W.P.
10597
C.2
Coastal Zone Information Center

AN ATLAS OF DELAWARE'S WETLANDS AND ESTUARINE RESOURCES

COASTAL ZONE INFORMATION CENTER
AUG 16 1977

TECHNICAL REPORT NUMBER 2 NOVEMBER 1976
DELAWARE COASTAL MANAGEMENT PROGRAM

Delaware Coast Management Program (State Planning Office)

D.P.

10597
C.2

AN ATLAS OF DELAWARE'S WETLANDS AND ESTUARINE RESOURCES

Technical Report Number 2

Delaware Coastal Management Program

November 1976

Property of CSC Library

Original Manuscript Prepared by:

Franklin C. Daiber
Lawrence L. Thornton
Karen A. Bolster
Thomas G. Campbell

Oliver W. Crichton
Gerald L. Esposito
David R. Jones
John M. Tyrawski

College of Marine Studies
University of Delaware
Newark, Delaware

COASTAL ZONE
INFORMATION CENTER

June 30, 1976

U.S. DEPARTMENT OF COMMERCE NOAA
COASTAL SERVICES CENTER
2234 SOUTH HOBSON AVENUE
CHARLESTON, SC 29405-2413

Under Contract to:

Delaware State Planning Office
Thomas Collins Building
Dover, Delaware 19901

This publication is financed in part through a federal grant from the Office of Coastal Zone Management, NOAA under the provision of Section 305 of the Coastal Zone Management Act of 1972 (Public Law 92-583).

Delaware Coastal Management Program (State Planning Office

GB459.4 .D49 no.2
3529169

APR 2 1 1997

TABLE OF CONTENTS

	Page
Acknowledgements	
Introduction	
Section I - Wetlands	
General Principles of Wetlands Ecosystems	1
Wetlands and Estuarine Productivity	10
Edaphic Algae	12
Phytoplankton	13
The Emergent Grasses	14
Animals and Wetlands	20
The Relationship Between Wetlands and Estuarine Water Quality	29
Silt	29
Sewage	31
Heavy Metals	34
Oil Pollution	37
Thermal Pollution	42
Pesticides	42
The Role of Wetlands in Estuarine Hydraulics	44
Definition and Classification of Wetlands	47
Definition of Wetlands	47
Predominant Plants of Delaware's Wetlands	53
Wetlands Classification System	71
Wetlands Zones and Properties	71
Wetlands Zones and Associated Vegetation	74
Zone I, Cordgrass Marsh	76
Zone II, Salt Meadow Marsh	78
Zone III, Salt Bush - Salt Meadow Marsh	80
Zone IV, Reed Grass Marsh	82
Zone V, Transition Marsh	84
Zone VI, Arrow-Arum - Pickerel Weed Marsh	86
Wetlands Atlas (Maps)	88
Wetlands Drainage Areas	115
Results of Mapping	115
Discussion of Drainage Areas	121
Survey of Delaware's Wetland Drainage Areas	125
Wetlands Destruction	165
Dredging and Bulkheading	165
Definition and Description	165
Impact	167
Beneficial Effects	171
Discussion	171
Factors Which Could Mitigate	172
Spoil Disposal	176

TABLE OF CONTENTS (continued)

	Page
Effects of Spoil	176
Beneficial Effects	182
Recommendations	182
Impounding	185
Definition and Description	185
Effects	186
Ditching	195
Definition and Description	195
Adverse Effects	196
Vegetation Type	198
Beneficial Effects	199
Mitigating Measures	200
Conclusions and Recommendations	202
Waste Disposal	205
Solid Waste Disposal	206
Liquid Waste Disposal	208
Residential, Commercial and Industrial Development	211
Marinas	224
Recommendations	232
Agriculture	233
Sediments	233
Nutrients	235
Pesticides	236
Environment Parameters	241
Dissolved Oxygen and Its Relationship to Estuarine Organisms	241
Temperature and Estuarine Organisms	254
Turbidity	267
Salinity	268
Tidal Flushing	277
Toxic Materials	283

Section II - Estuarine Resources

Introduction to Estuarine Inhabitants - Life Histories	285
The "Typical" Fish	285
Skates	289
Atlantic Sturgeon	297
The American Eel	303
The Herrings	309
Atlantic Menhaden	317
The Bay Anchovy	323
Freshwater Catfishes	329
Mummichog	335
Striped Killifish	341
Atlantic Silverside	345
The White Perch	351

TABLE OF CONTENTS (continued)

	Page
Striped Bass	355
Winter Flounder	359
Yellow Perch	365
Bluefish	373
Spot	377
Atlantic Croaker	381
Weakfish	387
The Northern Puffer	393
Summer Flounder	399
The Hogchoker	403
Jellyfish	409
Comb Jellies	415
The Hard Clam	417
The American Oyster	425
Oyster Drills	431
The Blue Crab	437
Zooplankton	443
Sources for Environmental Requirements	467
General References for Fishes	473
Introduction to Aves - Life Histories	475
The Great Blue Heron	479
Cattle Egret	484
The Snowy and Common Egrets	488
The Green Heron	490
The Black-Crowned Night Heron	493
Canada Goose	496
Snow Goose	499
Mallard	502
Black Duck	505
Pintail	508
Green-Winged Teal	510
Wood Duck	512
Scoters	516
Clapper Rail	519
King Rail	521
Virginia Rail	524
References for Shorebirds and Waterfowl	527

TABLES

Table		
1	A List of the Common and Scientific Names of Those Species of Plants Used to Define and Delineate the Wetlands of the State of Delaware According to the Wetlands Act of 1972	52
2	Area of Wetlands Contained in Each Drainage Area	118

TABLE OF CONTENTS (continued)

Table		Page
3	Percent Composition of Wetland Drainage Areas by Vegetative Zones in 1973: Percent of Wetlands Lost to Construction or Impoundment Since 1938	119
4	Total Attendance at the Five State Parks in the Coastal Zone (1965-1970)	226
5	Sales of Boat Licenses in Delaware (1962-1970)	226
6	Land Ownership in Delaware's Coastal Zone (1970)	227
7	Development of Delaware's Little Bays (1938-1969)	227
8	Grouping from the Literature of Selected Estuarine and Marine Fishes According to Physiological Studies and Studies on Their Resistance, Tolerance and Oxygen Consumption	247
9	Cumulative Annual Growth of Summer Flounder by Sex	400

ILLUSTRATIONS

Figure		
1	The Relationship Between Salinity and Plant Zonation in a Delaware Salt Marsh	7
2	Estuarine Food Chain	19
3	Arrow-Arum	54
4	Arrowhead	55
5	Cattails	56
6	Big Cordgrass	57
7	Salt Marsh Cordgrass	58
8	Groundsel Bush	59
9	High Tide Bush	60
10	Marsh Mallow	61
11	Pickerelweed	62
12	Pickerelweed	63
13	Reed Grass	64
14	Rush	65
15	Spike Grass	66
16	Salt Hay	67
17	Threesquare	68
18	Tide Marsh Water Hemp.	69
19	Wild Rice	70
20	Zone I, Cordgrass Marsh	77
21	Zone II, Salt Meadow Marsh	79
22	Zone III, Salt Bush - Salt Meadow Marsh	81
23	Zone IV, Reed Grass Marsh	83
24	Zone V, Transition Marsh	85
25	Zone VI, Arrow-Arum Marsh	87
26	Generalized Wetland Atlas, Key Map	89
27-50	Generalized Wetland Atlas	90
51	Wetland Drainage Areas of Delaware	117

TABLE OF CONTENTS (continued)

Figure		Page
52	Illustration of Vegetative Zones Within a Drainage Area: #11, St. Jones River	120
53	Longitudinal Section of a Dredge Lagoon, Typical of the Development Around the Small Bays in Delaware	169
54	Dredging	174
55	Dredging	174
56	Rip Rap and Bulkhead	175
57	Bulkheading	175
58	Dredge Spoil Disposal	179
59	Solid Waste Used as Fill	179
60	Dredge Fill and Bulkhead	180
61	Dredge Spoil Disposal Pile	180
62	Impoundment	192
63	Impoundment	192
64	Sluice Gate	193
65	Tide Gate	193
66	Ditching	203
67	Ditching	203
68	Solid Waste Disposal	210
69	Solid Waste Disposal and Bulkhead	210
70	Land Use Change: Masseys Landing Area - 1938	218
71	Land Use Change: Masseys Landing Area - 1954	219
72	Land Use Change: Masseys Landing Area - 1973	220
73	Dredge Lagoon and Mobile Home Development	221
74	Marina	231
75	Marina	231
76	Suspended Sediment Concentration Map	234
77	Environmental Dissolved Oxygen Concentration	250
78	Relationship Between Estimated Natural and Acceptable Seasonal Minimal Oxygen Concentrations	250
79	Molecular Movement Explanation	272
80	Salinity Distribution of Delaware's Tidal Wetlands	276
81	Tidal Flushing Map of Delaware	282
82	Diagram of Typical Fish With Terms Used in Life Histories	286
83	Clearnose Skate	294
84	Little Skate	295
85	Atlantic Sturgeon	300
86	American Eel	307
87	Alewife	312
88	American Shad	313
89	Blueback Herring	314
90	Atlantic Menhaden	319
91	Anchovy	326
92	White Catfish	331
93	Channel Catfish	332
94	Brown Bullhead	333
95	Mummichog	338

TABLE OF CONTENTS (continued)

Figure		Page
96	Striped Killifish	343
97	Atlantic Silverside	349
98	White Perch	353
99	Striped Bass	357
100	Winter Flounder	362
101	Yellow Perch	369
102	Bluefish	375
103	Spot	379
104	Croaker (Hardhead)	384
105	Weakfish (Sea Trout)	390
106	Northern Puffer	395
107	Summer Flounder	401
108	Hogchoker	406
109	Jellyfish	413
110	Quahog (Hard Clam)	421
111	American Oyster	428
112	Oyster Drill	433
113	Blue Crab	440
114	Copepod - Summer Distribution, Acartia tonsa	444
115	Copepod - Winter Distribution, Acartia tonsa	445
116	Copepod - Summer Distribution, Eurytemora (h & a)	446
117	Copepod - Winter Distribution, Eurytemora (h & a)	447
118	Copepod - Summer Distribution, Pseudodiaptomus coronatus	448
119	Copepod - Winter Distribution, Pseudodiaptomus coronatus	449
120	Copepod - Summer Distribution, Centropages (t & h) and Temora longicornis	450
121	Copepod - Winter Distribution, Centropages (t & h) and Temora longicornis	451
122	Copepod - Summer Distribution, Cyclops viridis	452
123	Copepod - Winter Distribution, Cyclops viridis	453
124	Amphipod - Summer Distribution, Gammarus fasciatus	454
125	Amphipod - Winter Distribution, Gammarus fasciatus	455
126	Oppossum Shrimp - Summer Distribution, Neomysis americana	456
127	Oppossum Shrimp - Winter Distribution, Neomysis americana	457

ACKNOWLEDGEMENTS

Throughout the course of the Wetlands and Water Resources Atlas project, our group has relied on the thoroughness and excellence of scientists, past and present, who have worked in Delaware's wetlands and on her tidal waters. Certainly we cannot begin to thank all those from whom we have borrowed ideas, concepts and facts.

However, we would like to acknowledge first, all those at the College of Marine Studies who helped us uncover and collect data -- a task which was vital to our overall effort.

Secondly, thanks to our friends in the State Planning Office who worked with us constantly, Mssrs. Dave Hugg and Ben Coston. Mention should also be given to our two "watchdogs", Joel Goodman and Paul Jensen. We would also like to recognize Norman Wilder, Charlie Lesser, Betty Ann Allen and Jack Linehan for their input to our Survey of Delaware's Tidal Wetlands.

And, last, but as usual, not least, we are greatly indebted to Ms. Ellen Ganzman for her typing skill, patience, and always smiling face.

Larry Thornton
Technical Director
Delaware Wetlands and Water
Resources Atlas Project

INTRODUCTION

It has been nearly twenty years since Delaware has produced an authoritative and comprehensive inventory and assessment of the State's wetlands and water resources*. Most of the changes since then, both good and bad, have resulted from the deliberate actions of man. This report, then, should be a valuable tool for those who have an interest in actions that in some way would affect the wetlands of the State.

It should be remembered, though, that a study of the wetlands cannot stop right at the wetlands boundaries. There are numerous interchanges occurring which inextricably tie the wetlands to their surroundings. For instance: there are exchanges of water and air (and their contaminants); animals migrate; fish may spawn in one area and spend all or a part of their adult lives in another place; deer often browse in the marshes and sleep and seek shelter in the uplands; birds and fur-bearing mammals carry and drop seeds from other places; and so forth. These are but a few of literally hundreds of examples that we can find of these interchanges. It quickly becomes evident that wetlands are not only of great importance in their own right but that they are a part of a larger, complex system.

For effective wetlands management, it is also necessary for one to understand the interrelationships that exist within and between the wetlands and the water resources of Delaware. This report provides the background data that is necessary for such an understanding.

Delaware has a wetlands law that carefully defines the legal boundaries of the State's wetlands. This report complements that law by presenting the biological involvement of the wetlands. This is done by first presenting the

*Delaware State Coordinating Committee, 1959, State of Delaware - Intrastate Water Resources Survey.

principles of the processes which are at work in the wetlands. Then, the life histories of the shorebirds, fish and other marine life are described in the text, and where appropriate, by graphic presentations.

In the report, wetlands are classified, in most cases, by the predominant type(s) of vegetation. In Delaware there are eight zones of wetlands. Their characteristics have been identified, and maps have been prepared showing the extent of the different zones.

It is generally agreed that certain activities are harmful to wetlands. For instance, dredging adversely affects the benthic (occurring at the bottom of a body of water) organisms in a body of water, and this is often doubly destructive since additional environmental damage usually occurs wherever the dredged material is deposited, whether at the site or in deeper water. Most development activities in the wetlands have visible environmental impacts, with some, such as landfills, dredging, and spoil disposal being very destructive to living things. Other activities, such as impounding, draining and crop harvesting, may be harmful in some respects, but they may be beneficial in providing food or shelter for plants or animals that did not previously inhabit the area.

There is a lot of truth in the statement that "an environment cannot be destroyed; it can only be altered". It is hoped, however, that this report will be used in weighing the consequences of a proposed activity so that conflicts between progress and the environmental integrity of our wetlands will be reduced to a minimum.

Described in the report are the habits and occurrences of the wetlands wildlife. Also, the environmental parameters (the life-sustaining limits of several measurable things, such as oxygen, temperature, etc.) are given for many of the estuarine wildlife species. In addition, maps showing distribution

information about the adult and juvenile populations, spawning areas, and other data are included for the estuarine species. The environmental parameters and the maps, together, show that minute variations in one or more of the critical parameters can shift or eliminate a whole population. Companion maps show the flushing actions and the salinity levels of Delaware's tidal waters, both of which have significant effects on the types of plant and animal life which occur in the wetlands.

In addition to the reference lists which are specifically noted in the Table of Contents, there are specialized reference lists following most sections of this report.

In Delaware, as in many other places, wetlands continue to be lost as development irreversibly takes parcel after parcel of land from the inventory of natural wetlands. It is hoped that the information presented in this report will be used as a guide by the citizens of Delaware when weighing the consequences of proposed activities which would have an impact on our wetlands and water resources.

This is Technical Report Number Two, prepared by the College of Marine Studies as part of the Delaware Coastal Management Program. The recommendations included are solely those of the authors and do not necessarily reflect the opinions or support of the Delaware State Planning Office or the Office of Coastal Zone Management of the U.S. Department of Commerce.

SECTION I

WETLANDS

SECTION I - WETLANDS

GENERAL PRINCIPLES OF WETLANDS ECOSYSTEMS

Looking out upon the marshes and wetlands of Delaware, it might appear that they are simple ecosystems. Only a few types of plants and animals live in such a habitat and of those that do, one or two species tend to dominate. In Delaware's salt marshes, cordgrass (S. alterniflora) dominates almost every marsh. Similarly, a few types of animals such as the fiddler crabs, marsh mussels and clapper rails dominate the marsh animal world.

Researchers are discovering that the simplicity that we associate with the wetlands is far more a reflection of our lack of understanding of these dynamic ecosystems rather than a reflection of the true nature of tidal marshes. Wetlands organisms have to contend and interact with a combination of biological, physical, chemical, and geological processes to which organisms in other ecosystems are not normally exposed. The fact that few species are present in the marshes is indicative, then, of an extremely stressful ecosystem in which few animals and plants can successfully thrive.

Similarly, the apparent stability seemingly evident among some mature wetlands ecosystems is not an indication that the processes of ecologic activity have ceased to occur or have been reduced in intensity. The stable wetland ecosystems, like a mature forest, are comprised of many complex processes that have successfully adjusted to one another but which do not necessarily change the outward appearance of the forest or marsh itself. The history of marshes and wetlands is one in which these numerous and complex processes are continually changing and interacting with one another. Marshes and wetlands, although they appear to be static, are truly complex and dynamic systems.

In considering the principles underlying wetlands ecosystems, it becomes difficult to identify and discuss individual processes one from another. They are all interdependent, each affecting the expression of the others in important,

sometimes subtle ways. It is the biotic or biological component -- the most obvious to the casual observer -- which is usually considered the culmination of the other processes responsible for marsh and wetland development. However, it is the non-biotic factors; the chemical, physical and geologic processes, which make the rules and mold the environment with which the biotic community must contend.

