapidus." Helgolander wiss. Meeresunters. 15:84-97.
- Crumb, S.E. 1977. "Macrobenthos of the tidal Delaware River between Trenton and Burlington, New Jersey." Ches. Sci. 18(3):253-265.
- Dame, R.F. 1972. "The ecological energies of growth, respiration and assimilation in the American oyster, Crassostrea virginica." Mar. Biol. 17:243-250.
- Davis, H.C. 1958. "Survival and growth of clam and oyster larvae at different salinities." Biol. Bull. 114(3):296-307.
- Davis, H.C. and A. Calabrese. 1964. "Combined effects of temperature and salinity on development of eggs and growth of larvae of M. mercenaria and C. virginica." USFWS Fishery Bull. 63(3):643-655.
- Dauer, D.M., W.W. Robinson, C.P. Seymour, and A.T. Leggett, Jr. 1979. Effects of non-point pollution on benthic invertebrates in the Lynnhaven river system. Bulletin 17. Virginia Water Resource Research Ctr. Virginia Polytechnic Institute and State Univ., Blacksburg, VA 112 pp.
- Dauer, D.M., R.M. Ewing, G.H. Tourtellotte, and H.R. Barker, Jr. 1980. "Nocturnal swimming of Scolecoplepes viridis (Polychaeta: Spionidae)." Estuaries 3(2):148-150.
- Dean, D. and H.H. Haskin. 1964. "Benthic repopulation of the Raritan River estuary following pollution abatement." Limnol. Oceanogr. 9(4):551-563.
- Dean, D. 1965. "On the reproduction and larval development of Streblospio benedicti." Biol. Bull. 128:67-76.
- Diaz, R. 1979. "The ecology of tidal freshwater and estuarine tubificid oligochaetes." pp. 205-329 IN: Brinkhurst, R.O. and D.G. Cook (eds.). Oligochaete Biology, Pellum Press, NY

- Ecological Analysts, Inc. 1974. Power plant evaluation: Aquatic biology, final report: Perryman Site. Md. DNR Power Plant Siting Program, PPSE-2-2. 193 pp.
- Faust, M.A. 1974. "Micromorphology of a small dinoflagellate, Prorocentrum mariaeae-lebourae." J. Phycol. 10:315-322.
- Feeley, J.B. 1967. The distribution and ecology of the Gammaridae (Crustacea: Amphipod) of the lower Chesapeake estuaries. M.S. VIMS, College of William and Mary. 75 pp.
- Gallagher, J.L. and H.W. Wells. 1969. "Northern Range Extension and Winter Mortality of Rangia cuneata." Nautilus 83:22-25.
- Galtsoff, P.S. 1964. "The American oyster, Crassostrea virginica, Gmelia." U.S. Fish & Wildlife Serv. Bull. 64:1-480/
- Gatz, A.J. Jr., V.S. Kennedy, and J.A. Mihursky. 1973. Effects of temperature on activity and mortality of the scyphozoan medusa, Chrysaora quinquecirrha. Ches. Sci. 14(3): 171-180.
- George, J.D. 1966. "Reproduction and early development of the spionid polychaete, Scolecopelides viridis." Biol. Bull. (Verrill) 130:76-93.
- Ginn, T.C., W.T. Waller, and G.L. Laurer. 1976. "Survival and reproduction of Gammarus spp. (Amphipod) following short-term exposure to elevated temperatures." Ches. Sci. 17(1): 8-14.
- Gordon, D.C. Jr. 1966. "The effects of the deposit feeding polychaete Pectinaria gouldii on the intertidal sediments of Barnstable Harbor." Limnol. Oceanogr. 11(3):327-332.
- Graham, J.G. and G.F. Beaven. 1942. Experimental sponge-crab plantings and crab larvae distribution in the region of Crisfield, Maryland. CBL Publ. #52.
- Grant, G.C. and S.P. Berkowitz. 1979. An environmental assessment of the summer plankton in the vicinity of the C.P. Crane generating station. Md. DNR Power Plant siting program, PPSP-CPC-2. January 1970. 72 pp.
- Grassle, J.F. and J.P. Grassle. 1974. "Opportunistic life histories and genetic systems in marine benthic polychaetes." J. Mar. Res. 32:253-284.
- Gordon, C.M. 1969. "The apparent influence of salinity on the distribution of barnacle species in Chesapeake Bay." Crustaceana 16(2):129-142.
- Harman, G. (in preparation). Patuxent River Estuary benthic macro-invertebrates. Study of the tidewater portion of the Patuxent River Estuary. Md. Water Resources Admin. Patuxent River Program, Annapolis, Maryland.

- Hartman, O. 1945. "The marine annelids of North Carolina." Duke U. Mar. Lab. Bull. 2:51 pp.
- Hartwell, A.D. and N.B. Savage. 1980. "Coastal boundary layer influences distribution of bivalve larvae." Coastal Oceanogr. Climatol. News 2(2):19.
- Haven, D.S., W.J. Hargis, Jr., J.G. Loesch, and J.P. Whitcomb. 1975. "The effect of Tropical Storm Agnes on oysters, hard clams, soft clams, and oyster drills." pp. D169-D208 IN: Impact of Tropical Storm Agnes on Chesapeake Bay, Chesapeake Research Consortium. Bull. No. 34.
- Haven, D.S. and R. Morales-Alamo. 1970. "Filtration of particles from suspension by the American oyster, Crassostrea virginica." Biol. Bull. 139(2):248-264.
- Hibbert, C.J. 1977. "Energy relations of the bivalve Mercenaria mercenaria on an intertidal mudflat." Mar. Biol. 44(1):77-84.
- Hirayama, K. and T. Kusano. 1972. "Fundamental studies on physiology of rotifer for its mass culture II. Influence of water temperature on population growth of rotifers." Bull. Jap. Soc. Sci. Fisheries 38(12):1357-1363.
- Hixon, J.H. 1978, 1979. "Representative important species study." IN: Data Summaries for Chalk Pt., Jan-June 1978, July-Dec 1978, Nat. Sci. Phil. for PEPCO.
- Hopkins, S.H. and J.D. Andrews. 1970. "Rangia cuneata on the east coast: thousand mile range extension or resurgence?" Science 169:868-869.
- Johns Hopkins University. 1972. Power Plant Site Evaluation Brandon Shores Site. Md. PPS Program, PPSE 1-2, 308 pp.
- Johnson, H.B., D.W. Crocker, B.F. Holland, Jr., J.W. Gilliker D.L. Taylor and M.W. Street. 1978. Biology and management of mid-Atlantic anadromous fishes under extended jurisdiction. Annual report, Anadromous fish project. NC DNR and Com. Dev. and VIMS.
- Jordon, R.A., R.W. Virnstein, J.E. Illowsky, and J. Colvocoresses. 1975. Yorktown power station ecological study. Phase II: Final Technical Report. VIMS Spec. Sci. Rep. No. 76, 462 pp.
- Kaufmann, L.S., D.S. Becker, and R.G. Otto. 1980. Patterns of distribution and abundance of macro-benthos at Taylors Island, Maryland, with implications for monitoring programs. CBI Spec. Rep. 81, Ref. 80-4, 34 pp.
- Kelley, B.J. Jr., and W.D. Burbank. 1972. "Osmoregulation in juvenile and adult Cyathura polita (Stimpson) subjected to salinity changes and ionizing Gamma irradiation (Isopod: Anthuridae). Ches. Sci. 13(3):201-205.