Non-biotic processes active in wetlands ecosystems can be grouped into two general categories, those that act continuously and occur on a somewhat regular basis, and those that are noncontinuous which occur more sporadically and which might be considered abnormal or extreme events. In the first category would be included such parameters as the tides, stream flow, light, temperature, and sedimentation cycles, and in the second such occurrences as storms, fires, and man-induced disturbances. It is not always easy to determine which group of factors has the greatest effect on the development of the system. At first, it might seem that the continuously acting factors would dominate since they affect the system directly at all times. However, one major storm, one man-made ditch or one large pollution point source can easily influence the wetland system for long periods of time. The effects of extreme events are not easily quantified or well understood but it must be kept in mind that they are important.

It is generally agreed that tidal inundation, drainage, and, to a large extent, salinity are the most important non-biotic factors which determine plant and animal distribution in the wetlands. Delaware has a variety of saltwater systems that are affected by tides and influenced by salinity. The large Delaware Bay, an estuary, is the most obvious, but we also have barrier bays (Indian River, Rehoboth and Assawoman Bays), small estuaries at the mouth of our tidal rivers (Mispillion, St. Jones, etc.) and the tidal creeks and guts located farther inland. The specifics of the tidal inundation in each of these systems

is different from the others.

The tides have several components which determine the kinds of effects that they have on a wetland system -- their intensity, vertical inundation, range and rhythm. The intensity of the tides refers to the amount of water and the force with which the water flows through the system and it determines the magnitude of the mechanical disturbance to the area. The vertical range is an indication of the height the water reaches on high tides, and so, determines how far the chemical effects of the saltwater will be carried up the banks of a tidal stream. The rhythm of tides refers to the natural frequencies of the tides.

The tides operate on a lunar rhythm which is out of phase with the diurnal rhythm of day and night; therefore, as the high and low tides progress through the lunar month (28 days) they occur at different times of the day and reach different heights each day. In Delaware, there are generally two high tides and two low tides in a day with the high and low tides occurring approximately one hour later from day to day. The dominant factors affecting the height and frequency of tides are the gravitational forces of the moon and the sun, but other factors are involved.

Due to the varying gravitational effects of the moon and sun, there occur each lunar month two spring tides and two neap tides. A spring tide is characterized by higher than normal high tides and lower than normal low tides which results in a large tidal range. A neap tide has lower than normal extremes in tide height which result in a small tidal range. Spring tides occur near the times of new and full moons; neap tides occur midway between spring tides. The actual level reached by any high or low tide depends on local factors of topography, stream flow, wind speed and direction in addition to the astronomical influences of the moon and sun.

In a tidal cycle, for instance, one marsh (or one area of a particular marsh) might be inundated at high tide for a different period of time than another marsh (or another area of the same marsh). Such emergence-submergence patterns, as they are called, determine how long particular areas are in direct contact with saltwater, and hence how great the influence of saltwater is on the plants and organisms covered. Although the height and time of the tides is predictable, the prediction is never exact.

The distribution and penetration of the salt contained in seawater into the wetland system is probably the most important parameter controlled by the tides. The salt concentrations of the soils, sediments and water are dominant factors determining the structure and zonation of the biological communities of marshes and wetlands. High salt concentrations dictate that only organisms having specialized and efficient means of eliminating large amounts of toxic salts, or those which have developed some kinds of immunities to these toxic effects, will be able to survive in saltwater inundated areas. The number of plants and animals that can withstand the saline conditions of the salt and brackish water marshes is indeed small.

While the simple presence or absence of salt is in itself important, the nature of the fluctuations occurring in the salt concentrations in particular marsh areas is equally important. Flooding tides in near shore environments are characterized by high salinity water due to the relative amounts of salt and freshwater in the system during these different tidal cycle stages. (See Map of Salinity Distribution of Delaware.) Most areas in the marshes then are exposed to waters of varying salinities periodically throughout the day. Depending on how far up or downstream a particular area is or how far away from the stream channel an area is, the degree of saline fluctuations can vary greatly. It is much more difficult for organisms to adapt to very greatly

fluctuating salinity conditions than it is for them to adapt to a less fluctuating though possibly higher salt environment. Species that can withstand a mean salinity level of 17‰ in an area with a salinity range of 16-18‰ might not be able to withstand a mean salinity level of 17‰ in an area where the range is 5-25‰.

In addition to the salinity regime of the waters, there are also important salinity regimes of the soils and sediments. Since the salts tend to be retained, translocated and often concentrated in the soils, the soils have important effects on the distribution of salt in any system. Areas which are only infrequently inundated with saltwater can have soils or sediments with very high salt concentrations, for as the tidal water percolates through the soil and/or evaporates, the salts remain in the soil. Every time the area is washed with saltwater, more salt is added to the soil. The salt concentration does not increase indefinitely for only so much salt will be retained in the soil depending on the soil type, frequency of innundation, precipitation cycles and groundwater levels. But soil salinities must be included in those important parameters controlling the structure of the biological communities of marshes and wetlands. In salt pannes, located in areas above mean high water, the salinity of the soil can exceed 100‰ (see Figure 1).

The alternating cycle of inundating and receding waters affects much more than just the distributions of salt. The temperature of soils, sediments and water, the amount of light reaching the marsh surfaces, the patterns of nutrient cycling in both soils and waters, the transport of sediments, the existence of the groundwater system, the exchange of gases between organisms and their environments, the physical development of the marsh surface and all activity cycles of the marsh organisms are some of the many factors strongly influenced by the tidal cycle.

As the distance from the mouth of a creek or river increases, the effects of tidal inundation are reduced accordingly. Such changes in tidal influence can be seen in changes that occur in the nature of the marsh community as one proceeds both laterally across the marsh surfaces away from the stream channels and up the course of the stream system.

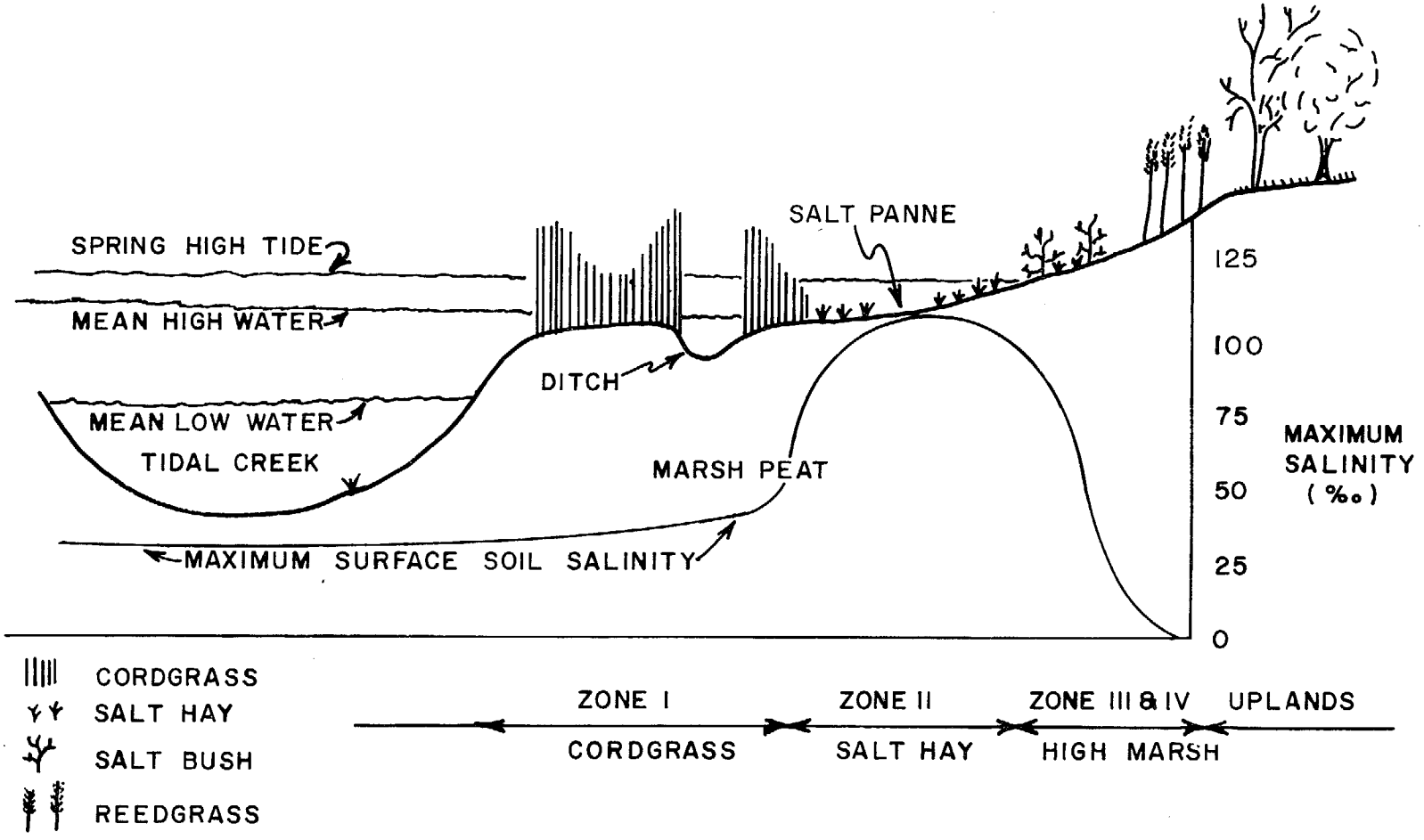
Lateral zonation of the vegetation is very characteristic of most of the marsh and wetland areas of Delaware*. Cordgrass (Spartina alterniflora, Zone I), the major grass species of Delaware's wetlands, exists in those areas most affected by tidal inundation. Along the creek banks where inundation is most frequent and water fluctuations the greatest, cordgrass is found to grow in mostly pure stands of very tall plants. The only other vegetation in this zone are the minute algal forms that grow throughout the marsh systems. As the degree of tidal inundation decreases so does the height of the Spartina community so that areas of medium sized and short plants are found behind the tall Spartina zones. Usually, these zones are pure Spartina except at their landward edges where other plants begin to appear (see Figure 1).

Salt hay (Spartina patens) and spike grass (Distichlis spicata, Zone II) are two of the common species found in areas bordering the cordgrass zone (Zone I). These species occur together as well as in almost pure stands of each depending on the characteristics of the marsh. The locations in which they are found are, topographically, slightly higher than the cordgrass areas which is the reason the salt hay-spike grass zones are not normally inundated by the tides. These plants can withstand high soil salinities but not the periodic inundations that the cordgrass can tolerate. More species such as high tide bush (Iva frustescens, Zone III) and groundsel bush (Baccharis halimifolia, Zone III) are found landward of the salt hay and spike grass where tidal influence is reduced (see Figure 1).

*See detailed discussions of Wetlands Zones.

FIGURE I

THE RELATIONSHIP BETWEEN SALINITY AND PLANT ZONATION IN A DELAWARE SALT MARSH



Some areas such as tidal creek banks are also present in which obvious vegetation is lacking. Because of the mechanical disturbances common to the creek and ditch banks in the marshes caused by water flow and activity of some crab species, grasses are often unable to successfully colonize these areas. Some of the minute, microscopic algal forms are, however, present on the exposed mud surfaces in usually very characteristic assemblages. There are also sites on the marsh surface, known as salt pannes, where the grasses are not present. Some factors, not completely understood, have created these usually small, bare areas. The chemical nature of the soils in the salt pannes is usually different from that of the surrounding marsh soils, probably accounting for the absence of the grass. Again, these salt pannes are colonized by some smaller algal forms for which the conditions of the panne are not too severe.

In concert with the floral changes one sees when traversing the marsh, are changes in the types of animals found in the particular floral zones. The crabs and snails common to the tall cordgrass (S. alterniflora, Zone I) marsh, for example, are different from those common to the salt hay marsh (D. spicata and S. patens, Zone II). Faunal zonation has not been as intensively mapped as the vegetative zonation. However, scientists unfamiliar with all the details of the faunal distributions do know that species, zones or territories do exist.

Interestingly, the relative dominance by a few species of plants in the marsh is mimicked in the faunal kingdom as well, for only a few species of animals are present in large numbers over extensive areas of the marsh surface. Other species are represented by even fewer individuals with a more limited spatial distribution. The floral zones have distinct growth forms that offer certain advantages to particular types of animals. These vegetational characteristics are augmented by characteristics of the tidal regime in different areas and partially control the distribution of animals.

The relationship between animals and vegetation is a complex one. The obvious benefits accrued by the animals from vegetation are protection and shelter as well as general habitat sites and food sources. The benefits to the vegetation are more obscure.

The influence of tidal saltwater is reduced in the upstream portions of the wetlands as sources of freshwater become more prominent. While freshwater performs many of the same functions as does the saltwater (affecting nutrient cycle, temperature cycles, detrital transport, sedimentation and erosion cycle, among others), fluctuations in the character of freshwater are of a much lower magnitude than are those of estuarine waters. The chemical composition of freshwater is relatively more stable and exhibits less of a physiological stress than waters of the intertidal areas (see Salinity and Estuarine Organisms). Some fluctuations do occur on a seasonal basis, but these are still of a lower magnitude than those fluctuations occurring daily in the strongly tidal influenced areas.

As a result of the more constant conditions and lower salinity levels, greater numbers of species are found in the upper wetlands areas (transition marsh, Zone V). As one progresses upstream through the marshes, the increased species diversity (both plant and animal) is usually very evident and well-coordinated with the decreasing salinities and degree of stressful environmental fluctuations.

Although it is relatively more difficult for most organisms to survive in the intertidal wetlands areas, those that do can receive some benefits from living in such a habitat. The major benefit is that competition from other species for the same resources is reduced, as are some predator pressures. In the low marsh areas, for example, cordgrass (S. alterniflora) finds few competitors and exists in almost pure stands over large areas bordering the bay

and tidal creeks. In areas of fresher water where cordgrass is still present, it must share the area and its resources with numerous other plants like the rushes (Scirpus sp.), marsh mallow (Hibiscus palustris), bit cordgrass (Spartina cynosuroides) and reedgrass (Phragmites communis) that can effectively compete with cordgrass in these freshwater areas.

The distinctions between high and low marsh and up- and down-stream portions of a wetland area are obviously somewhat artificial. They are as much the creations of scientists who must dissect the systems in order to understand them as they are real and distinct components of the marshes and wetlands. Such distinctions become much more artificial when considering the flow of energy through these systems. All the organisms, processes and areas are very directly connected in this regard -- without the divisions. As discussed in more detail in a following section, the productivity of the wetlands begins with the energy captured by it in various vegetative communities. Through several pathways, this energy is then channeled to other levels in the system and is eventually consumed by the numbers of fish and other animals of the estuaries. It is an intricate energy-flow system that reflects both the complex and dynamic nature of the wetlands ecosystems.

WETLANDS AND ESTUARINE PRODUCTIVITY

Except for a handful of farsighted individuals who were perceptive enough to consider the importance of the wetlands, people have historically viewed these areas more as wastelands than as anything else. Unlike the ties between man and the forests, farmlands, and cities which have always been strong and fairly obvious, those between man and marsh systems have been weaker and more obscure. As a result, people have looked upon wetlands as useless and non-productive. The main importance of the marsh systems, then, usually depended on

how they could be modified to resemble the systems more useful to man.

It is now known that the true importance of marshes and wetlands lies not in their modification potential but in their basic function as the foundations of total estuarine productivity. Our estuaries, those areas where salt and freshwaters meet, including the marshes, tidal creeks, tidal mud flats and bays, are decidely some of the most productive systems known. Man has created certain specialized agricultural systems that are extremely productive and rival the estuaries in this respect. But, he has done so only at the expense of great amounts of energy subsidies in the forms of manpower, fertilizers, pesticides and machinery. The estuarine areas, however, exhibit high productivity without the direction or input of man; they are self-fertilizing, self-sustaining energy production and transfer systems.

Each estuarine system is slightly different from all others for the conditions responsible for their development and maintenance -- the geology, the geographic location and climatic regime, the circulation and tidal patterns, and the chemical characteristics of the water -- vary greatly from estuary to estuary. Such variations are reflected in both the physical structure of the system and the assemblage of plants and animals that are characteristic of it.

What all these systems do have in common is that a large part of the productivity of the estuary is dependent on the organic material produced in the marsh and wetland areas. Green plants are the only organisms which can capture the energy of the sun and transform it into organic material. Wetlands with their various vegetative communities are the primary sources of organic material for estuaries.

Primary producers of the wetlands can be divided into three groups: the emergent grasses, the phytoplankton of the water, and the attached or edaphic

algae of the mud surfaces. Each one of these groups is present to some extent in all marsh systems. Just how much each contributes depends upon the particular characteristics of each marsh and estuary. In most cases, in fact, the contributions are yet to be adequately defined for scientists have not identified all of the factors controlling productivity. In Delaware's marshes, as in most marsh systems, it appears that the importance of the emergent grasses is far greater than either the phytoplankton or edaphic algae. The phytoplankton and edaphic algae are important for scientists are discovering that their contribution to primary productivity, although small, is an essential component of a healthy estuary.