- Kelley, B.J. Jr. and W.D. Burbank. 1976. "Responses of embryonic Cyathura polita (Stimpson) (Isopoda: Anthuridae) to varying salinities." Ches. Sci. 17(3):159-167.
- King, C. 1967. "Food, age, and the dynamics of a laboratory population of rotifers." Ecology 48:111-128.
- Kennedy, V.S. and J.A. Mihursky. 1971. "Upper temperature tolerances of some estuarine bivalves", Ches. Sci. 12(4):193-204.
- Knowlton, R.E. and A.B. Williams. 1970. "The life history of Palaeomonetes vulgaris (Say) and P. pugio (Holthuis) in coastal North Carolina." J. Elisha Mitchell Soc. 86:1851.
- Kremer, P. 1975. "Nitrogen regeneration by the ctenophore Mnemiopsis leidyi." IN: Mineral Cycling in Southeastern Ecosystems. Howell, F.G., and J.B. Genry, and M.H. Smith (eds.). 894 pp.
- Kruczynski, W.L. and C.B. Subrahmanyam. 1978. "Distribution and breeding cycle of Cyathura polita (Isopoda: Anthuridae) in a Juncus roemerianus marsh of Northern Florida." Estuaries 1(2):93-100.
- Kuznetsova, I.A. 1973. "Utilization of certain types of food by cirriped crustaceans." Hydrobiol. Journal 9(4):33-40.
- Kuznetsova, I.A. 1978. "Feeding habits of cirripedia." Hydrobiol. Journal 9(4):33-40.
- Landers, W.S. and E.W. Rhodes, Jr. 1970. "Some factors influencing predation by the flatworm, Stylochys ellipticus (Gerald), on oysters." Ches. Sci. 11(1):55-60.
- Littleford, R.A. 1937. "A study of the life history of Dactylometra quinquecirrha and the taxonomic validity of the species." Biol. Bull. 77(3):368-381.
- Loeb, M.J. 1972. The Chesapeake Bay sea nettle - a formidable jellyfish. Report of Naval Research Laboratory Progress.
- Loi, T.N. and B.J. Wilson. 1979. "Macrofaunal structure and effects of thermal discharges in a mesohaline habitat of Chesapeake Bay, near a nuclear power plant." Mar. Bio. 55:3-16.
- Lonsdale, D.J., D.R. Heinle, and C. Siegfried. 1979. "Carnivorous feeding behavior of the adult calanoid copepod Acartia tonsa Dana." J. Exper. Mar. Biol. Ecol. 36:235-248.
- Loosanoff, V.L. 1952. "Behavior of oysters in water of low salinities." Proc. Natl. Shellfish Assoc. 43:135-151.
- Mansueti, R.J. 1961. "Movements, reproduction and mortality of the white perch, Roccus americanus, in the Patuxent estuary, Maryland." Ches. Sci. 2(3-4):142-205.
- Mansueti, R.J. 1963. "Symbiotic behavior between small fishes and jellyfishes, with new data on that between the Stromateid

Peprilus alepidotus, and the scyphomedusa, Chrysaora quinquecirrha. Copeia 1:40-80.

- Manzi, J.J. 1970. "Combined effects of salinity and temperature on the feeding, reproduction and survival rates of Eupleura caudata (Say) and Urosalpinx cineria (Say). Biol. Bull. 138:35-46.
- Marsh, G.A. 1970. A seasonal study of Zostera epibiota in the Tork River, Virginia. Ph.D. Dissertation, College of Wm. and Mary. 156 pp.
- Massmann, W.H., J.J. Norcross, and E.B. Joseph. 1962. Atlantic menhaden larvae in Virginia coastal waters. Ches.Sci. 3(1):42-45.
- Maurer, D., L. Watling and G. Aprill. 1974. "The distribution and ecology of common marine and estuarine pelecypods in the Delaware Bay area." Nautilus 88:38-45.
- McErlean, A.J. 1964. "Characteristics of Macoma balthica populations in the middle Patuxent estuary." Ches. Sci. 5(4):200-208.
- McHugh, J.L., R.T. Oglesby, and A.L. Pacheco. 1959. Length, Weight, and Age composition of the menhaden catch in Virginia waters." Limnol. Oceanog. 4(2):145-162.
- McKenney, C.L. Jr. and J.M. Neff. 1979. "Individual effects and interactions of salinity, temperature, and zinc on larval development of the grass shrimp Palaemonetes pugio 1. Survival and developmental duration through metamorphosis" Marine Biol. 52:177-188.
- Merrill, A.S. and K.J. Boss. 1966. "Benthid ecology and faunal change relating to oysters from a deep basin in the lower Patuxent River, Maryland." Proc. Nat. Shellfish Assoc. 56:81-87.
- Mihursky, J.A., A.J. McErlean, V.S. Kennedy and W.H. Roosenburg. 1970. "Regional planning and the Chesapeake Bay environment" IN: Proceedings of the New England Coastal Zone Management Conference:47-74.
- Miller, R.E., S.D. Sulkin and R.L. Lippson. 1975. "Composition and seasonal abundance of the blue crab, Callinectes sapidus Rathbun, in the Chesapeake and Delaware Canal and adjacent waters." Ches. Sci. 16(1):27-31.
- Mills, E.L. 1964. "Amplisca abdita, a new amphipod crustacean from eastern North America." Canadian J. Zoo. 42:559-575.
- Mills, E.L. 1967. "The biology of an ampliscid amphipod sibling species pair." J. Fish. Res. Bd. Canada 24:305-355.