Edaphic Algae

The edaphic algae are plants both microscopic and macroscopic which grow on the exposed mud surfaces of the marsh. They are found in numerous places in the marshes and wetlands including the open areas between individual grass stems in zones colonized by the grasses, on the banks of the tidal creeks, and on the open surfaces of the mud flats. While some of these areas can be some distance from the regular flow of the waters of the marsh, most are at least within the range of the high spring tides. Therefore, there is a direct link between these edaphic communities and other systems in the wetlands.

Most of the time, these mud algae seem very inconspicuous, especially when compared to some of the emergent grasses. In truth, the quantity of algae that can be found at any one time (the standing crop) is very small. The standing crop, however, is not really indicative of how much material these plants produce or how much energy they can provide for other groups. Each time a particular area is washed by the tides, some of the algae is removed with the receding waters. In the water they are available to the creatures that eat

the algae -- the zooplankton, small fish and benthic invertebrates, or to the bacteria that break them down if they are not directly consumed. The algae that are left on the marsh surfaces are constantly growing and reproducing so that those algae that were removed with the water are quickly replaced. This pattern of growth, loss, and rapid replacement goes on continuously. Edaphic algae are also important for the generation of oxygen during the photosynthetic process.

The lack of detailed information concerning edaphic algae productivity does not obscure the fact that these forms are important primary producers of the estuaries. This importance is further heightened by the knowledge that the edaphic algae appear to be very active in the fall and winter when the grass communities are lying dormant. During these times, the food they provide for the plant and detritus eating organisms of the estuary can be especially important.

Phytoplankton

Phytoplankton are minute plants that are found living in all natural water systems. Freshwater lakes, bogs, ponds, streams, and rivers plus tidal creeks, ponds, bays and even the upper portions of the oceans all have their own complement of phytoplankton. The forms found are very diverse but they all share the characteristic of being able to produce organic matter from sunlight, water and CO_2. The pigment systems of the phytoplankton are slightly different than those of larger plants for the sunlight used by them is that which passes through both air and water. The light available to them, then, has slightly different characteristics than that available to emergent vegetation, and the phytoplankton have adapted pigment systems to make the best use of this light.

Like the edaphic algae, the phytoplankton standing crop is usually

relatively small compared to the amount of material this community produces. Nutrients in the water are utilized by the phytoplankton for their growth, maintenance and reproduction. The phytoplankton in turn, are a food source for a host of herbivores including zooplankton such as the copepods, bivalves (such as clams and oysters) and larval fish. The crop of phytoplankton is usually kept low because increases in the numbers of phytoplankton organisms are followed quickly by increases in the number of herbivores.

As in the edaphic algae, the relationships between the phytoplankton and its predators, the grazing herbivores, the decomposing bacteria, and the nutrient supply in the water, are very complex. Phytoplankton are probably more important in the open areas of the estuary such as the bays than they are in the small tidal creeks of the true wetlands areas. But they are very productive and their productivity ultimately depends on the nutrients contributed by the wetlands areas to the entire estuary. It is difficult to set figures on how much material the phytoplankton produce; how much of this group is consumed; how much is decomposed; what amount of nutrients is involved; and finally, how much of this production ends up as a higher organism. The role of the phytoplankton as a primary producer, however, is of extreme importance to the estuary and total wetlands.

The Emergent Grasses

By far the most important group of primary producers are the grasses, which dominate the marsh landscape. While many different plants might be found in various wetlands areas throughout the state, most of the production can be traced to a few dominant species. The salt marsh cordgrass, Spartina alterniflora, is definitely the most prevalent and most important grass in Delaware's wetlands as it is in the wetlands along the entire Eastern seaboard.

Cordgrass productivity is supplemented by that of salt hay, Spartina patens, spike grass, Distichlis spicata, several species of the Juncus group, some of the rushes (Scirpus sp.) and others. Unlike the small amount of algae present at any one time, there is a very large standing crop of cordgrass present at most times during the growing season.

These grasses are very productive despite the low efficiency at which they convert sunlight, water and CO_2 into plant material. The most productive Atlantic coast marshes are estimated to capture only 1 per cent of all the incident sunlight and many marshes capture less than 0.5 per cent. Further, of the energy these plants receive from this light, most of it is used for the maintenance of the plants themselves. That is the price that halophytes (plants which grow in salty habitats) pay for living in this harsh estuarine environment. These inefficiencies, however, are compensated for by the amounts of grasses involved, the long growing season, the habits halophytes have developed and the large amounts of nutrients and water available to wetlands plants. There is always enough plant material produced so that large amounts of plant material, detritus and consequently nutrients, are exported to other parts of the estuary.

The nutrient reserve that marsh plants enjoy takes a long time to develop and is an integral part of the development of the whole marsh area. Marshes are created through a complex process involving water flow characteristics, sedimentation rates and sediment types, and invasions by the various plants and animals which modify and contribute to this developmental process. As the marsh grows, much of the organic material produced by the plants and animals becomes mixed with sands and muds creating the marsh soils. In the early phase of development the amounts of organic material being incorporated into the soil system are larger than those being extracted so a reserve of organic material builds up. This reserve is further augmented by the nutrients being carried

in the waters that flow through the marshes. Much of the waterborne nutrients become incorporated into the soils as the water percolates through them. In time a fairly large nutrient reserve is built up in the soil system of these areas which, combined with the nutrients constantly being supplied by the flowing waters, forms the basis for the productivity of the grasses.

The productivity of the Spartina is not important in itself since it is not directly useful to higher organisms. The organic material of the grasses must be converted to other forms before the cycle is completed. The conversion only takes place through two pathways in estuarine areas: direct utilization of live material and utilization of the dead plant material, the latter appearing to be the more important pathway.

Very little of the live marsh grasses are directly consumed unlike an agricultural crop whose energy is utilized directly by the consumption of live material. Investigators estimate that as little as 5 to 8 percent of the total material produced by the Spartina community is directly consumed by organisms, usually insects and marsh crabs. This percentage varies, but it is obvious that only a relatively small amount of the grass is ever utilized while still alive.

Plant decomposition through the detrital cycle is the process through which Spartina makes its great contribution to the estuary. As the plants die and fall to the ground, they are physically broken down by the action of the water and some of the animals of the marsh. As this mechanical breakdown proceeds, chemical breakdown of the material is also occurring. This is accomplished by the actions of the numerous bacteria and fungi of the marsh surfaces and waters as well as many macroinvertebrates that find the plant particles very suitable nutrient sources. The microorganisms rapidly colonize the detritus, extracting what they can from the plant tissues.

As the bacteria and fungi grow and colonize the material, not only do

they break down the plant detritus into more elemental components, they also create important food particles for other organisms. In itself, plant detritus is not especially nutritious. Live Spartina, in fact, is only about 10 per cent protein; and, by the time the plants die and fall to the marsh surfaces, the protein content is very much less than this. By comparison, the protein contents of bacteria and fungi are high and as these microorganisms multiply on the plant particles, they multiply the overall nutritional value. The filter-feeding organisms that ingest such particles -- notably the zooplankton animals -- then find detrital particles a very nutritious package.

Some of the primary consumers utilize the whole microorganism/plant particle; others just strip off the bacterial colony and return the detrital particles to the water where they are recolonized by more microorganisms. This process continues over and over again until the plant material is finally broken down. Also in this process, some of the components of the plant material are simply released into the water and serve as nutrient sources for the phytoplankton and benthic algae.

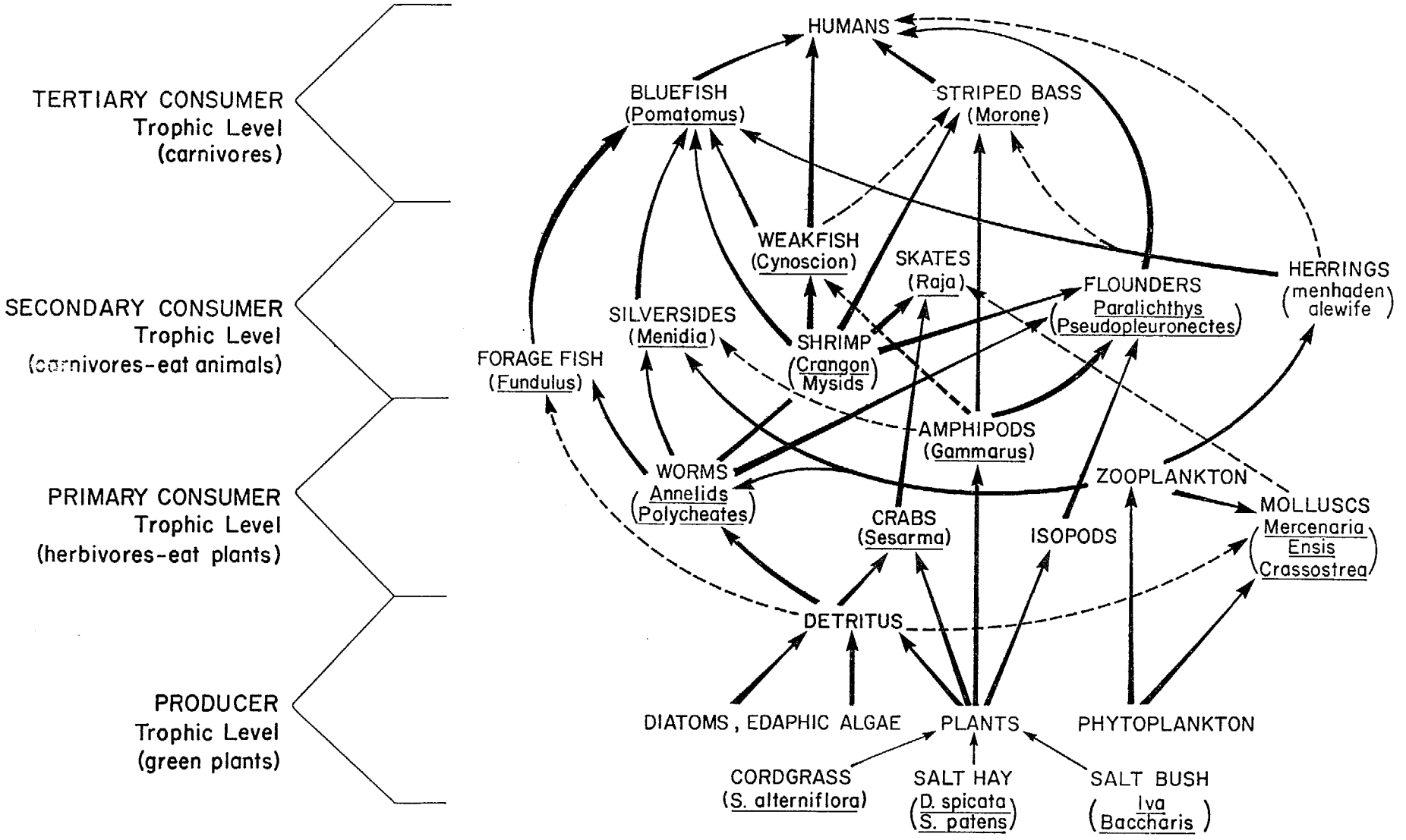
Overall, the detrital cycle is an effective energy cycling system. Detrital material has storage, transport and buffer functions that allow for more complete utilization of energy. Until the plant material is broken down, it represents stored energy and as such can be used as an energy source for some time. Likewise, through the actions of the water in the marshes and estuaries, this stored energy can be transported from one area to another. Closely associated with these two functions is the buffer function wherein detritus provides energy to the system when other energy-producing components are nonfunctional. This characteristic becomes important in the fall, winter and early spring and assures that a year-long nutrient source is available to higher levels of the estuarine ecosystem.

Most of the zooplankton organisms are dependent both on the phytoplankton of the estuaries and on these bacterial-detrital particles for their energy sources, as are other larger invertebrate filter feeders. Herbivores are then preyed upon by many types of animals including other zooplankton, and young and adult fishes of all types. The specific paths the energy is cycled through are extremely complex but all start originally with the phytoplankton.

Figure 2 is an example of a "typical" estuarine food chain which illustrates the dependency of the estuarine animals on the sun energy fixed by plants through photosynthesis. Both types of food chain, the detrital food chain and the direct utilization chain, are included in the figure since the two chains are not independent. The organisms shown are meant only to be representative of the many found on each trophic level. The trophic level classification is one of function, not of the species as such; a given species may occupy more than one level depending on the source of energy consumed. Of the available sun energy only 0.5 to 1.0 per cent is fixed by the marsh plants; further, only 10 to 20 per cent of the food energy is passed from one trophic level to the next, the remainder being lost as heat. As a consequence, for every pound of bluefish or striped bass consumed by man, at least 150 pounds of plant material is required.

While the wetlands make up only a small portion of the total land area in any region, it is estimated that 80 to 90 per cent of our total seafood harvest is dependent in one way or another on the estuaries. Most of the species of fish with which we are familiar spend important parts of their life cycle in the estuaries, either as spawning adults or as juveniles. The high level of wetland and estuarine primary productivity supports the zooplankton and other small invertebrates that the fish feed on. We have only to look at areas where wetlands losses have been directly related to losses in important fish species to see that the connection is real. The wetlands areas are truly the foundation of estuarine productivity.

Figure 2 ESTUARINE FOOD CHAIN



ANIMALS AND WETLANDS

It is only in relatively recent years that man has begun to comprehend the role of the wetlands in the estuarine ecosystem. In particular, wetlands are said to be of utmost importance to the health and welfare of numerous fishes and shellfishes. Although this relationship is an extremely important and essential one, it must be kept in mind that the wetlands and marshes are also important to many other animals including song birds, ducks and geese, wading shore birds, birds of prey, fur-bearing mammals, plus some amphibians and reptiles. The dependence of these animals on wetlands must also be considered when establishing policies and programs for our natural systems.

Much of the importance of wetlands to these other animals has become apparent only after the implementation of many mosquito control projects undertaken in the 1930's. Historically, there has been a definite conflict of interest between insect and wildlife management practices (see Ditching and Impounding). The ditching and draining of many marsh and wetland areas -- the most common manner through which mosquito control problems have been approached -- has affected much more than just the mosquito populations. Usually, these manipulations have also resulted in major changes in the animal populations. Invertebrates, fur-bearing mammals, and many birds do not find the ditched marshes to be suitable habitats and so their use of these areas often declines although there is some conflicting data surrounding this point. It is in response to man's various activities and the presumed harm to associated wetlands organisms that the importance of properly maintained wetlands to the many types of animals whose livelihood depends on wetlands has become apparent.

The list of animals that are commonly found and whose lives depend on the wetlands of Delaware is, indeed, a long one. Each of these animals plays an

important role in maintaining the ecological balance of the system as they interact with the wetlands by feeding, nesting, spawning and dying. Many of these animals spend their lives in particular zones or areas in the marsh. Yet, in many cases, it is difficult to determine specific ranges of certain wetlands-dependent organisms.

Every marsh and wetlands area is composed of different floral zones with each zone being characterized by particular vegetation types (see "General Principles of Wetlands Ecosystems"). Each vegetation type is a reflection of particular salinity, soil moisture and time of inundation existing in the different marsh areas which change across the marsh as the tidal and freshwater influences change.

The plant zonation is the most obvious configuration existing in the biotic community. But, the animals also reflect the changing pattern of marsh conditions to some extent in their own distributions. They inhabit those vegetative zones in which they are best able to produce the materials they need for their survival, and a relationship develops between animals and vegetative zones -- one that is dependent ultimately on the relationship between the vegetation and the tides.

However, it must be remembered that the animal distributions are not always as distinct as are the plant distributions. The correlation between plant and animal distributions is a definite one, but it is not always an exact one. Animals are mobile organisms, and while some seem to move only in relatively small areas, others range over larger regions of the marsh from the upland margins to the tidal creeks. However, even these animals have a home base to which they return when their hunting is done and so they can be thought of in terms of a particular home zone.

Of the animals that do spend most of their lives in one part of the marsh,

many are smaller forms such as the invertebrates, birds and small mammals. Invertebrates such as the snails (Melampus bidentatus), the fiddler crabs (Uca sp.) and the ribbed mussels (Modiolus demissus) are common low marsh inhabitants of Delaware's tide lands.

The ribbed mussels have very little choice for they are attached forms, similar in this respect to the plants. They survive because they possess their own shelters (their shells) and filter food out of the tidal waters that continually wash over them. The crabs and snails, on the other hand, are mobile forms that still tend to stay in a relatively small area, bound to the environmental cycles existing there. Snails move up and down the grass stems with the rising and falling tides, while the crabs move in and out of the burrows they have dug in the mud. For food, both utilize the plant detritus that is always available on the marsh surfaces. For example, researchers in Delaware have found that the marsh crab (Sesarma) feeds directly on living cordgrass.

Some marsh birds can be found in these low marsh areas where they remain for a large part of their lives. Clapper rails (Rallus longirostris) are typical low marsh residents who build their nests and raise their young among the stems of the tidal grasses. Both clapper rails and black ducks consume low marsh inhabitants, the crabs and snails. Seaside sparrows, red wing blackbirds and sharp-tailed sparrows consume principally cordgrass seeds. Some cordgrass is also consumed by insects which form the base of the diet of many birds. Another common inhabitant is the willet (Cataptrophorous semipalmatus) whose noisy call usually precedes any strange visitor.

Among the small mammals who tend to remain in a fairly limited area are the meadow mouse (Microtus pennsylvanicus) and the muskrat (Ondatra zibethica). The meadow mouse is usually found in the landward edges of the wetlands near

the salt hay (Spartina patens) zone. Mice range over large areas but still spend much time in the area of their nests. The nests represent safety and shelter and during adverse conditions the mice seldom leave them. The muskrat is a very well known marsh inhabitant about which more will be said later. It, too, chooses a particular area in which to reside and tends to remain close by.