- Nagabhushanam, R. 1961. "Tolerance of the prawn, *Palaemonetes vulgaris* (Say), to waters of low salinity." Sci. Cult. 27:43.
- Neves, R.J. and L. Depres. 1979. "The oceanic migration of American Shad, *Alosa sapidissima*, along the Atlantic coast." Fish. Bull. 77(1):199-212.
- Nichols, F.H. 1975. "Dynamics and energetics of three deposit-feeding benthic invertebrate populations in Puget Sound, Washington." Ecolog. Managr. 45:57-82.
- Nichols, F.H. 1976. "Dynamics and production of *Pectinaria koreni* (Malmgren) in Kiel Bay, West Germany" pp. 453-463. IN: Keegan, B.F., P.O. Ceidigh, and P.J.S. Boaden (eds.) Biology of benthic organisms. 11th European Symposium on Marine Biology, Galway, Ireland. Oct. 1966. Pergamon Press, N.Y. 630 pp.
- O'Dell, J., J. Gabor, R. Dintamin, J. Mower. 1976. Survey of Anadromous Fish Spawning areas. Segment Report, Project AFC-9-1. Jan 1975-76 for Chester River Drainage in Kent Co. MD-DNR in Cooperation with NMFS (unpubl.)
- Olson, M.M. and L.E. Sage. 1978. (Draft MS) Nearfield zooplankton studies at the Calvert Cliffs Nuclear Power Plant, 1977. Draft report to B.G. & E. No. 78-32D. Academy of Natural Sciences of Phila., Benedict Estuary Research Lab., Benedict Maryland.
- Pearson, J.C. 1948. "Fluctuations in abundance of the blue crab in Chesapeake Bay." USFWS Res. Rep. 14. 25 pp.
- Pearson, J.G. and E.S. Bender. 1975. "Effects of Tropical Storm Agnes on the Benthos in the Upper Chesapeake Bay." pp. D33-D50. IN: Impact of Tropical Storm Agnes on Chesapeake Bay, Chesapeake Research Consortium, Inc. Publ. No. 34.
- Peddicord, R.K. 1977. "Salinity and substratum effects on condition index of the bivalve *Rangia cuneata*." Mar. Bio. 39:351-360.
- Peer, D.L. 1970. "Relation between biomass, productivity, and loss to predators in a population of a marine benthid polychaete, *Pectinaria hyperborea*." J. Fish. Res. Bd. Canada 27(12):2143-2153.
- Pfitzenmeyer, H.T. 1962. "Periods of spawning and setting of the soft shelled clam, *Mya arenaria* at Solimons, Maryland." Ches. Sci. 3:114-120.
- Pfitzenmeyer, H.T. 1965. "Annual cycle of gametogenesis of the soft shelled clam, *Mya arenaria* at Solomons, Maryland." Ches. Sci. 6(1):52-59.
- Poddubnaya, T.L. 1973. "Production of tubificids of the Ivan'kooo Reservoir in the vicinity of the discharge of effluent from the Konakovo Power Plant." Hydrobiol. Journal 9(6):261-265.

- Reeve, M.R. and M.A. Walter. 1978. "Nutritional ecology of ctenophores - a review of recent research." Adv. Mar. Biol. 15:249-283.
- Reinharz, E., O. Vricker, A. O'Connell. 1979-1980. Data report: Chesapeake Bay Earth Science Study, Animal-Sediment Relationships. Data report to EPA Chesapeake Bay Program, Toxics Group, Grant No. R805964.
- Ritchie, Jr., D.E. and T.S. Y. Koo. 1973. "Hydrographic and ecological effects of enlargement of the Ches. and Delaware Canal." Appendix VIII Fish Movements - Maryland Study. CBL, Univ of Md, and Johns Hopkins.
- Richman, S., Heinle, D.R. and R. Huff. 1977. "Grazing by adult estuarine calanoid copepods of the Chesapeake Bay." Mar. Biol. 42(1):69-84
- Rupp, N.M. 1969. Seasonal and spatial distribution of Acartia tonsa and A. clausi in Chesapeake Bay. MA Thesis, Johns Hopkins University. 1969. 45 pp.
- Sandoz, M. and R. Rogers. 1944. "The effect of environmental factors on hatching, moulting and survival of zoea larvae of the blue crab Callinectes sapidus Rathbus." Ecology 25(2):216-228.
- Sheomaker, C.R. 1932. "A new amphipod of the genus Leptocherus from Chesapeake Bay." J. Wah. Acad. Sci. 22:548-551.
- Spektorova, L.V. , T. Aronovich and M.P. Aronov. 1975. "Rotifer population density in relation to food concentration and water salinity." Hydrobiol. Journal 11(1):26-30/
- Stauber, L.A. 1943. "Ecological studies on the oyster drill, Urosalpinx cineria, in Delaware Bay, with notes on the associated drill, E. caudata, and with practical consideration of control methods." Oyster Res. Lab Report, N.J.
- Stophan, P.E. 1974. Surface phytoplankton community structures of Molyack Bay and York River, Virginia. Ph.D. Dissertation. Coll. of William and Mary.
- Storms, S.E. 1975. Selective feeding, ingestion, and assimilation rates, and distribution of the copepod Acartia in Chesapeake Bay. Ph.D. Dissertation, Johns Hopkins, U. 163 pp.
- Tenore, K.R., D.B. Horton, and T.W. Duke. 1968. "Effects of bottom substrate on the brackish water bivalve Rangia cuneata." Ches. Sci. 9(4):238-248.
- Tenore, K.R. 1970. The macrobenthos of the Pamlico River estuary, N.C. Report #40. PB197-591. N.C. State Univ., Raleigh, NC
- Thomas, D.L. 1971. "An ecological study of the Delaware River in the vicinity of Artificial Island, III. The early life history and ecology of six species of drum (Sciaenidae) in the lower Delaware River, a brackish tidal estuary. Ichthy-

- Thorp, J.H. and D.H. Hoss. 1975. "Effects of salinity and cyclic temperatures on survival of two sympatric species of grass, shrimp (*Palaemonetes*), and their relationship to natural distributions." J. Mar. Biol. Ecol. 18:19-28.
- Tunncliffe, V. and M.J. Risk. 1977. "Relationships between the bi valve *Macoma balthica* and bacteria in intertidal sediments: Minas Bay, Bay of Fundy." J. Mar. Res. 35:499-507.
- Turpaeva, E.P. and R.G. Simkina. 1961. "The behavior of the Black Sea barnacle, *Balanus improvisus*, Darwin in conditions of reduced salinity." Trudy. Inst. Okeanol. Akad. Nauk. SSSR 49:205-223.
- Tyler, M.A. and H.H. Seliger. 1980. "Selection for a red tide organism: physiological responses to the physical environment." Limnol. Oceanogr. In press
- Watling, L. and D. Maurer. 1972. "Shallow water amphipods of the Delaware Bay region." Crustaceana Suppl. 3:251-266.
- Watling, L. 1975. "Analysis of structural variation in a shallow estuarine deposit feeding community." J. Exp. Mar. Biol. Ecol. 19:275-313.
- Watson, A.T. 1927. "Observations on the habits and life-history of *Pectinaria* (*Lagis*) *koreana* Mgr." Proc Trans. Liverpool Biolog. Soc. 42:25-60.
- Wells, H.W. 1957. "Abundance of the hard clam *Mercenaria mercenaria* in relation to environmental factors." Ecology 38(1):123-128.
- Welsh, B.L. 1975. "The role of the grass shrimp, *Palaemonetes pugio* in a tidal marsh ecosystem." Ecology 56:513-530.
- Wheeler, A. 1975. Fishes of the World. Macmillan Publ. Co. Inc. New York 366pp.
- Whitney, R.W. (ed.) 1961. The Susquehanna Fishery Study 1957-1960: A report on a study on the desirability and feasibility of passing fish at Conswinger dam. MD Dept. Res. and Edu. Solomons, MD and Susquehanna Elec. Co.
- Wood, C.E. 1967. "Pysioecology of the grass shrimp, *Palaemonetes pugio*, in the Galveston Bay estuarine system." Contrib. Mar. Sci. Univ. Tex. 12:54-79.
- Zhdanova, G.A. and T.V. Frinovskaya. 1976. "Effect of algae as food on the growth, fecundity and life-span of *Bosmina longirostris* (O.F. Muller)." Hydro. Journal 12(4):66-69.

#### OTHER REFERENCES

- Academy of Natural Sciences of Philadelphia. 1972. Potomac River Survey. (Dickerson) 1968 for the Potomac Electric Power Company. 90 pp.
- Andrews, J.D. 1967. "Interaction of Two Diseases of Oysters in Natural Waters." Proc. Nat. Shellfish Assoc. 57:38-49.
- Bahr, L. 1974. Aspects of the Structure and Function of the Intertidal Oyster Reef Community in Georgia. Ph.D. Dissertation. University of Georgia.
- Boesch, D.F. 1971. The Distribution and Structure of Benthic Communities in a Gradient Estuary. Ph.D. Dissertation. College of William and Mary. 132 pp.
- . 1972. "Species Diversity of Marine Macrobenthos in the Virginia Area." Ches. Sci. 13(3):206-211.
- . 1973. "Classification and Community Structure of Macrobenthos in the Hampton Roads area, Virginia." Mar. Biol. 21(3): 226-244.
- . 1977. "A New Look at Zonation of Benthos Along the Estuarine Gradient." IN: Ecology of Marine Benthos. B.C. Coull (ed.). University of South Carolina Press. Columbia, South Carolina.
- Boon, J.D. III, M.E. Boule, G.M. Silberhorn. 1977. Delineation of Tidal Wetlands Boundaries in Lower Chesapeake Bay and Its Tributaries. Spec. Report No. 140 in applied marine science and ocean engineering. VIMS, Gloucester Point, VA. 127 pp.
- Bosch, H.F. and W.R. Taylor. 1968. "Marine Cladocerans in the Chesapeake Bay Estuary." Crustaceana 15(a):161-164.
- . 1973. "Distribution of the Cladoceran Podon polyphemoides in the Chesapeake Bay." Mar. Biol. 19:161-171.
- Bryan, B.B. 1977. The Ecology of the Marine Cladocera of Lower Chesapeake Bay. Ph.D. Dissertation. University of VA. 101 pp.
- Burrell, V.G. 1972. Distribution and Abundance of Calanoid Copepods in the York River Estuary, Virginia, 1968 and 1970. Ph.D. Dissertation. College of William and Mary. 234 pp.

- Burrell, V.G. Jr. and W.A. Van Engel. 1976. "Predation by and Distribution Of a Ctenophore Mnemiopsis leidyi, A. Agassiz, in the York River Estuary." Estuar. & Coastal Marine Sci. 4(3):235-242.
- Cain, T.D. 1974. "Combined Effects of Changes in Temperature and Salinity on Early Stages of Rangia cuneata." Va. J. Sci. 25(1):30-31.
- Carriker, M.E. 1955. "Critical Review of Biology and Control of Oyster Drills, Urosalpinx and Eupleura." USF&W S.S.R:148.
- Carriker, M.R. 1967. "Ecology of Estuarine Benthic Invertebrates: a Perspective." IN: Estuarines. G.H. Lauff (ed.). A.A.A.S. Publ. 83, 757 pp.
- Carter, N. 1980. Unpublished data.
- Castagna, M. and P. Chanley. 1973. "Salinity Tolerance of Some Marine Bivalves from Inshore and Estuarine Environments in Virginia Waters or the Western Mid-Atlantic Coast." Malacoe 12(1):47-96.
- Clark, J. 1977. Coastal Ecosystem Management. John Wiley and Sons. New York.
- Cory, R.L. 1967. "Epifauna of the Patuxent River Estuary, Maryland, for 1963-1964." Ches. Sci. 8(2):71-89.
- Cory, R.L. and \_\_\_\_\_ Dressler. 1980. Unpublished data.
- Coull, B.C. 1973. "Estaurine Microfauna, A Review: trophic relationships and microbial interactions." IN: Estuarine Microbial Ecology. Stevenson, L.H. and R.R. Colwell (eds.). Univ. South Carolina Press. Columbia, SC. 536 pp.
- Dahl, E. 1956. "Ecological Salinity Boundaries in Poikilohaline Waters." Oikos 7:1-23.
- Dahlberg, M.D., P.A. Dahlberg, and P.V. Morgan. 1973. An Ecological Survey of the Potomac River at Douglas Point, Maryland. Pepco Report, by NUS Corp., Cyrus Wm. Rice Division. Pittsburg, PA. 365 pp.
- Davies, T.T. 1972. "Effect of Environmental Gradients in the Rappahannock River Estuary on the Molluscan Fauna." Geol. Soc. Am. Memoir 133:263-290.
- Day, J.H. 1951. "The Ecology of South Africa Estuaries." Part 1: General Considerations. Trans. Roy. Soc. So. Africa 33:53-91.