There are also animals that are essentially upland species but that occassionally roam into the marsh and wetlands areas in search of food. Racoons (Procyon lotor), oppossums (Didelphus marsupiala) and woodchucks (Marmota monax) often travel into the lower marsh areas to feed on shellfish and crabs. When the conditions on the marsh are not too severe, as during neap tide periods, these animals may remain on the marshes for several days at a time feasting on these delicacies. Weasels (Mustela frenata), red and gray foxes (Vulpes fulva and Urocyon cineraoargenteus), deer (Odocoileus virginiana) and rabbits (Sylvilagus floridanus) also travel from upland to lower marsh areas on occasion. Most of the time the presence of these animals is known to us only through the characteristic tracks they leave on the marsh surfaces.

Other extremely important users of the marshes and wetlands are the transient species to whom the marshes represent feeding and resting sites. The most common of these are the waterfowl that make great use of wetland areas during their migrations. Delaware is situated along one of the major flyways of the North American continent, and as a result, Delaware wetlands are used extensively by many different migrating species. Mallards (Anas platyrhynchos), pintails (A. acuta), blue and green-winged teals (A. carolinensis and A. discors), black ducks (A. rubripes), and gadwalls (A. strepera) are some of the duck species that can be found in Delaware's wetlands along with the magnificent Canada goose (Branta canadensis), the mainstay of the waterfowl hunter. The same necessities

that attract the more permanent marsh residents -- food, water and shelter -- also attract these migrating birds. The importance of the wetlands to the survival of the waterfowl species has been well established.

The larger animals of the marshes distribute themselves partially according to their uses of the plant materials and partially according to their uses of the smaller invertebrates associated with each zone. Clapper rails are common in the tall cordgrass (Spartina) areas both because they use the cordgrass for their chief food sources, and fiddler and marsh crabs also live in the Spartina zones. Salt bush zones (Iva frutescens and Baccharis hamilifolia) offer nesting areas and shelter for a wide variety of wildlife but are of little nutritive value. Giant reed grass zones (Phragmites communis) are similar in function. In more brackish water sections where rushes (Scirpus sp.) and big cordgrass (Spartina cynosuroides) are common, periwinkles and marsh snails are also common and black ducks and teals can often be found here supplementing their plant diets with these invertebrates. Blue herons (Ardea herodins) commonly stalk the fishes which live in the intertidal waters.

Predator-prey interactions also involve the top predatory species such as the foxes, the otter (Lutra canadensis) and the hawks. Foxes are sometimes seen in the upland margins stalking feeding ducks. Marsh hawks (Circus cyaneus), the most common bird of prey found in Delaware's wetlands, are often seen fringing many wetlands areas in search of the mice, rats and young muskrats upon which they feed.

Most of the animal species that serve as prey for the predators are herbivores who derive their food from vegetation. The meadow mice exist partially on the seeds and young shoots of salt hay (Spartina patens) and spike grass (Distichlis spicata). Seaside sparrows (Ammospiza maritima) are known to eat cordgrass (Spartina alterniflora) seeds. Canvasbacks, mallard

and pintail ducks often consume the seeds of the wild rice plants (Zizania aquatica). Even the large Canada goose, whose major predator is man, is a plant eater, feeding on widgeon grass (Ruppia maritima), cordgrass (S. alterniflora) and three-square bullrush (Scirpus americanus).

The use of the plants changes as the seasons advance and as the physical structures of the plants change. In the spring, young tender shoots of marsh grasses and root stocks filled with starches are important food items. In the late spring and summer, the leaves and flowers are consumed because they are plentiful. In the fall and winter, fruits and seeds develop and attract many animals searching for food, while stalks of plants are sought after for nesting material.

One of the most studied and important relationships of animals and wetlands is that of the muskrat, Ondatra zibethica, and several of the marsh grasses. Muskrats have always held an important place in the lives of people living near wetlands for they have provided both food and fur pelts. The market for both of these products has declined drastically in recent years, and this fact coupled with destruction of the muskrat habitat has lead to a reduction in the importance of the muskrat to man. But trapping continues in Delaware, and muskrats are still important components of the marshes they inhabit.

Muskrats are more common in brackish water areas than in the saline areas for the foods they commonly utilize, Olney's three-square (Scirpus olneyi) and cattails (Typha sp.), grow in brackish water areas. Cordgrass (Spartina alterniflora) is usually present in these areas and is used by the muskrats as construction material for their houses and occassionally as food. Areas where all of these grass species are present support the best muskrat populations, but populations can also be found in less preferable areas. In these less suitable areas, the density and general health of the muskrat populations are known to be

lower than those characteristic of populations in the preferred habitats.

Much of the relationship of the wetlands to the muskrat was brought to light after their habitats had been destroyed or considerably altered. Ditching has been noted to decrease the availability of freshwater in some systems leading to vegetational changes in the wetlands. Muskrat foods such as the rushes and cattails are often replaced by other less favorable food species, and this replacement leads to reduction in the size of the muskrat population that can be supported. Ditching also tends to create uplands by draining the marsh and lowering the water table. Hence, upland species of little value to the muskrat begin to invade areas that were once cordgrass, cattail, and bullrush.

Similar post-ditching reductions have been noted in the invertebrate populations of the marshes and in the animal species which utilize these invertebrates as food. Some extensive studies have been made in Kent County marshes before and after ditching operations were completed in the later 1930's. The results of these studies showed that in most vegetative zones, the numbers of invertebrates found were significantly lower after the ditching operations had been completed. Reductions varied depending on the particular area and season but were usually around 50 per cent and often as high as 90 per cent of the pre-ditching populations. Therefore, even the predators whose food sources are not plants but the smaller marsh invertebrates are affected when the wetlands are disturbed.

A more recent study has indicated that certain invertebrates, such as fiddler crabs and salt marsh snails, were more numerous in ditched marsh than in unditched marsh. Snails and crabs are typical of salt marsh bank-water interfaces. Consequently, it seems reasonable that increasing the area of marsh bank through the construction of ditches would also tend to increase the

abundance of these certain, specialized invertebrates. However, the great majority of salt marsh invertebrates do not inhabit this niche. Ditching, then, by lowering the water table of the marsh, tends to be detrimental to the majority of the invertebrates on the marsh.

Not all actions of man have been necessarily harmful to the wildlife resources. Delaware enjoys a large winter waterfowl population because of the effort that has been devoted to creating attractive feeding sites for geese and ducks. Impoundments have been developed near feeding areas so waterfowl find proper food and shelter during their migrations. The impoundments have also been shown to increase the use of certain areas by other birds and mammals. Where ditching lowers water levels, impounding increases freshwater levels leading to increases in brackish and freshwater plant species used as food by many animals.

There are problems with impounding though, for this practice often appears to conflict with those attempting to maintain and improve fish and shellfish populations in the estuaries. Impounding prevents water from flowing out of the wetlands areas to the estuaries, and the estuaries are deprived of the nutrient materials these waters contain. The productivity of estuaries is directly dependent on the nutrient materials originating in the wetlands (see Wetlands and Estuarine Productivity). Without them, phytoplankton and zooplankton populations -- direct utilizers of wetlands nutrients -- might be affected. If these populations are adversely affected, the fish and shellfish that eat the plankton organisms will also be affected (see Figure 1 in Estuarine Productivity).

Curiously enough, various species of fish feed on the low cordgrass marsh. Mullet (Mugil cephalus), mummichogs (Fundulus heteroclitus) and juvenile sport fishes such as the red drum (Scianops occelatus) are known to

feed over the marsh on high tides. Resident species such as mummichogs, sheepshead minnows (Cyprinodon variegatus) and striped killifish (Fundulus majalis) all can be found over the marsh on high tides. In addition, researchers here in Delaware have some preliminary evidence that the mummichog lays its eggs on the base of cordgrass (S. alterniflora) stalks on high tides during the spring and summer.

All too often, man has interacted with the wetlands with only a few of the functions of these systems in mind. Marshes were ditched to reduce mosquito populations, but these practices also led to unplanned reductions in larger invertebrate, bird and mammal populations. Impoundments have been constructed which increase animal usage of wetlands but which interrupt estuarine nutrient cycling, ultimately affecting phytoplankton, zooplankton, fish and shellfish populations.

In undisturbed areas there seem to be few conflicts among the many ways in which wetlands can serve animal populations. The interactions are so subtle that we really have little insight into their complexity and interpretations. However, it is when the balance has been upset in the disturbed areas that the extent of the perturbations of the wetlands becomes apparent. Often, impact becomes more apparent when we try to restore the balance, finding instead that simply reversing the nature of our interferences with the wetlands leads to even more disruptions of these systems. This is occasionally the price we pay for acting unwisely in the first place. As it stands now, few areas remain undisturbed and it is therefore more imperative than ever that all the animals that use the wetlands be accommodated in all further wetlands-estuarine management plans.

THE RELATIONSHIP BETWEEN WETLANDS AND ESTUARINE WATER QUALITY

The title of this section is somewhat vague and therefore open to interpretation. What is meant by the terms "relationship" and "water quality"? "Relationship" was interpreted as meaning both how the wetlands affect water quality and how water quality affects the wetlands. "Water quality" includes the factors of sewage loading, silt content, heavy metals, pesticides, oil pollution and thermal pollution.

Dissolved oxygen and salinity were omitted from consideration under water quality despite their obvious importance. Both are discussed in the Marine Habitat-Environmental Parameters section. Dissolved oxygen is influenced by sewage loading and the resuspension of sediment. Salinity is altered by man when dams and flood gates are used to restrict stream flow (See Wetland Destruction Section).

Silt

Estuaries are characterized by muddy bottoms that are continuously being added to by deposited sediments. The organic and inorganic material that constitutes silt can originate from river input, shore erosion, resuspension from the bottom, waste disposal, dredging and spoil deposition activities. Inorganic particles can be rock and mineral fragments such as quartz, feldspar or mica. The organic material can be considered detritus, the origin of the detrital food chain. Silt particles can also be a combination of inorganic particles covered with microorganisms. Silt particles have the ability to absorb many materials including nutrients (nitrates, phosphates, etc.), heavy metals, radionuclides, pesticides and oil products.

Silt and sediment can affect the biota in a variety of ways. Heavy

silt loads can smother nonmobile benthic organisms, eggs and larvae. Less severe loadings can impair gill respiration. Particles suspended in the water can impair light penetration and thus reduce primary productivity by limiting the depth of the water column in which the rate of photosynthesis exceeds respiration. Resuspended sediment that is coated with organic material can exert an oxygen demand that is higher than that of the same material in bottom deposits. Silt loads can also affect plant growth by absorbing nutrients, but the mechanisms of absorption are complicated and as yet not fully understood.

Marshes effectively function as sediment traps. Water current velocity in marshes is typically quite slow and this allows silt to settle out as sediment. With each high tide that floods the marsh surface, more sediment is deposited. The result is a slow, continuous build-up of the marsh. By absorbing various materials, silt can act to concentrate nutrients, trace metals, and toxic pollutants as it settles onto the marsh surface.

The basic relationships between physical and chemical apsects of suspended and deposited sediments and the responses of estuarine organisms are poorly understood. Particulate matter affects the growth, survival or reproductive aspects of estuarine organisms both directly and indirectly at the organisms' several life stages. Evaluation of the problem is further complicated by the different sensitivities of life stages to varying conditions of temperature, salinity and dissolved oxygen. The observed responses of organisms may not be due to either turbidity or suspended sediment concentrations, commonly expressed as extinction values or tons/day or mg/l, but rather to their size distribution, shapes, types, presence of organic matter, metalic oxide and organic coatings, or the adsorptive properties of the particles.

Because of its commercial value, the American oyster (Crassostrea virginica) has been studied relative to various sediment loads. The earlier

life stages of the oyster are more sensitive to sediment loads than adults. Severe larval mortality occurs in concentrations of suspended material above 100 mg/l. This same concentration caused a drastic decrease in the adult pumping rate, but no significant adult mortality was observed.

Prior to any wetlands/estuarine project that will produce increased sediment loads, the following aspects should be investigated:

1. The range and types of particles to be resuspended and transported, where they will settle, and what substratum changes or modifications otherwise created by project activities will occur in the dredged and disposal areas.

2. The biological activity of the water column, the sediment-water interface, and the deeper substrate material which often houses burrowing organisms.

3. The release into the water column of sediments, those substances originally dissolved or complexed in the interstitial water of the substratum, and those beneficial or detrimental chemicals sorbed or otherwise associated with particles which may be released wholly or partially after resuspension.

4. The relationships between properties of the suspended load and the permanent or resident species of the project area and their ability for and dynamics in repopulation, and the transitory species which use the project area only at certain seasons of the year.

For more information see Agriculture, Spoil Disposal and Environmental Requirements.

Sewage

Due to their proximity to population centers, estuaries often receive the effluent from municipal sewage plants and individual septic-field leachate. Municipal sewage is treated in three steps -- primary, secondary and tertiary. Primary treatment removes the solids and with them some of the biological oxygen

demand (B.O.D.) load and heavy metals. Through the oxidation of organics, secondary treatment removes the organics and most of the remainder of the heavy metals. Tertiary treatment removes the inorganic nutrients such as nitrates and phosphates.

Currently in the State of Delaware most sewage treatment plants provide secondary treatment. A few plants provide only primary treatment of the sewage, while at present there are no tertiary treatment plants.

Several damaging effects can result from excessive sewage loading. The dumping of raw or primary treated sewage can result in reduced, dissolved oxygen levels. Municipal sewage that includes industrial input contains heavy metals that are not completely removed even by secondary treatment. Dumping of all sewage except for tertiary treated material results in increased nutrients and therefore possible eutrophication. Raw or improperly treated sewage can cause increased fecal coliform bacteria counts.

It is generally agreed that marshes and estuaries are not suitable for treating raw or primary treated sewage. Marsh systems already have naturally high B.O.D.'s due to their high organic content and thus cannot handle additional organic loading. Some investigations have pointed to the marshes as sources of organics due in part to the excreta of the resident wildlife and waterfowl.

An exception to the unsuitability of marshes for primary or secondary water treatment was revealed in a study of the Tinicum Marsh near the Delaware River in Pennsylvania. Analyses of water taken before and after covering the marsh surface showed that the marsh decreased the B.O.D. levels in 57 per cent of the samples and increased the dissolved oxygen in 73 per cent of the samples.

Municipal sewage systems that have industrial waste input have high levels of heavy metals. Over half of the heavy metals are removed by primary and secondary treatment, but that still leaves considerable heavy metal discharge for those systems receiving industrial wastes. The relationship of heavy

metals to the marsh are discussed in the next section.

High discharge rates of secondary treated sewage can increase the inorganic nutrient levels and thus cause eutrophication of estuaries. The term eutrophication is widely used, but not accurately defined. In an estuary, eutrophication means an increase in nutrient supply. Nutrients might be considered the primary cause of eutrophication by definition, but the symptom or effect is expressed as an over-abundance of plant biomass. It is important to note that most estuaries are eutrophic but not necessarily out of ecological balance since the grazing segment of the community may be well adjusted to the system. Artificial enrichment is usually referred to as cultural eutrophication. Information on agriculture's contribution of nutrients from field runoff is discussed in the Agriculture Section.

Some researchers believe the marsh is well suited for tertiary treatment of waste water already secondarily treated. This appears to be a possibility because the marsh system is an active system that can store and recycle nutrients with great efficiency. Tertiary water treatment is the most expensive treatment step if done by man, so marsh lands could have great value if used as tertiary treatment areas. Unfortunately, the large areas of marsh required to absorb the nutrients are not available. Even though we are fortunate that eutrophication of estuarine areas from municipal sewage inputs appear to enhance rather than harm productivity of marsh grasses, the bounty is not so great that the tertiary treatment of wastes from coastal cities will come cheaply.

Fecal coliform bacteria in sufficiently high concentrations can cause the closing of estuarine areas to shellfishing and bathing. Improperly treated sewage can raise the coliform bacteria count to levels above the State criteria for primary recreation which is 200 cells/100 ml. of water. The wildlife, especially waterfowl, that rest and feed in the wetlands add to the background

coliform count. The Leipsic and Broadkill Rivers have elevated counts partially because of the Bombay Hook and Prime Hook Wildlife Refuges respectively. Bacteria counts in excess of water quality standards is a major surface water quality problem in Delaware.

Three major problems are exacerbated by sewage input -- B.O.D. loading with resultant lower dissolved oxygen levels, increased nutrient loading and increased fecal coliform bacteria counts. Marshes may be able to lower the B.O.D. levels and raise the dissolved oxygen (D.O.) levels. They can remove moderate amounts of nutrients introduced from sewage outfalls, but unfortunately, the marshes contribute to the bacteria problem rather than improve the water quality of rivers receiving sewage treatment plant effluent.

Heavy Metals

Heavy metal pollution is an aspect of water quality that can be associated with sewage effluent. Heavy metals (generally those metals heavier than iron on the Periodic chart) are not a concern when they are present in normally low levels, but when the concentration levels are increased as a result of a man-made input, heavy metals can become dangerous (such as the methyl-mercury poisoning in Japan). Heavy metals are also of concern only when they are available to organisms, normally in the form of ions or complexed with organic molecules. The addition of heavy metals to an estuarine system is of particular concern because heavy metals are not degradable and therefore have a long life-time. Also, physical, chemical and biological processes within estuaries and wetlands may combine to concentrate these materials.