- Day, J.H. 1967. "The Biology of the Knysna Estuary, South Africa." IN: Estuaries. G.H. Lauff (ed.). A.A.A.S. Publ. 83, 757 pp.
- Diaz, R.J. 1977. The Effects of Pollution on Benthic Communities of the Tidal James River, Virginia. Ph.D. Dissertation University of Virginia. 158 pp.
- Douglas, P.A. and R.H. Stroud (eds.). 1971. A Symposium on the Biological Significance of Estuaries. Sport Fishing Institute. Washington, D.C. 111 pp. March 1971.
- Dozier, H.L. 1947. "Salinity as a Factor in Atlantic Coast Tidewater Muskrat Production." Trans. North Am. Wild. Conf. 12:398-420.
- Durbin, A.G. 1976. The Role of Fish Migration in Two Coastal Ecosystems: The Atlantic menhaden (Brevoortia tyrannus) in Narragansett Bay, and the alewife (Alosa pseudoharengus) in Rhode Island ponds. Ph.D. Dissertation. Univ. of Rhode Island, Kingston, RI.
- Federal Register: July 1, 1975. Threatened or Endangered Fauna or Flora: Review of status of vascular plants and determination of "Critical Habitat". U.S. Fish and Wildlife Service. 40:127. Washington, D.C.
- Goodwin, F. Jr. 1970. "Zooplankton" IN: Gross Physical and Biological Effects of Overboard Spoil Disposal in Chesapeake Bay. (Interim and final reports). Final Report, NRI Spec. Rep. #3.
- Grant, G.C. 1977. "Seasonal Distribution and Abundance of the Chaetognatha in the Lower Chesapeake Bay." Estaur. Coastal Mar. Sci. 5:809-824.
- Grant, G.C. and J.E. Olney. 1979. Lower Bay Zooplankton Monitoring Program: an introduction to the program and results of the initial survey of March 1978. VIMS SSR #93. 92 pp.
- Gunter, G. 1955. "Mortality of Oysters and Abundance of Certain Associates as Related to Salinity." Ecology 36(4):601-605.
- Hale, S.S. 1976. The Role of Benthic Communities in the Nitrogen and Phosphorus Cycles of an Estuary. Univ. Rhode Island Mr. Reprint 57. Reprinted from: Howell, F.G., J.B. Gentry and M.H. Smith (ed.). Mineral cycling in southeastern ecosystems. ERDA Symposium series 1975.

- Hamilton, D.H. and R.S. LaPlante. 1972. Cove Point Benthic Study. Annual Report. Chesapeake Biol. Lab., Nat. Res. Inst. Ref. No. 72-36. 66 pp.
- Harrison, W., J.J. Norcross, N.A. Pore, and E.M. Stanley. 1967. Circulation of Shelf Waters off the Chesapeake Bight, Surface and Bottom Drift of Continental Shelf Waters Between Cape Henlopen, Delaware, and Cape Hatteras, North Carolina. June 1963-December 1964. U.S. Dept. of Commerce, Prof. Paper 3, Environmental Sci. Ser. Admin., Washington D.C. 82 pp.
- Hart, C.W. Jr. and S.L. H. Fuller. 1972. Environmental Degradation in the Patuxent River Estuary, Maryland. Cont. No. 1 from Dept of Limnology, Academy of Natural Sciences of Philadelphia.
- Haven, D.S. 1957. "Distribution, Growth, and Availability of Juvenile Croaker, Micropogon undulatus, in Virginia." Ecology 38(1):88-97.
- \_\_\_\_\_. 1980. Personal communication. Virginia Institute of Marine Science. Gloucester Point, VA.
- Haven, D.S., W.J. Hargis, Jr., and P.C. Kendall. 1978. The Oyster Industry of Virginia: its status, problems and promise. S.R.A.M.S.O.E. No. 168 VIMS.
- Haven, D.S., J.P. Whitcomb and P.C. Kendall. 1977. The Present and Potential Productivity of Baylor Grounds in Virginia. Phase I. The Rappahannock River. Annual contract report for the period 15 September 1976 to 15 July 1977. Contract No. 3-265-R-1 to the National Marine Fisheries Resources Commission. VIMS. Gloucester Point, VA. 65 pp.
- Haven, D.S., J.P. Whitcomb, and P.C. Kendall. 1979. The Present and Potential Productivity of Baylor Grounds in Virginia. Phase II. The Great Wicomico and Piankatank Rivers. Annual Contract Report for the period 15 July 1977 to 15 May 1978. Contract No. 3-265-R-2 to the National Marine Fisheries Service through VIMS. Gloucester Point, VA. pp. 108.
- Heinle, D.R. 1966. "Production of a Calanoid Copepod, Acartia tonsa, in the Patuxent River Estuary." Ches. Sci. 7(2) 59-74.
- \_\_\_\_\_. 1969. Effects of Temperature on the Population Dynamics of Estuarine Copepods. Ph.D. Dissertation. Univ. of Maryland 132 pp.
- \_\_\_\_\_. 1974. "An Alternate Grazing Hypothesis for the Patuxent Estuary." Ches. Sci. 15(3):146-150.

- Heinle, D.R., H.S. Millsaps, and C.V. Millsaps. 1975. "Effects of Tropical Storm Agnes on Standing Crops and Age Structure of Zooplankton in Middle Chesapeake Bay." D117-D136. IN: The Effects of Tropical Storm Agnes on the Chesapeake Bay Estuarine System. Davis, Jr. (ed.). CRC Publ. No. 34.
- Heinle, D.R., S. Richman, S.D. Van Valkenburg, and J.D. Allan. 1978. Seasonal Interactions Among Estuarine Primary Producers and Herbivores. Final Tech. Rep. to ERDA, UMCEES Ref. 78-29CBL.
- Herman, S.S., J.A. Mihursky, and A.J. McErlean. 1968. "Zooplankton and Environmental Characteristics of the Patuxent River Estuary 1963-1965." Ches. Sci. 9(2):67-82.
- Hildebrand, S.F. and W.C. Schroeder. 1928. Fishes of the Chesapeake Bay. Bull. U.S. Bureau Fish. V. 53. pt 1. (Reprint 1972 by Smithsonian Inst. Washington, D.C.)
- Hodgkin, E.P. and R.J. Rippingale. 1971. "Interspecies Competition in Estuarine Copepods." Limnol. Oceanogr. 16:573-576.
- Holland, A.F., N.K. Mountford, M. Keigel, D. Cargo, and J.A. Mihursky, MMC and CBL. 1979. Results of Benthic Studies at Calvert Cliffs, Final Report. Md. DNR PPSP-MP-28, UMCEES Ref. 79-119-CBL.
- Homer, M. and W.R. Boynton. 1978. Stomach Analysis of Fish Collected in the Calvert Cliffs Region, Chesapeake Bay - 1977. Final Report to: Md. DNR Power Plant Siting Program. Annapolis, MD.
- Hopkins, S.H., J.W. Anderson, and K. Horvath. 1973. The Brackish Water Clam Rangia cuneata as Indicator of Ecological Effects of Salinity. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., Contract Rep. 250.
- Jacobs, F. 1978. Zooplankton Distribution, Biomass, Biochemical Composition and Seasonal Community Structure in Lower Chesapeake Bay. Ph.D. Dissertation. University of Virginia 105 pp.
- Jeffries, H.P. 1962. "Copepod Indicator Species in Estuaries." Ecology 43(4):730-733.