Physical processes include sorption onto suspended solids, sedimentation, current dispersion, turbulent dispersion, and resuspension of sediment. The chemical processes within the estuary including ion exchange, complex formation,

chelating flocculation, and coprecipitation are poorly understood. The biological processes on the ecosystem or community level involved in heavy metal cycling and concentrating are also very poorly understood.

Sources of heavy metals can be classified according to the type of source. Point sources include industrial and municipal outfalls, dumping sites and dredging projects. Diffuse sources include agriculture runoff, urban runoff, and scrubbing out of air pollution.

The effects of high levels of heavy metals on wetlands organisms manifest themselves in three basic forms. Extremely high levels cause direct acute toxicity and "kills". Somewhat lower levels cause indirect food chain effects wherein lower trophic levels are reduced thus resulting in reduced food for higher organisms. Lastly, lower levels of heavy metals result in chronic toxicity which causes reduced growth, viability, reproducibility and increased susceptability to diseases. Organisms such as clams, oysters and crabs exposed to elevated levels of heavy metals can also be dangerous when consumed by man.

The probable sources and deposition areas of trace metals adsorbed onto fine-grained suspended material in Delaware Bay have recently been described. Silt as suspended sediment originates from the Delaware River, eroded from tidal marshes, and from the ocean. This suspended material with its attached heavy metals is then deposited in the ship channel and along the shoreline especially in the area between Port Mahon and the St. Jones River mouth. The Delaware River was found to be the primary source of iron, zinc, lead, cadmium, mercury, and nickel while the ocean was the primary source of magnesium, chromium, copper and strontium. The currents in the bay were found to be the main factor influencing the distribution of all these metals, irrespective of their source area.

Sediment is constantly being deposited on the marsh surface when high tides flood the marsh. Since heavy metals are attached to the silt particles,

deposition of sediment on the marsh also serves to concentrate heavy metals. Approximately half of the mercury entering the estuary on silt particles ends up in the sediment.

Plants in the marsh accumulate the heavy metals which have been deposited on the marsh surface. When the plants die and enter the water as detritus, they carry with them the accumulated metals. Thus animals feeding on detritus rather than phytoplankton consume higher levels of heavy metals such as lead and mercury. Once consumed, heavy metals are slow to be released. For example, a northern pike held in high levels of methyl mercury released almost no mercury over a period of one year following transfer to clean water.

Data on direct, acute toxicity to heavy metals in estuarine animals is limited in scope and volume. The soft shell clam has been tested for acute toxicity to cadmium; the blue mussel, Mytilus edulis, has been tested for mercury, copper and cadmium. Little or no data exists on acute toxicity for the blue crab, Callinectes sapidus, or for most sport and commercially valuable fish. The American oyster, Crassostrea virginica, has been tested for cadmium and lead poisoning. Oyster larvae were found to be 14 to 1,000 times more susceptable than adults to mercury, copper and zinc. The reported susceptability of oyster larvae is characteristic of many estuarine organisms. It is ironic that the life stage most susceptable to metal poisoning is the stage that uses the estuaries for nursery and feeding grounds. Data on the chronic effects of low heavy metal concentrations is most essential for assessing long-range ecological trends, and more research is needed on this critical subject.

So little is known about the complicated biochemistry of heavy metals that it is impossible to state what levels of each metal are dangerous, toxic, or lethal for the many estuarine organisms. The bioavailability of heavy metals can be altered by changes in salinity, pH, dissolved oxygen, temperature,

currents, or any combination of factors. For example, decreased pH supresses the sorption of copper, lead, and zinc onto particulate matter; and increased temperature, as in the thermal plumes from a stream electric plant, increases the availability of heavy metals from suspended sediments. The susceptability of organisms to trace metals in addition to the bioavailability is also influenced by many chemical and physical factors. Several species of isopods are more susceptable to mercury at decreased salinity and increased temperatures.

The cycling of heavy metals in the estuary and wetlands is very complicated and as yet, poorly understood. However, several facts can be stated: 1) Heavy metals can be dangerous or fatal to estuarine organisms and man; 2) Trace metals are normally found in very low concentrations; 3) Elevated and potentially dangerous levels are still relatively low concentrations; 4) The marsh and its organisms are very susceptible to elevated levels of heavy metals because of the marsh's ability to concentrate the metals and also because of the larval forms' susceptibility to metals.

Oil Pollution

The wetlands in Delaware are vulnerable to any oil spill occurring in Delaware Bay or offshore. The seven major refineries located along the Delaware River require about 300 million barrels of crude oil each year when running at capacity. All of this crude reaches the refineries by ship, and roughly 15 per cent or 45 million barrels are transferred to barges or smaller ships in a process called lightering, prior to moving up the Bay. Offshore, tracts of the continental shelf will soon be leased to commercial oil interests for exploration.

Specifically, there are several potential sources of oil pollution. There can be leaks during the lightering operations in the Bay. Spills can occur due to ship groundings or collisions. The cleaning of tanks and bilges can result

in oil discharges. Leaks during exploration or actual drilling offshore can occur. Finally, industrial waste discharge containing petroleum products can be a chronic source of oil pollution.

The same characteristics that make the marsh vulnerable to other forms of pollution make it vulnerable to oil pollution: 1) the marsh is close to man's activities; 2) oil enters the sediment due to the constant deposition of particulate material; 3) the marsh and estuaries serve as spawning and nursery grounds to larval stages of many organisms that are high vulnerable to pollution stress; 4) the low, flat nature of the marsh surface is periodically covered with flood tides which can cover large areas with oil.

Toxicity of oil pollution varies with the petroleum fraction involved. In a decreasing order of toxicity are gasoline, diesel, bunker C, and crude. The most toxic oil products have the largest percentage of volatiles, therefore, they become less toxic very rapidly as the volatiles evaporate. The process by which the composition of spilled oil changes with time is called weathering. Ironically, the detergents used to disperse oil spills are often more toxic than the spill itself.

Weathering of an oil slick begins immediately and proceeds via several means. Depending on the temperature and wind velocity, the volatile fraction of a spill evaporates rapidly. Within twelve hours of a crude oil spill roughly 40 per cent is evaporated or in the water column while 60 per cent remains as a tarry slick. The oil can also be abraded by the sand on beaches or consumed by browsing invertebrates. The oil coats suspended particular matter and sinks to the bottom. The spill can be a source of energy for certain bacteria that are capable of oxidizing the oil. Thin layers of crude oil can be colonized by bacteria in two to three weeks and completely decomposed in two to three months.

The effect of an oil spill on the marsh depends on the size of the spill,

the duration of the release, and the type of oil spilled. At the very least, the aesthetic values of the wetlands are decreased. The various habitats of the estuary and marsh if sufficiently modified can cause a decrease in the number of susceptible species and an increase in the number of tolerant species. A spill can cause a decrease in fishery and wildlife resources for years to come if juvenile stages are affected. A hazard to humans also exists through contaminated seafood.

Prediction of a spill's severity is difficult because of many compounding factors. Fate of a spill depends on the prevailing winds, water current and temperature. Toxicity to an organism depends on the temperature, salinity and the life stage exposed. The tide stage at the time of the oil's entry into the marsh determines how much marsh surface is covered by a spill. Also, the number of wildlife potentially affected by a spill changes with the seasons.

Marsh grasses are the most obvious indicator of the high marsh productivity. A crude oil spill on the marsh can cause a die-back of the grasses within two to three days. The greatest area of the marsh is affected during a spring flood tide when the marsh receives the highest water. A die-back caused by the toxic fraction of a spill can recover by the following season, but the effects of seeds smothered by the oil can have lasting effects. Shallow water plants with small food reserves such as Salicornia are the least tolerant, while perennials with large food reserves such as Spartina and Juncus are more tolerant of oil pollution. Filamentous green algae is moderately tolerant but tends to be replaced by blue-green algae following a spill.

Delaware's wetlands serve as a refuge for thousands of waterfowl each year. An oil spill that moves into a refuge area during the winter can spell disaster for thousands of ducks and geese. Since the oil is most damaging to waterfowl while it is in the form of a slick, the application of dispersants

before the spill reaches the refuge can reduce the damage to the waterfowl. The surface of an oil spill causes the natural oils in feathers to lose their waterproof properties; the birds get wet and die of exposure. Waterfowl do not recognize the danger of spilled oil and land in the slicks. Those species that are divers such as the common ducks become completely coated if they dive through a slick. Bird cleanup procedures have become more effective in recent years (from 5 per cent to 50 per cent survival of those cleaned), but the mortality is still very high since most birds die before they can be treated. Those species with low reproduction rates are the most vulnerable because of their lower capacity for replacement of those killed.

There is considerable knowledge on the effects of spilled oil on adult oysters. It has been found that adult oysters are very tolerant of oil. Oysters pick up some of the fractions through ingestion of coated particles and may "taste" if consumed. A number of studies have shown that the oysters can eliminate the contaminants in ten to fifty days if the oysters are moved to clean areas. There is at least one reported instance in which oysters did not eliminate the oil, even after considerable time.

Oyster larvae are much more sensitive to crude concentrations than are adults. If a spill occurs during the summertime when larvae are in the water column, a number can be killed outright. Larval distribution in the water is patchy and it would be difficult to estimate the effect of larval mortality on the fishery of the estuary unless one knew the area effected by the spill in relation to the total estuarine area and the total larval population. It is clear, though, that considerable mortality of larvae could occur in the affected area during the summer months.

During the winter when commercial fishing for oysters is active, there can be considerable effect on the livelihood of fishermen in the area since

the adult oysters may pick up an unpalatable "taste" due to the oil, and the beds may be closed. Since some of the spilled crude may reach the bottom attached to sediment particles, the "taste effect" on adult oysters may last for a considerable time.

Other estuarine organisms besides oysters are affected by an oil spill. Small invertebrates such as marsh crabs inhabiting the marsh surface can be smothered by the heavy oil residue. Mobile animals such as fish can escape to cleaner water. Oil enters the sediment to a depth of at least 70 centimeters through settling of oil-coated particulate matter and reworking of the existing sediment. Oil-decomposing bacteria are ubiquitous in the marine environment -- 4×10^8 individuals/ml of sediment were found along the Cornish coast following the Torrey Canyon oil spill. However, the anoxic conditions of estuarine sediments significantly retard bacterial degradation of oil. Contrary to common belief, no magnification of oil concentrations in higher trophic levels was seen in a recent study. The level of contamination depended on the characteristics of each organism rather than its position in the food chain.

Discussion thus far has been concerned with the effect of oil pollution on the marshes and estuaries. Despite the scarcity of information on oil pollution in the marsh compared to rocky intertidal or sandy beaches, it appears that the marsh may have a positive effect on an oil spill. Due to the marsh's low surface, it can store and gradually release oil on successive high tides. The emergent grasses provide conditions favorable to microbial breakdown of oil in moderate quantities. Microbial breakdown of oil is enhanced by high D.O. levels, nutrient levels and temperature, all of which exist on the marsh surface. However, a heavy influx of oil onto the marsh can smother the bacteria and kill the grass thus reducing the ability of the marsh to break down the oil.

In conclusion, it is strongly advised that if an oil spill occurs, it

should be prevented from entering the estuaries and marshes. An oil spill has the potential to kill thousands of waterfowl, contaminate shellfish, kill fish, crab and bivalve larvae, foul the bottom sediments, kill emergent grasses -- in short, disrupt the entire marsh ecosystem. The amount of damage depends on the size and type of spill, the season, the prevailing winds, plus the water salinity and temperature.

Thermal Pollution

Temperature is a critical aspect of water quality. It directly affects the rate of all chemical reactions whether within organisms or in their surrounding environment. Changes in temperature are also essential as clues to migration, mating and spawning behavior. The natural temperature regimes are being threatened by ever-increasing numbers of electric generating plants that use the water from rivers and estuaries to produce steam and then to remove waste heat. A complete discussion of temperature and thermal pollution is given in Temperature and Its Relationship to Estuarine Organisms.

Pesticides

Pesticides are of extreme potential harm to estuarine organisms. Pesticides washed into estuarine waters tend to "salt out" onto sediment particles and are deposited in estuarine sediments. Hence, pesticides become concentrated in estuarine sediments. Many marine organisms concentrate pesticides in their tissue due to biological magnification, i.e., many animals, especially shellfish, can selectively remove pesticide type materials from the environment and store them. Biological manification of harmful substances (DDT, PCB, toxaphene, dieldrin, kepone) can cause lethal and sublethal effects in estuarine animals and those who consume them.

In Delaware, a pesticide survey completed in 1969 showed that three species

of shellfish throughout Delaware had relatively moderate concentrations of DDT and its metabolites, and dieldrin. Delaware did not seem to be harmed significantly by these pesticides, now restricted by the federal government. However, as citizens of this state, we must take care and insure that adequate measures are taken to prevent pesticide pollution disasters in Delaware. For a detailed discussion of pesticides, see Agriculture.

Six main topics have been treated in this section on estuarine water quality. It is hoped that the interdependency of these factors and complexity of the estuarine/marsh system is appreciated. While some aspects of water quality are well understood, the complexity of water chemistry has made a complete understanding of the processes impossible thus far. It is fairly safe to say, however, that perturbation of one aspect such as temperature would cause repercussions in other aspects of water quality.

References

Bopp, F. and R. B. Biggs. 1972. Trace metal environments near shell banks in Delaware Bay.

Delaware 1975 State Water Quality Inventory. 1975. DNREC, Division of Environmental Control.

Flemer, D. A. 1972. Current status of knowledge concerning the cause as biological effects of eutrophication in Chesapeake Bay. Ches. Sci. 13 (Supplement): 144-149.

Frazier, J. M. 1972. Current status of knowledge of the biological effects of heavy metals in the Chesapeake Bay. Ches. Sci. (Supplement): 149-153.

Grant, R. R., Jr. and R. Patrick. 1970. Tinicum marsh as a water purifier. In: Two studies of Tinicum Marsh. The Conservation Foundation, Washington, D. C., 123 pp.

Leland, H. V., E. D. Copenhaver, and D. J. Wilkes. 1975. Heavy metals and other trace elements. J. Water Poll. Contr. Fed. 476: 1635-1656.

Nixon, S. W. and C. A. Oviatt. 1973. Analysis of local variation in the standing crop of Spartina alterniflora. Bot. Marina 16: 103-109.

Odum, E. P. 1973. The pricing system. Ga. Conservancy 1973(4): 8-10.

Petroleum in the marine environment. 1975. National Academy of Science. Washington, D. C., 107 pp.

Proceedings of joint conference on prevention and control of oil spills, 1973. American Petroleum Institute, Washington, D. C.

Sherk, J. A. 1972. Current status of the knowledge of the biological effects of suspended and deposited sediments in Chesapeake Bay. Ches. Sci. 13 (Supplement): 137-144.

THE ROLE OF WETLANDS IN ESTUARINE HYDRAULICS

Of the many subject areas covered within the Wetlands Atlas, this topic is probably the least understood or investigated. Virtually no information is in the literature, and discussions with experts in estuarine circulations also produced only limited information on the role of wetlands in estuarine hydraulics.

It appears that of the wetlands areas, only the marshes have an effect on estuarine hydraulics. Because of their low elevation, marshes are able to absorb the energy of spring flood tides and storm surges as they cover the marsh surface. The absorption of energy is principally accomplished through friction between the marsh surface together with its emergent grasses and the thin sheet of advancing water. It is also felt that marsh peat readily soaks up floodwaters thus reducing their damaging effects.

Usually marshes are able to absorb the energy without noticeable damage, but extensive damage to the vegetation can be sustained in cases of extreme weather. The marsh grasses along the Gulf Coast were uprooted and carried away by hurricane Camille. A year following the storm some marsh species still had not recovered, and the overall plant cover was still less than before the hurricane.

There exists a general transgression of the sea onto the land caused by a combination of the rising sea level and subsiding land. These two factors

cause coastal erosion on most beaches and marshes fronting the Bay and Ocean. As sediments are torn away from the edges of marshes they are redeposited by tides on the top of the marsh. The marsh grasses are primarily responsible for "trapping" the sediment. As the surge slows whole passing over the vegetation on the marsh surface, the suspended silt settles onto the marsh. The marsh, then, acts as a buffer by protecting upland areas by absorbing storm surge energy and in turn is built up by acting as a sediment trap. The end result is that a long-term shoreward and upward movement of marshes and beaches is occurring along the bay and ocean margins.

References

Chabreck, R. H. and A. H. Palmisano. 1973. The effects of hurricane Camille on the marshes of the Mississippi River delta. Ecology 54(5): 1118-1123.

Silberhorn, G. M., G. M. Dawes and T. A. Barnard, Jr. 1974. Coastal wetlands of Virginia. Interim Report Number 3. VIMS, Gloucester Point, Virginia, 53 pp.

DEFINITION and / CLASSIFICATION of WETLANDS

DEFINITION AND CLASSIFICATION OF WETLANDS

DEFINITION OF WETLANDS

Defining wetlands in an ecologically significant manner that is also applicable to legal delineation is difficult. Recent concern over wetlands destruction and ownership, however, has necessitated that an ecologically sound but legally practical solution to the problem of delineating wetlands be found. Therefore, states have developed various definitions of wetlands that include ecological validity and provide a base by which the delineation of wetlands from uplands can be implemented from a legal point of view at a reasonable expense.

Hawkes (1966) summarized some criteria used for defining wetlands: 1) presence of underlying peat; 2) position of land-water interface; 3) tidal elevations; 4) vegetative zonation; 5) level of nutrient production, and 6) soil salinity.

There are many problems associated with defining wetlands by these criteria:

1. Local tidal level information is limited.

2. The datum lines of mean low water (MLW), mean high water (MHW), extreme high water and mean sea level (MSL) are not consistent. Mean high water as defined by the U. S. Coast and Geodetic Survey requires nineteen years of observations. Accuracy is very important since a difference of only .1 feet in MHW can mean several hundred feet of associated flat land lost or gained.

3. Correlation of tide data with land topography is difficult.

4. Using physical parameters alone to describe wetlands is risky since a very complex and varying set of physical factors combine to make a wetlands area.

5. Boundaries based on physical factors do not take into account the concepts of nutrient and energy flows, primary productivity, etc. (One of the principal values of wetlands is their biological productivity.)

6. Vegetative zonation is ambiguous in transition zones between wetlands and uplands. The characteristic species from each habitat grade into each other.

7. The level of nutrient production criteria would require extensive field work and tends to ignore other values of wetlands.

8. The soil salinity criteria would be only useful for wetlands adjacent to saline water and would require extensive field work.

In 1963, Massachusetts became the first state to enact legislation controlling the use of coastal wetlands. In 1965, Rhode Island passed its wetlands legislation. Maine and New Hampshire effected dredging and filling legislation in 1967. In 1969, Connecticut passed the first laws requiring an inventory of wetland areas. The states of New Jersey, Maryland, Florida and Virginia all enacted wetlands legislation in 1972. In 1973, Delaware effected its Wetlands Act and New York passed its Tidal Wetlands Act.

The marked differences in the definition of wetlands in each state's law mean large amounts of land are included or excluded from wetlands legislation. Definitions can be 1) a very general description; 2) a list of vegetation and presence of salt marsh peat; 3) a list of vegetation and a specified height above a tide marsh; 4) a combination of one through three. The several states using definition three list from thirteen to seventy-four vegetative species in addition to any one of several heights above mean high water or mean low water.

Lagner (1975) in a review of wetlands legislation concluded that "...vagueness, all-inclusiveness, ambiguous terminology, and difficulty in delineating boundaries

combine to weaken the power of wetlands legislation". The following definitions of wetlands illustrate this point:

Massachusetts --

> any bank, marsh, swamp, meadow, flat, or other low land subject to tidal action or coastal storm flowage and such contiguous land as the commissioner reasonably deems necessary.

Rhode Island --

> the presence of any of certain plant species (19 species) and the occurrence and extent of salt marsh plant at the undisturbed surface.

Connecticut --

> (an) area whose surface is at or below an elevation of one foot above local extreme high water; and upon which may grow or be capable of growing some, but not necessarily all, of the following: (74 species including those of freshwater wetlands).

A confusing definition of wetlands is found in Maryland's Wetland Act of 1970. It defines "state wetlands" as:

> all land under the navigable waters of the state below the mean high tide which is affected by the regular rise and fall of the tide.

Private wetlands are defined as:

> all lands not considered "state wetlands" bordering on or lying beneath tidal waters, which are subject to regular or periodic tidal action and which support aquatic growth.

These examples show that definitions are inconsistent between states, and in themselves ambiguous, and sometimes indeterminable. Many of the species lists contain plants that could grow in places other than a salt marsh or on land contiguous to a salt marsh. How is "extreme high water" determined in Connecticut? The wetlands defined as 3.5 feet above MHW (New Hampshire),

or 1.5 times the mean tide range at the site (Virginia) appear to be almost arbitrary definitions. Wetlands legislation in order to be effective must have definitions that are clear and concise. Further, states must be able to reasonably apply their definition of wetlands to the wetlands such that they can, in fact, be delineated from non-wetlands. Only in this way can the legal regulations be enforced.

Delaware made its contribution to wetlands legislation in 1973. According to the Wetlands Act (Delaware Code, Chapter 66), "Wetlands shall mean those lands above the mean low water elevation including any bank, marsh, swamp, meadow, flat or other low land subject to tidal action in the State of Delaware... whose surface is at or below an elevation of two feet above local mean high water, and upon which may grow or is capable of growing any but not necessarily all of the following plants"...(see Table 1).

"Further, the secretary of the Department of Natural Resources shall inventory, as promptly as he is able, all wetlands with the State..."

Although Delaware's definition of the wetlands uses both the physical parameter of 2.0 feet above MHW and characteristic vegetation, the actual delineation of the wetlands based on the Acts' definition has proved to be expedient, relatively inexpensive and quite accurate. This is due principally to the twenty-nine species of plants which have proved to be a comprehensive listing, at least for Delaware, of all the dominant species which grow almost exclusively in the wetlands. Thus, detection of these plants is tantamount to legally delineating wetlands. Also, successful analysis of wetlands through interpretive aerial photography by other states has proved reasonable and inexpensive. Thus, from 1973-75, an inventory of the State was made by photo interpretation based on the twenty-nine species listed in the Wetlands. Act. In addition to indicating the upland boundary, the use of vegetation also provides information

about the ecological characteristics -- as community associations, primary production, and associated wildlife throughout the wetlands. Once the photo inventory has been accepted as the official delineation of the wetlands following public hearings, the two-foot elevation above local mean high tide will not apply to any area outside the designated wetlands area.

Delineating the upland boundary of wetlands vegetative zoning, as stated earlier, can cause problems (refer to page 48, number 6). However, in delineating the upland boundary, the maps take a conservative line. That is, in every case, the most shoreward wetlands boundary delineated on the maps is below the two-foot mean high water line. Thus, absolutely no "uplands" are identified as wetlands on the maps, although it is possible (and highly probable) that some wetlands may have been "left out". In addition, the transition marshes in Delaware are, fortunately, relatively narrow.

At this point, Delaware has taken a giant step toward establishing a bank of sound management procedures through which to guard her wetlands. All but a very few minor activities designed for wetland areas must first come under close scrutiny of the State through the Department of Natural Resources and Environmental Control. Also, many activities which have proven to be deleterious to the wetland and estuarine flora and fauna in the past have been outlawed outright (e.g., the dredging of dead-end lagoons, unless aerators and water circulators are used, - DNREC, January 19, 1976). The legislation and final adoption of regulations is almost complete. It remains to be seen whether effective implementation of the legislation can be carried forth.

TABLE 1

A List of the Commom and Scientific Names of Those Species of Plants Used to Define and Delineate the Wetlands of the State of Delaware According to the Wetlands Act of 1972.

Common Name	Scientific Name
Black Grass	Juncus jerardii
Bladder Wrach	Fucus vesiculosis
Cattail (Broad leaved)	Typha latifolia
Cattail (Narrow leaved)	Typha angustifolia
Dwarf Glasswort	Salicornia bigelovii
Eel Grass	Zostera marina
Groundsel Bush	Baccharis halimifolia
Marsh Aster	Aster tenuifolius
Marsh Elder	Iva frutescens var. oraria
Mock Bishop's Weed	Ptilimnium capillaceum
Marsh Mallow	Hibiscus palustris
Orach	Atriplex patula var. hastata
Perennial Glasswort	Salicornia virginica
Sago Pondweed	Potamogeton pectinatus
Salt Marsh Fleabane	Pluchea purpurascens
Salt Marsh Cordgrass	Spartina alterniflora
Salt Marsh Grass	Spartina cynosuroides
Salt Marsh Hay	Spartina patens
Samphire	Salicornia europaea
Sea Blete	Suaeda linearis
Sea Blete	Suaeda maritima
Sea Lavender	Limomuium carolinianum
Seaside Goldenrod	Solidago sempervirens
Seaside Plantain	Plantago aliganthos
Spike Grass	Distichlis spicata
Switch Grass	Panecum virgatum
Three-Square Rush	Scirpus americanus
Torrey Rush	Scirpus torreyi
Widgeon Grass	Ruppia maritima

References

Delaware Code, Chapter 66, Sections 6603, 6607.

DNREC, Proposed Wetland Regulations, Division of Environmental Control, January 19, 1976.

Hawkes, A. L. 1966. Coastal wetlands -- problems and opportunities. N. Amer. Wildl. Conf., Trans. 51: 59-72.

Lagna, L. 1975. The relationship of Spartina alterniflora to mean high water. 48 pp.

Predominant Plants of Delaware's Wetlands

The following plants are predominant in Delaware's wetlands. Other plants can be found in selected locations but those listed below are most common and can be useful in wetlands identification processes:

CHECKLIST OF PLANTS*
(Names after Chamberlain, 1951)

Common Name	Scientific Name (Genus and Species)
Arrow-arum (Duck-corn)	Peltandra virginica
Arrowhead (Duckpotato, wapato)	Sagittaria spp.
Cattail	Typha spp.
Cordgrass	Spartina spp.
Cordgrass, Big	Spartina cynosuroides
Cordgrass, Salt Marsh	Spartina alterniflora
Groundsel bush (Marsh elder)	Baccharis halimifolia
High tide bush (Salt bush, Myrtle)	Iva frutescens
Marsh mallow	Hibiscus palustris
Pickerel weed	Pontederia cordata
Reed grass (Giant reed, Feathergrass)	Phragmites communis
Rush	Juncus spp.
Spike grass (Salt hay)	Distichlis spicata
Salt hay (Salt meadow grass)	Spartina patens
Three-square, American	Scirpus americana
Three-square, Olney's	Scirpus olneyi
Tide marsh water hemp (Pikebush)	Acnida cannabina
Wild rice	Zizania aquatica

*Many other species can be found in Delaware's wetlands; the above are the most predominant.

Following are photographs of the major species as they are seen in the field. In some cases, close-up inserts of a single plant are included to aid in identification.

FIGURE 3

ARROW-ARUM
(Peltandra Virginia)

Smyrna River

FIGURE 4

ARROWHEAD
(Sagittaria Spp.)

Drawyers Creek

FIGURE 5

CATTAILS
(Typha Spp.)

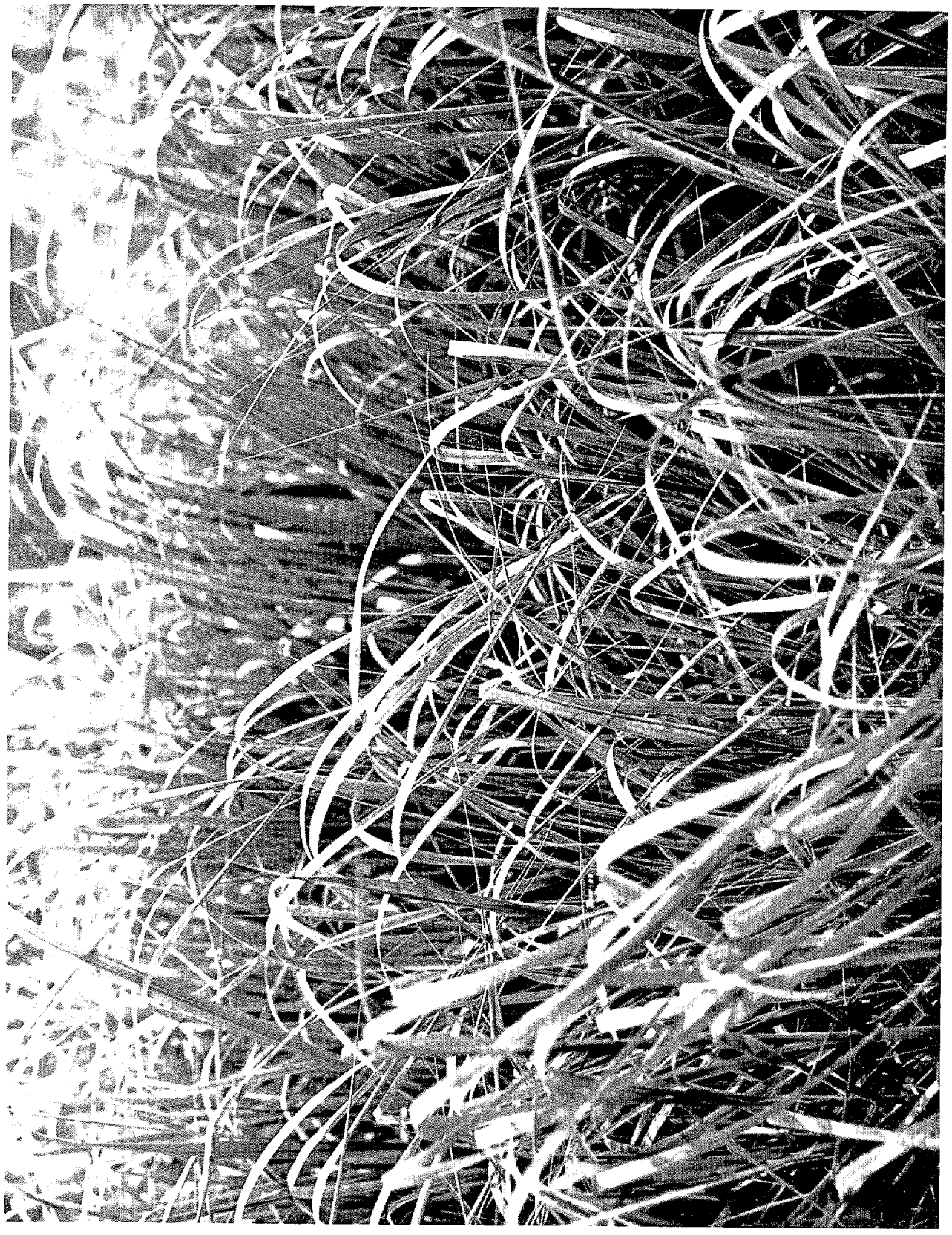
Drawyers Creek

FIGURE 6

BIG CORDGRASS
(Spartina Cynosuroides)

Taylors Bridge

FIGURE 7



SALTMARSH CORDGRASS
(Spartina Alterniflora)

Taylors Bridge

FIGURE 8

GROUNDSEL BUSH (MARSH ELDER)
(Baccharis Namifolia)

Drawyers Creek

FIGURE 9

HIGH TIDE BUSH
(Iva Frutescens)

Little Creek

FIGURE 10

MARSH MALLOW
(Hibisas Palustris)

Indian River Inlet

FIGURE 11

PICKERELWEED
(Pontendria Cordata)

Red Lion Creek

FIGURE 12

PICKERELWEED
(Pontendria Cordata)

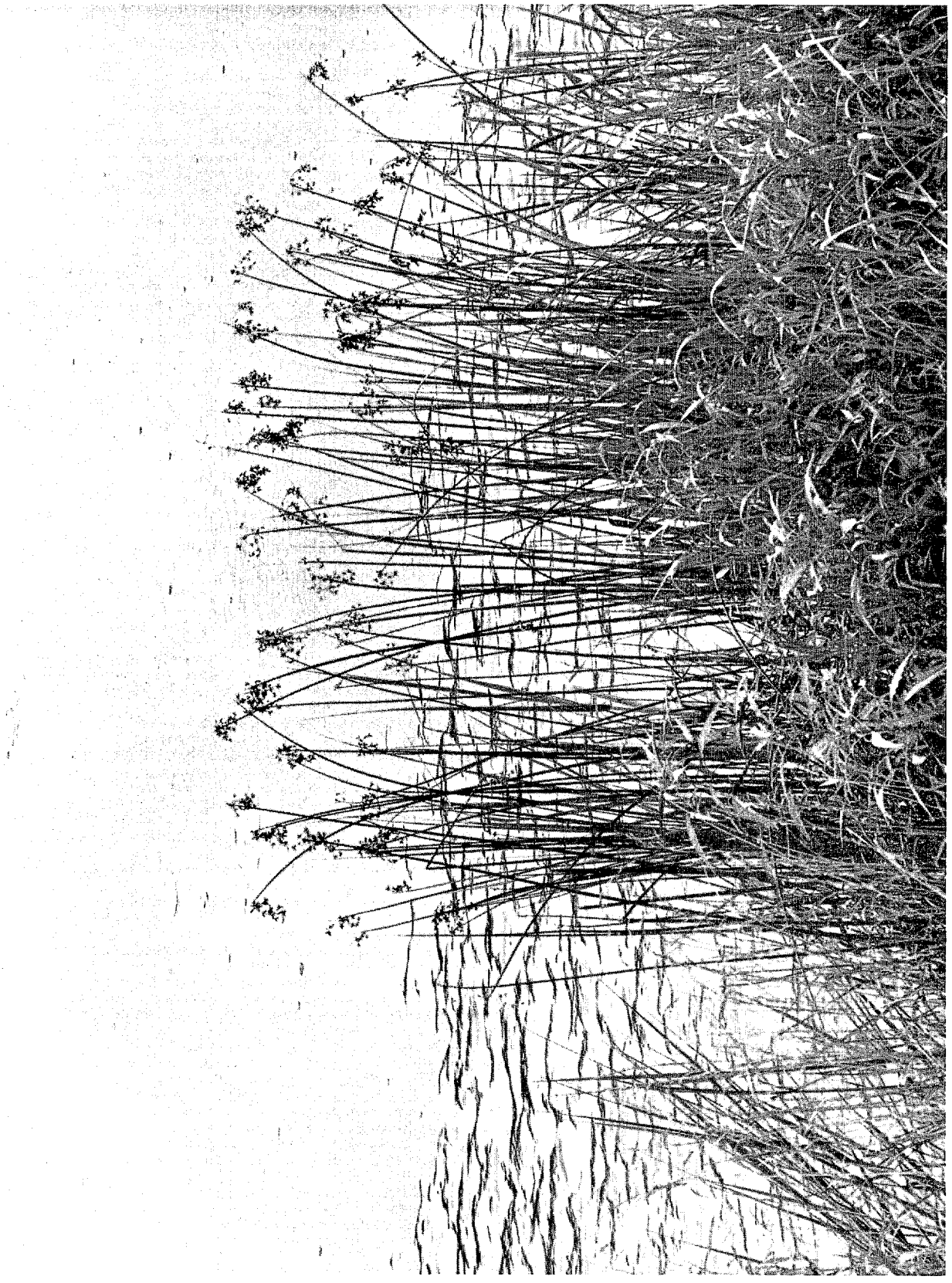
Red Lion Creek

FIGURE 13

REED GRASS
(Phragmites Communis)

Near Army Creek

FIGURE 14



RUSH
(Juncus Spp.)