- Keefe, C.W. 1973. "Standing Crop of Salt Marshes Surrounding Chincoteague Bay, Maryland-Virginia." Ches. Sci. 14(2): 117-123.
- Khlebovich, V.V. 1969. "Aspects of Animal Evolution Related to Critical Salinity and Internal State." Marine Biol. 2:338-345.
- Kinne, O. 1963. "Salinity, Osmoregulation, and Distribution in Macroscopic Crustacea." IN: Marine Distributions. M.J. Dunbar (ed.). Roy. Soc. Canada Spec. Publ. No. 5.
- \_\_\_\_\_. 1964. "The Effects of Temperature and Salinity on Marine and Brackish Water Animals. II. Salinity and Temperature - salinity combinations." Oceanogr. Mar. Biol. Ann. Rev. 2:281-339.
- \_\_\_\_\_. 1966. "Physiological Aspects of Animal Life in Estuaries with Special Reference to Salinity." Neth. J. Sea. Res. 3(2):222-244.
- Kinner, P. and D. Maurer. 1978. "Polychaetous annelids of the Delaware Bay Region." Fishery Bull. 76(1):209-224.
- Kinner, P. and D. Maurer, and W. Leathem. 1974. "Benthic Invertebrates in Delaware Bay: Animal-sediment associations of the dominant species." Int. Revue. ges. Hydrobiol. 59(5):2-18.
- Kremer, P. 1977. "Respiration and Excretion by the Ctenophore Mnemiopsis leidyi." Marine Biology 44:43-50.
- Larson, P. 1974. Quantitative Studies of the Macrofauna Associated with the Mesohaline Oyster Reefs of the James River, Virginia. Ph.D. Dissertation 1974, College of William and Mary. 215 pp.
- Lear, D.W. and S.K. Smith. 1976. "Phytoplankton of the Potomac Estuary." IN: The Potomac Estuary: Biological Resources, Trends and Options. Mason, W.T. and K.C. Flynn (eds). Proc. Symp. Interstate Comm. Potomac River Basin. Bethesda, MD Tech Publ. 76-1, 140 pp.
- Levinton, J.S. 1977. "Ecology of Shallow Water Deposit-Feeding Communities, Quisset Harbor, Massachusetts." IN: Coull B.C. (ed.). Ecology of Marine Benthos. Univ. of South Carolina Press.
- Lippson, A.J. (ed.). 1973. The Chesapeake Bay in Maryland; An Atlas of Natural Resources. Johns Hopkins University, Baltimore, MD. 55 pp.

- Lippson, A.J. and R.L. Moran. 1974. Manual for Identification of Early Development Stages of Fishes of the Potomac River Estuary. Power Plant Siting Program, Md. Dept Nat. Res. 282 pp.
- Lippson, A.J. , M.S. Haire, A.F. Holland, F. Jacobs, J. Jensen, R.L.M. Johnson, T. Polgar, and W.A. Richkus. 1979. Environmental Atlas of the Potomac Estuary. Martin Marietta, Baltimore, MD. 279 pp.
- McCarthy, J.J., W.R. Taylor, T.J.L. Taft. 1977. "Nitrogenous Nutrient of the Plankton in the Chesapeake Bay, 1: Nutrient Availability and Phytoplankton Preferences." Rimnol. Oceanogr. 22(6):996-1011.
- McErlean, A.J., C. Kerby, R.C. Swartz, and L.C. Kohlenstien. 1972. "Conclusions and Recommendations" Ches. Sci. 13 Suppl:58-516.
- Mackiernan, G.B. 1968. Seasonal Distribution of Dinoflagellates in the Lower York River, Virginia. M.A. Thesis. College of Williams and Mary. VIMS. 122 pp.
- Marsh, G.A. 1973. "The Zostera epifaunal community in the York River, Virginia." Ches. Sci. 14:87-97.
- Marshall, H.G. 1966. "The Distribution of Phytoplankton along a 140-mile Transect in the Chesapeake Bay." Va. Journal of Science 17(2):105-119.
- \_\_\_\_\_. 1967. "Plankton in James River Estuary, Virginia. I: Phytoplankton in Willoughby Bay and Hampton Roads." Ches. Sci. 8(2): 90-101.
- Maryland Dept. of Natural Resources. 1967-1968. Unpublished Data from Wetland Habitat Inventory. Water Resources Administration, Annapolis, MD.
- Maryland Dept. of Natural Resources. 1975-1979. Maryland Midwinter Waterfowl Surveys, Waterfowl Population Estimates. MD, DNR, Wildlife Administration, Annapolis, MD.
- Maurer, D., L. Watling, P. Kinner, and C. Wethe. 1978. "Benthic Invertebrates Assemblages of Delaware Bay." Marine Biol. 45:65-78.
- Metzgar, R.G. 1973. Wetlands in Maryland. Pub. #157. Dept. of State Planning DNR, Dept of Economic & Comm. Dev., Baltimore, MD.
- Morse, D.C. 1947. "Some observations on seasonal variations in plankton population, Patuxent River, Maryland, 1943-1945." Chesapeake Bio. Lab. Publ. No. 65, May 1947, 21 pp.