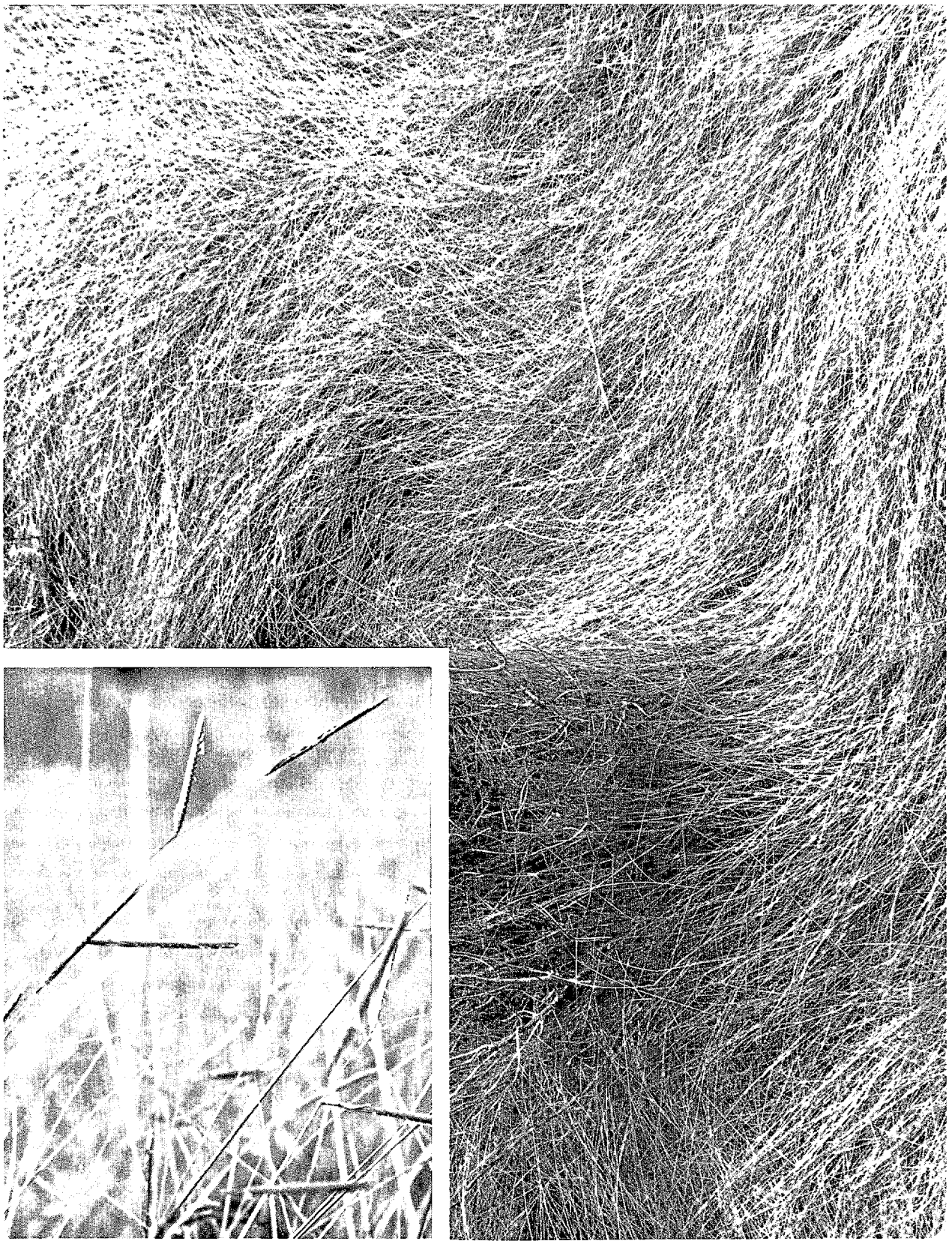
Dover

FIGURE 15

SPIKE GRASS
(Distichlis Spacata)

Little Creek

FIGURE 16



SALT HAY
(Spartina patens)

Woodland Beach
Wildlife Area

FIGURE 17

THREE SQUARE
(Scirpus Spp.)

Little Creek

FIGURE 18

TIDEMARSH WATER HEMP
(Acnida Cannabina)

Little Creek

FIGURE 19

WILD RICE
(Zizania Aquatica)

Appoquinimink River

WETLANDS CLASSIFICATION SYSTEM

In developing a Wetlands Atlas for the State of Delaware, a Wetlands Classification System composed of eight zones was instituted. The classification system evolved naturally from extensive ground truth experience and color infrared aerial imagery. The system is based on interpretation of marsh vegetation since it is the vegetation of the wetlands which largely creates the habitat, acts as a source of food for animals, recycles nutrients and creates a trap for sediments.

Vegetation is an accurate and specific reflection of all the many complex physical and chemical factors that are acting in wetland areas. In addition, once a vegetative zone has been identified, generalizations concerning production, animal associations and value of the area can be made. Vegetation can be mapped easily, at low cost and with reasonable accuracy using color infrared aerial photographs.

WETLANDS ZONES AND PROPERTIES

The system used for classification of Delaware's wetlands is derived from natural associations of plants found in the field. There are six floral zones (Zones I-VI), and there are two zones (Zones X, X^i) which refer to areas that were once marsh but have since been reclaimed by man for construction or impounding, respectively. Each floral zone is based on "dominant" vegetation (i.e., one or two major species which cover at least 50 per cent of a contiguous wetland area) with the exception of Zone V, Transition Marsh. For instance, Zone I is a marsh or wetland in which 50 per cent of the area is of one

species, Spartina alterniflora, salt marsh cordgrass. Species which are also commonly found in the area are listed as Associated Species. In many cases, the associated species depend on the location of the wetland area being mapped. New Castle County cordgrass marshes have associated species that differ somewhat from those found in the cordgrass marshes of the Small Bay areas in Sussex County (see Description of Drainage Areas).

Provided with a description of each wetland zone, a manager can more accurately evaluate and compare wetland areas. The evaluation will also allow the manager to weigh the costs and benefits of alternative uses for each area.

Each zone is described in terms of seven general parameters:

1. Primary flora - Primary flora identifies the dominant species present in the zone. A dominant species comprises at least 50 percent of the zone.

2. Growth habit - Growth habit describes the actual appearance of the plant as it appears in the marsh.

3. Primary production - Primary production is the amount of plant material produced in a growing season and is expressed as grams of dry weight of plant tissue per square meter (area) produced in a year (gm(dry) m^{-2} m^{-1}). An approximation of primary production is peak standing crop. The latter, based on a one-time sampling of a species when maximum growth has been achieved, is usually determined in August and is expressed as grams of dry weight per square meter (gm(dry) M^{-2}).

The term "detritus" refers to all the particulate organic matter derived from the decomposition of dead organisms, especially plants. In the process of decomposition nutrients are released, and these nutrients plus the detrital particles are moved out of and into the marshes by tidal action. These nutrients are a food source for micro-organisms and plants that form the base of the marine food chain.

Primary productivity and peak standing crop are important measurements since they determine how much detritus can become available for either peat accumulation or as a food source. In general, plants with high production values produce more detritus than do less productive species. The availability of detritus to the estuarine food web is also dependent upon the height of the marsh and the flushing rate of marsh streams.

4. Physiographic conditions - This term describes the location where the dominant flora can be expected to grow. Some species grow better at higher elevations and lower salinities than others. Physiographic conditions, then, describe where in a marsh the dominant species for each zone can be expected to be found.

5. Associated flora - Although most of the vegetative zones are dominated by one or sometimes two species of plants, there are, associated with each zone, other plants which are conspicuous to the observer. These species are listed as associated flora (see species pictures).

6. Associated waterfowl and wildlife - Waterfowl and wildlife are often attracted to a particular vegetative zone for food and/or shelter. For example, muskrats use cordgrass stems for their houses and cattails for food, and several species of ducks feed on seeds from the marsh, while geese consume the roots of the three-square.

7. Biting flies and mosquitos - The production of biting flies and mosquitos varies with vegetative zone. Areas regularly flushed by the tides are generally poor breeding areas for the salt marsh mosquito but may produce large numbers of biting flies.

Following is a list of the zones and associated vegetation, along with photographs of a typical example of each zone.

WETLANDS ZONES AND ASSOCIATED VEGETATION

ZONE I. Cordgrass Marsh

A. Dominant species - Salt marsh cordgrass (Spartina alterniflora)

B. Associated species - Big cordgrass (Spartina cynosuroides)
Salt hay (Spartina patens)
High tide bush (Iva frutescens)
Groundsel bush (Baccharis halimifolia)
Spike grass (Distichlis spicata)

C. Others, depending on location: Salt wort (Salicornia sp.)
Three-Square (Scirpus sp.)
Rush (Juncus gerardi)
Marsh mallow (Hibiscus palustris)
Spike rush (Eleocharis sp.)
Giant reed grass (Phragmites communis)

ZONE II. Salt Hay Marsh

A. Dominant species - Salt hay (S. patens)
Spike grass (D. spicata)

B. Associated species - Salt marsh cordgrass (S. alterniflora)
Big cordgrass (S. cynosuroides)
Groundsel bush (B. halimifolia)

ZONE III. Salt Bush Marsh

A. Dominant species - High tide bush (I. frutescens) or,
Groundsel bush (B. halimifolia)

Salt hay (S. patens) or,
Spike grass (D. spicata)

B. Associated species - Big cordgrass (S. cynosuroides)
Salt marsh cordgrass (S. alterniflora)
Marsh mallow (H. palustris)
Giant reed grass (P. communis)

ZONE IV. Giant Reed Grass Marsh

A. Dominant species - Giant reed grass (P. communis)

B. Associated species - Generally, none.

ZONE V. Transition Marsh

A. Dominant species - No dominants

B. Associated species - Salt marsh cordgrass (S. alterniflora)
Big cordgrass (S. cynosuroides)
Giant reed grass (P. communis)
Marsh mallow (H. palustris)
Three-Square (Scirpus sp.)
Cattail (Typha sp.)
Wild Rice (Zizania aquatica)
Arrow-arum (Peltandra virginica)
Pickerel weed (Pontederia cordata)
Tide marsh water hemp (Acnida cannabina)

ZONE VI. Arrow-Arum or Pickerel Weed Marsh

A. Dominant species - Arrow-arum (P. virginica) or,
Pickerel weed (P. cordata)

B. Associated species - Wild rice (Z. aquatica)
Marsh mallow (H. palustris)
Arrowhead (Sagittaria sp.)

ZONE X. Lost Marsh (1937-38 to present)

ZONE X^i. Impounded Marsh

ZONE I. Cordgrass Marsh

Primary Flora: Salt marsh cordgrass (*Spartina alterniflora*, Loisel)

Growth Habit: A stout, erect grass, with long smooth tough leaf-blades, and strong creeping rhizomes, usually growing in pure stands. Tending to occur in a tall form near the water's edge followed by a smaller dwarf form to approximately the level of mean high water. The surface of the marsh is usually clearly visible between individual plants at low tide.

Primary Production:

Value	Measure	Size	Locale	Source
445	$g(dry)m^{-2}yr^{-1}$	mixed	Canary Crk.	Morgan, 1961
517	$g(dry)m^{-2}$	short	Canary Crk.	Sullivan and Daiber, 1974
362	$g(dry)m^{-2}$	short	Canary Crk.	Clark, 1975
1419	$g(dry)m^{-2}$	tall	Canary Crk.	Clark, 1975
704	$g(dry)m^{-2}$	mixed	Murderkill	Crichton and Fornes, 1973

Physiographic Conditions: Growing from mean sea level to approximately mean high water in saline to brackish water on a layer of peat formed from roots and accumulated muddy sediment.

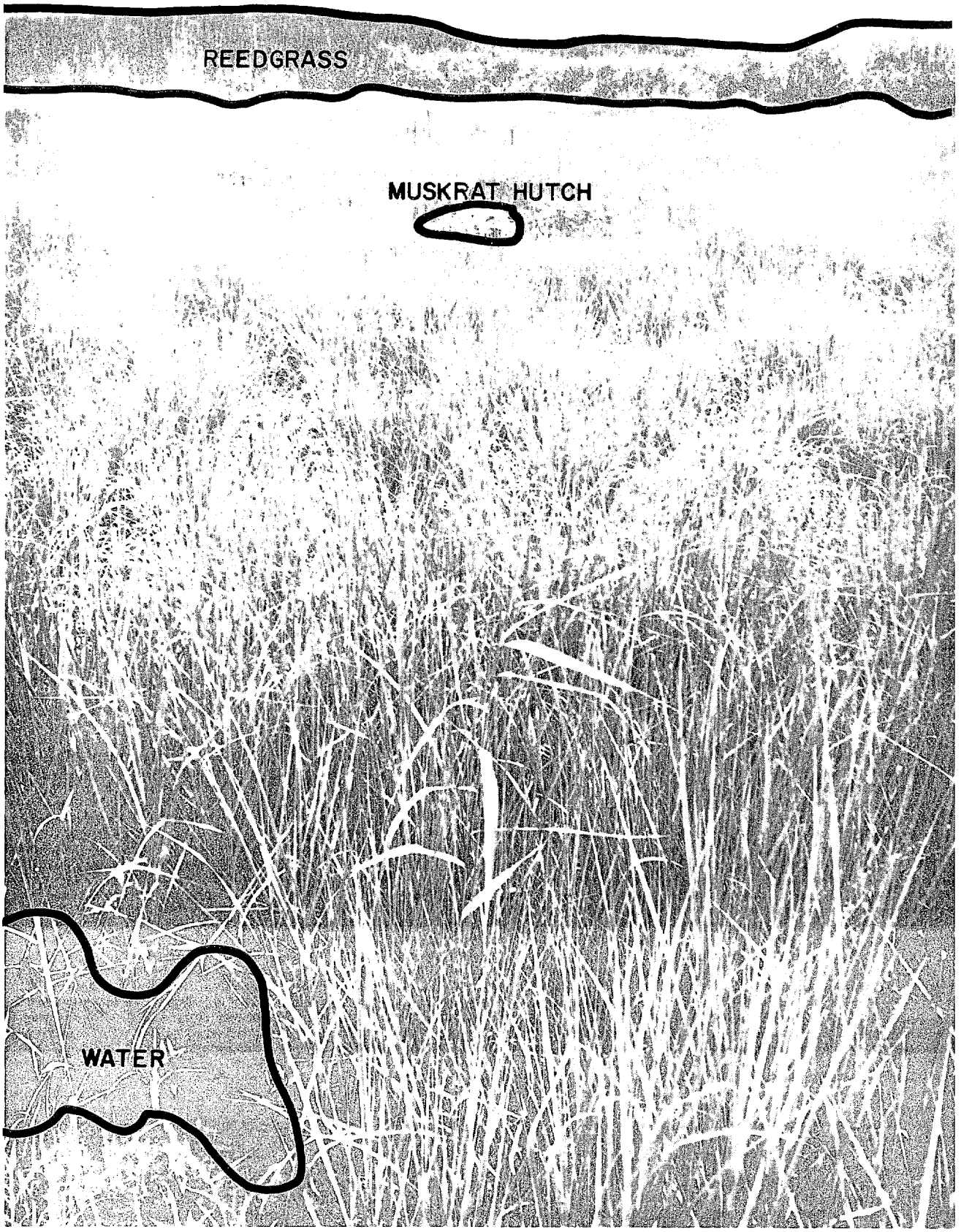
Secondary Flora: (Usually associated with spoil banks along drainage ditches and portions of the marsh above mean high water.) Salt hay (*Spartina patens* (L.) Greene), Big cordgrass (*Spartina cynosuroides* (L.) Roth), Spike grass (*Distichlis spicata* (L.) Greene), Salt wort (*Salicornia* sp.), High tide bush (*Iva frutescens* L.), Groundsel bush (*Baccharis halimifolia* L.), Reed grass (*Phragmites communis* Trinius), Marsh mallow (*Hibiscus* sp.)

Associated Waterfowl and Wildlife: Canada goose, Black duck. Roots and rhizomes eaten by waterfowl such as Black duck, Green-winged Teal and leaves and stems eaten by geese and muskrats (along with root stocks). Stems used for muskrat lodges. Nesting material for rails and willets. Protective cover. Seeds eaten by several kinds of ducks, especially the Black duck.