- Mountford, K. 1977. "Phytoplankton and Primary Productivity" IN: Academy of Natural Sciences of Philadelphia. Morgantown Station and the Potomac Estuary: a 316 environmental demonstration. Vol. II. PEPCO Report by ANSP, Sept. 1977.
- Mountford, N.K., A.F. Holland, and J.A. Mihursky. 1977. "Identification and Description of Macrobenthic Communities in the Calvert Cliffs Region of the Chesapeake Bay." Ches. Sci. 18(4):360-369.
- Mulford, R.A. 1972. "An Annual Plankton Cycle on the Chesapeake Bay in the Vicinity of Calvert Cliffs, Maryland." June 1969-May 1970. Proc. Acad. Nat. Sci. Phila. 124(3):17-40.
- Munro, . 1979. Unpublished data. Migratory bird habitat Research Laboratory, Patuxent, Maryland.
- National Marine Fisheries Service. 1976. Fishery Statistics of the United States, 1973. Statistical Digest No. 67. U.S. Government Printing Office, Washington, D.C.
- . 1977. Fishery Statistics of the United States, 1974. Statistical Digest No. 68. U.S. Government Printing Office Washington, D.C.
- . 1978. Fishery Statistics of the United States, 1975. Statistical Digest No. 69. U.S. Government Printing Office, Washington, D.C.
- NOAA. 1976. Fisheries of the United States, 1975. U.S. Dept. of Commerce, NOAA/NMFS, Washington D.C. Current Fisheries Statistics No. 6900. 100 pp.
- . 1977. Fisheries of the United States, 1976. U.S. Dept. of Commerce, NOAA/NMFS, Washington, D.C. Current Fisheries Statistics No. 7200. 96 pp.
- . 1978. Fisheries of the United States, 1977. U.S. Dept. of Commerce, NOAA/NMFS, Washington, D.C. Current Fisheries Statistics No. 7500. 112 pp.
- . 1979. Fisheries of the United States, 1978. U.S. Dept. of Commerce, NOAA/NMFS, Washington, D.C. Current Fisheries Statistics No. 7800. 120 pp.
- Orth, R.J. 1973. "Benthic Infauna of Eelgrass, Zostera marina, beds." Ches. Sci. 14(4):258-269.
- . 1975. "Destruction of Eelgrass, Zostera marina, by the Cownose Ray, Rhinoptera Bonasus, in the Chesapeake Bay." Ches. Sci. 16(3):205-208.

- Orth, R.J., K.A. Mcore, and H.H. Gordon. 1979. Distribution of Abundance of Submerged Aquatic Vegetation in the Lower Chesapeake Bay, Virginia. Final Report to EPA, NO. 600/8-79-029/SAV 1, 199 pp.
- Patten, B.C., R.A. Mulford, and J.E. Warinner. 1963. "An Annual Phytoplankton Cycle in the Lower Chesapeake Bay" Ches. Sci. 4(1):1-20.
- Penhale, P.A. 1977. "Macrophyte-epiphyte Biomass and Productivity in an Eelgrass (Zostera marina) Community." J. Exp. Mar. Biol. Ecology 26:211-224.
- Perry, M.C. and F.M. Uhler. 1976. Availability and Utilization of Canvas-back Food Organisms in Chesapeake Bay. Pres. at Atlantic Estuarine Res. Soc. Conf., Rehobeth Beach, Del. 6-8 May 1976.
- Pfitzenmeyer, H.T. 1961. "Benthic Shoal Water Invertebrates from Tidewaters of Somerset County, Maryland" Ches. Sci. 2(1-2):89-94.
- . 1970. "Benthos" IN: Gross Physical and Biological Effects of Overboard Spoil Disposal in Chesapeake Bay. (Interim and Final Reports). Final Report, NRI Spec. Rep. #3.
- . 1973. Hydrographic and Ecological Effects of Enlargement of the Chesapeake and Delaware Canal. Appendix III. "Benthos of Maryland Waters in and near C&P Canal." NRI Ref. #73-113. CBL, Univ. of Maryland, CBI, Johns Hopkins Univ., College of Mar. Studies, Univ. of Delaware. 38 pp.
- . 1975. Benthos. IN: A Biological Study of Baltimore Harbor. CEES, Univ. of Maryland. Spec. Rep. No. 6, 115 pp.
- . 1976. "Some Effects of Salinity on the Benthic Macro-invertebrates of the lower Potomac" IN: The Potomac Estuary Biological Resources, Trends and Options." Mason, W.T. and K.C. Flynn (ed.). Sympos. Proc., Interstate Comm. Potomac R. Basin Tech. Publ. 76-2, 140 pp.
- Polgar, T.T., G.M. Krainak, and H.T. Pfitzenmeyer. 1975. A Methodology for Quantifying the Responses of Benthic Communities to Environmental Perturbations. Morgantown Monitoring Program Rep. Ser. REF. No. MT-75-2. January 1975. 35 pp. & appendices.
- Pritchard, D.W. 1956. "The Dynamic Structure of a Coastal Plain Estuary." J. Mar. Research 15:33-42.
- . 1967. "Observations of Circulation in Coastal Plain Estuaries" IN: Estuaries. G.H. Lauff (ed.). American Assoc. Adv. Sci. Publ. 83, Washington, D.C.

- Rawls, C.K. In press. Food Habits of Waterfowl in the upper Chesapeake Bay. CBL. unpublished M.S.
- Reinharz, E., O. Bricker, and A. O'Connell. 1979. Chesapeake Bay Earth Science Study; Animal-Sediment Relationships. EPA Chesapeake Bay Program Data Report. 8 pp.
- Rhoads, D.C. and D.K. Young. 1970. "The Influence of Deposit-Feeding Organisms on Sediment Stability and Community Trophic Structure." J. Mar. Res. 28:150-178.
- Ritchie, D.E. Jr. 1970. "Fish." IN: Gross Physical and Biological Effects of Overboard Spoil Disposal in Chesapeake Bay. (Interim and Final Report) Final Report, NRI Spec. Rep. #3
- Rupp, N.H. 1969. Seasonal and Spatial Distribution of Acartia tonsa and A. clausi in Chesapeake Bay. MA Thesis, Johns Hopkins University, 45 pp.
- Sage, L.E., J.M. Summerfield, and M.M. Olson. 1976. "Zooplankton of the Potomac Estuary" IN: The Potomac Estuary: Biological resources, trends and options. W.T. Mason and K.C. Flynn (eds.). Symp. Proc., Interstate Comm. for the Potomac River Basin, ICPRB Tech. Publ. 76-2, 140 pp.
- Sage, L.E. and M.M. Olson. 1977. "Zooplankton" IN: Morgantown Station and the Potomac Estuary: a 316 environmental demonstration. Vol. II. PEPCO Report prepared by ANSP.
- Sandifer, P.A. 1973. "Distribution and Abundance of Decapod Crustacean Larvae in the York River Estuary and Adjacent Lower Chesapeake Bay, Virginia, 1968-1969." Ches. Sci. 14(4):235-257.
- \_\_\_\_\_. 1975. "The Role of Pelagic Larvae in Recruitment to Populations of Adult Decapod Crustaceans in the York River Estuary and Adjacent Lower Chesapeake Bay, Virginia." Estuarine & Coastal Mar. Sci. 3:269-279.
- Schubel, J.R. 1972. "The Physical and Chemical Conditions of the Chesapeake Bay." J. Wash. Acad. Sci. 62(2):56-87.
- Scott, R.F. and J.G. Boone. 1973. Fish Distribution in Various Areas of Maryland Tidewater as Derived from Shore Zone-seining 1956-1972. Md. Dept. Nat. Res. Fish. Admin., Annapolis MD.
- Seliger, H.H., M.E. Loftus, and D.V. Subbarao. 1975. "Dinoflagellate Accumulations in Chesapeake Bay." IN: V.R. LoCicero (ed.) Proc. First Intern. Conf. on Toxic Dinoflagellate Blooms, Nov. 1974, Mass. Sci. & Technol. Found. Wakefield, Mass.

- Sharaf El Din, S.H. 1977. "Effect of Aswan High Dam on the Nile Flood and on the Estuarine and Coastal Circulation Pattern along the Mediterranean Egyptian Coast." Limnol. Oceanogr. 22:194-207.
- Shea, G.B. 1976. Evaluation of Pocomoke River Swamp, Worcester County, Maryland, for Designation as a National Natural Landmark. National Park Service, Philadelphia, PA.
- Smith, R.F., A.H. Swartz, and W.H. Massman. 1966. A Symposium on Estuarine Fisheries. Am. Fisheries Soc. Spec. Publ. No. 3, 154 pp.
- Smithsonian Institution. 1975. Compendium of Natural Features Information, Vols. I and II. Center for Natural Areas and Maryland Dept. of State Planning. Annapolis, MD.
- Snedaker, S., D. deSylva, and D. Cottrell. 1977. A Review of the Role of Freshwater in Estuarine Ecosystems. U. Miami School of Marine Science, Final Report to S.W. Fla. Water Management District, May 1977, 126 pp.
- Sprague, V. E.A. Dunnington, and E. Drobeck. 1969. "Decrease in Incidence of Minchinea Nelsoni in Oysters Accompanying Reduction of Salinity in the Laboratory." Proc. Nat. Shellfish. Assoc. 59:23-26.
- Stevenson, J.C. and N.M. Confer. 1978. Summary of Available Information on Chesapeake Bay Submerged Aquatic Vegetation Biological Services Program, FWS/OBS-78/66. MD. Dept. of Natural Resources, U.S. EPA Fish and Wildlife Service, Annapolis, MD, Dept. of the Interior, Washington, D.C. 335 pp.
- Stewart, R.E. 1962. Waterfowl Populations in the Upper Chesapeake Region. U.S. Fish and Wildlife Serv. Spec. Sci. Rep. No. 65, 208 pp.
- Stroup, E.D, AND R.J. Lynn. 1963. "Atlas of Salinity and Temperature Distributions in Chesapeake Bay 1962-1961 and Seasonal Averages." 1949-1961. Graphical Summary Report 2 Ref. 63-1, CBI, Johns Hopkins Univ., Baltimore, MD. 410 pp.
- Swartz, R.C. 1972. "Biological Criteria of Environmental Change in the Chesapeake Bay." Ches. Sci. 13 Suppl:17-41.
- Taft, J.L. and W.R. Taylor. 1976. "Phosphorus Distribution in the Chesapeake Bay." Ches. Sci. 17:67-73.
- Tagatz, M.E. 1968. "Biology of the Blue Crab, Callinectes sapidus, in the St. John's River, Florida." Fish. Bull. 67:17-33.
- Tyler, M.A. and H.H. Seliger. 1978. "Annual Subsurface Transport of a Red Tide Dinoflagellate to its Bloom Area: Water Circulation Patterns and Organism Distributions in the Chesapeake Bay." L&O 23(2):227-246.

- U.S. Army/Corps of Engineers - Baltimore District. 1973. Existing Conditions Report. Appendix C, The Bay, Processes and Resources. Baltimore, MD.
- \_\_\_\_\_. 1977. Chesapeake Bay Future Conditions Report. Vol. II, Biota. Baltimore, MD.
- U.S. Fish & Wildlife Service. 1979. "List of Endangered and Threatened Wildlife and Plants" Federal REG. 44(12):3636-3654.
- Van Engel, W.A. 1958. "The Blue Crab and Its Fishery in Chesapeake Bay, Part I: Reproduction, Early Development, Growth, and Migration." Comm. Fish. Review 20 (6):6-17.
- Van Valkenburg, S.D. and D.A. Flemer. 1974. "The Distribution and Productivity of Nanoplankton in a Temperate Estuarine Area." Estuarine & Coastal Marine Sci. 2:311-322.
- Van Valkenburg, S.D., J.K. Jones and D.R. Heinle. 1978. "A Comparison by size, class and volume of detritus versus phytoplankton in Chesapeake Bay." Estuarine and Coastal Mar. Sci. 6:569-582.
- Virginia Commission of Game and Inland Fisheries 1975-1979. Virginia midwinter Waterfowl Surveys, Waterfowl Population Estimates. Va. Comm. of Game and Inland Fisheries, Tappahannock, VA.
- Virginia State Wetlands Survey Series 1973-1979. VIMS SRAMSOE Reports: 45, 47, 53, 58, 59, 60, 62, 63, 64, 108, 118, 137, 138, 139, 167, 169, 187, 188 (various authors).
- Virnstien, R.W. 1977. "The Importance of Predation by Crabs and Fishes on Benthic Enfauna in Chesapeake Bay." Ecology 58:1199-1217.
- \_\_\_\_\_. 1979. "Predation on Estuarine Infauna: Response Patterns of Component Species." Estuaries 2(2):69-86.
- Wass, M.L. (ed.) et al. 1972. A Checklist of the Biota of Lower Chesapeake Bay. Spec. Sci. Report #65. VIMS, Gloucester Point, VA. 290 pp.
- Wells, H.W. 1961. "The Fauna of Oyster Beds, with Special Reference to the Salinity Factor." Ecol. Mono 31:239-266.
- Whittaker, R.H. 1970. Communities and Ecosystems. The Mac-Millan Co., New York. 158 pp.

Willner, G.R., J.A. Chapman and J.R. Goldsberry. 1975. A Study and Review of Muskrat Food Habits with Special Reference to Maryland. MD Wildlife Admin., Publ. Wild. Ecol. 1. 25 pp.

Wolff, W.J. 1973. "The Estuary as a Habitat. An analysis of data on the soft bottom macrofauna of the estuarine area of the Rivers Rhine, Meuse, and Scheldt." Zool. Verhandl. 126:1-243.

Wood, L.H. and W.J. Hargis Jr. 1971. "Transport of Bivalve Larvae in the Tidal Estuary." IN:D.J. Crisp (ed.). Fourth European Marine Biology Symposium, Cambridge University Press, Cambridge.

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