Biting Flies and Mosquitoes: Mosquito production varies in this zone, depending upon the frequency of inundation. In most cases, breeding is low in frequently flooded tall salt marsh cordgrass areas. Abundant breeding may be expected, however in areas of salt marsh cordgrass where the marsh surface is flooded less than eight days per lunar month.

Greenhead flies (Tabanids) breed and develop in greatest numbers in the wetter parts of marshes. Most larvae are recovered in the regularly flooded cordgrass zone than elsewhere. One study ranked biting fly production according to vegetation in the following decreasing order: salt marsh cordgrass, big cordgrass and spike grass. Adult greenheads, however, tend to be found in the greatest numbers at the marsh uplands border.

Figure 20



ZONE I CORDGRASS MARSH Taylors Bridge

ZONE II. Salt Meadow Marsh

Primary Flora: Salt hay (*Spartina patens* (L.) Greene)
Spike grass (*Distichlis spicata* (L.) Greene)

Growth Habit: Salt hay growing in dense yellowish-green mats, often resembles a meadow with swirls or "cowlicks". Spike grass, darker green and often growing along with salt hay but frequently occurring in dense, erect, pure stands, resembles a lawn with dense sods. Accumulated dead and decaying grass completely hides the marsh surface.

Primary Production:

	Value	Measure	Locale	Source
S. patens	537	$g(dry)m^{-2}$	Murderkill River	Crichton and Fornes, 1973
	908	$g(dry)m^{-2}$	Sussex County	Reimold and Gallagher, 1973
D. spicata	629	$g(dry)m^{-2}$	Murderkill River	Crichton and Fornes, 1973
	460	$g(dry)m^{-2}$	Sussex County	Reimold and Gallagher, 1973

Physiographic Conditions: Growing at elevations that are generally flooded only by tides that exceed the mean high level. Marsh surface formed of peat with less mud than the cordgrass zone.

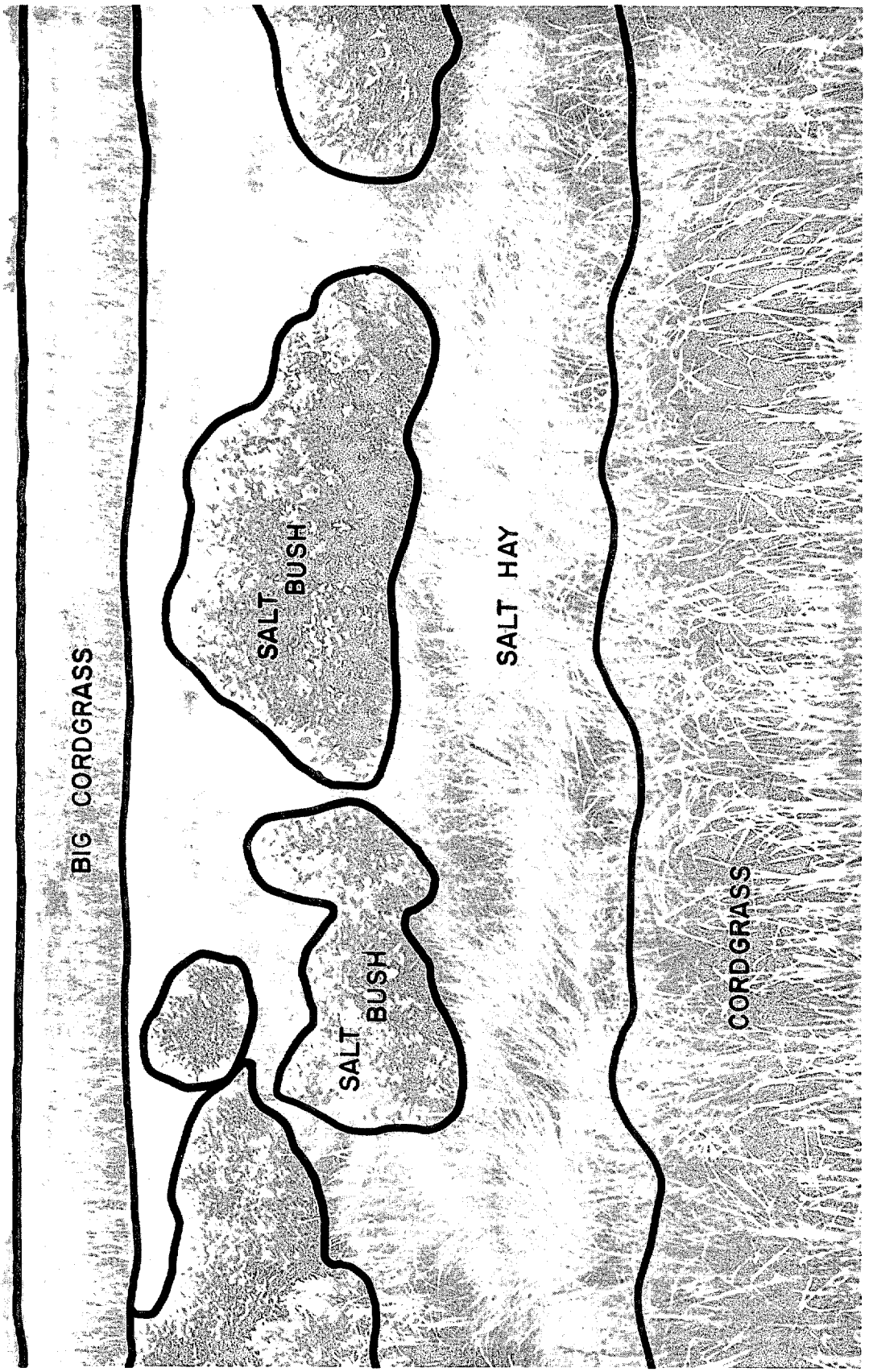
Secondary Flora: Salt marsh cordgrass along drainage ditches and in depressions. Big cordgrass growing in wetter areas often separating the salt meadow from the cordgrass. High tide bush and marsh mallow in the higher areas, and sometimes scattered throughout the meadow. Reed grass in small patches and near upland margins.

Associated Waterfowl and Wildlife: A source of food in the form of seeds and root stocks for ducks, rails, geese and muskrats. Spike grass seed heads, young plants and root stocks are eaten by ducks and rails. Dense growth provides nesting cover for waterfowl, especially teal. Browsed by deer.

Biting Flies and Mosquitoes: Being an area infrequently inundated and flushed and often with shallow pools of stagnant water, mosquito production in this zone is usually very high. Conditions such as those that often occur in the salt hay are ideal for mosquito breeding.

Biting fly production is less than that in the salt marsh cordgrass zone. Generally, the number of larvae decrease as the ground elevation increases from that of the salt marsh cordgrass zone.

Figure 21



ZONE II SALTMEADOW MARSH Taylors Bridge

ZONE III. Salt Bush - Salt Meadow Marsh

Primary Flora: Salt bushes - High tide bush (*Iva frutescens*, L.) or,
Groundsel bush (*Baccharis halimifolia*, L.)
Salt hay (*S. patens*) or,
Spike grass (*D. spicata*)

Growth Habit: Marsh surface densely covered with salt hay and spike grass as in Zone II but with numerous plants of either High tide bush or Groundsel bush.

Primary Production:

	Value	Measure	Locale	Source
Iva frutescens	448*	$g(dry)m^{-2}$	Sussex County	Reimold and Gallagher, 1973
	626*	$g(dry)m^{-2}$	Sussex County	Reimold and Gallagher, 1973
Baccharis halimifolia	--	--	--	--

*Estimated from living biomass.

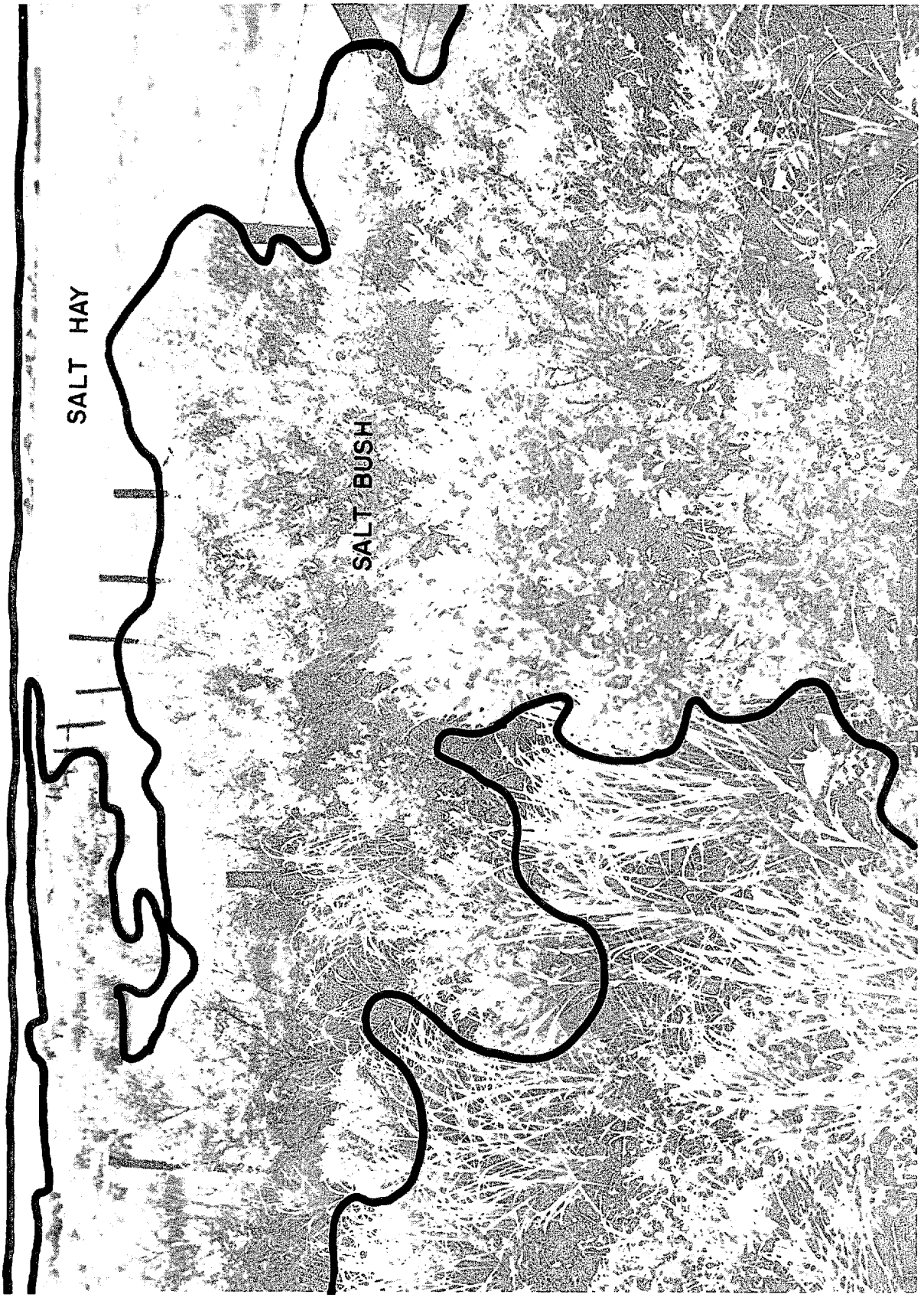
Physiographic Conditions: Very similar to Zone II but drier and usually occurring in closer proximity to the uplands. Represents the upper limit of the salt marsh.

Secondary Flora: Salt marsh cordgrass and Big cordgrass near drainage ditches and wherever the marsh is wet and low. Marsh mallow tends to occur scattered throughout this area. Reed grass may occur in patches and at upland border. Switch grass (*Panicum virgatum*) can occur between this zone and upland, especially near fields and roads.

Associated Waterfowl and Wildlife: Similar to Zone II due to abundance of salt hay and spike grass. It provides a nesting area for small birds and cover for a great variety of wildlife. Salt bushes themselves, however, provide no significant food value to the inhabitants.

Biting Flies and Mosquitoes: Mosquito larvae are usually few in number in this zone, as there is little standing water and the soil is generally too dry. Similarly, few greenhead fly larvae are found. Adult mosquitoes and greenheads are frequently found in Zone III, however, because salt bushes frequently form boundaries between the marsh and uplands.

Figure 22



ZONE III SALT BUSH-SALT MEADOW MARSH Grecos Canal

ZONE IV. Reed Grass Marsh

Primary Flora: Reed grass (Phragmites communis)

Growth Habit: Tending to grow in colonies of tall, stout, leafy plants with feathery terminal panicles or seed heads. Difficult to walk through due to the accumulation of dead stalks and leaves. Isolated colonies often form circular patches. Tending to take over and displace the original vegetation in marshes that have been disturbed.

Primary Production:

Value	Measure	Locale	Source
1379	$g(dry)m^{-2}$	Sussex County	Reimold and Gallagher, 1973
1900	$g(dry)m^{-2}$	Freeman Highway, Lewes	Tyrawski, 1975
1450	$g(dry)m^{-2}$	Milford	Tyrawski, 1975
861	$g(dry)m^{-2}$	Murderkill River	Crichton and Fornes, 1973
1812	$g(dry)m^{-2}$	Blackbird Creek	Crichton and Fornes, 1973

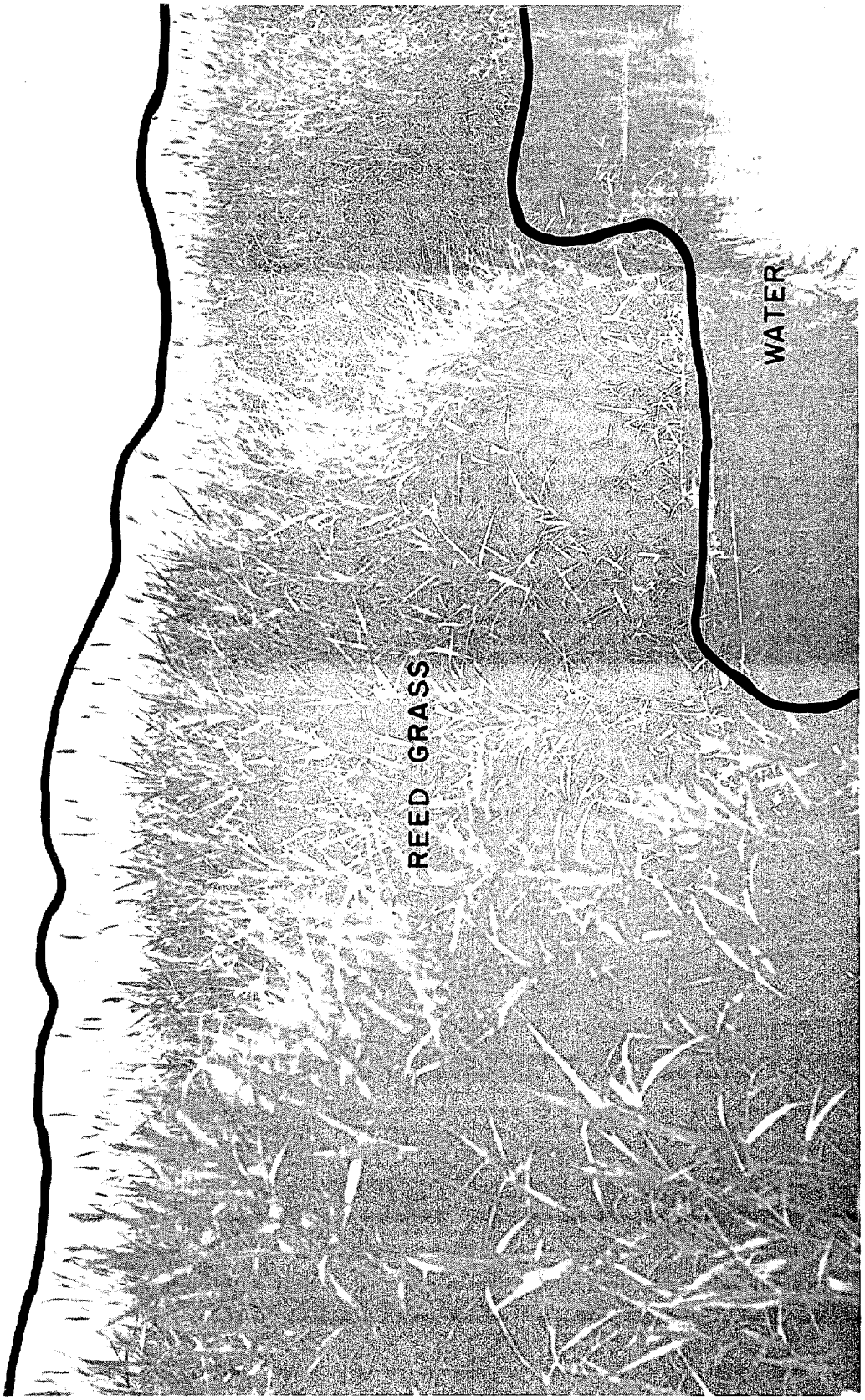
Physiographic Conditions: Growing at or above mean high tide and frequently colonizing disturbed areas such as spoil piles.

Secondary Flora: Reed grass tends to grow in pure stands with essentially no secondary flora. Frequently, however, especially before reed grass has completely taken over a marsh, it occurs in circular patches of various sizes, which tend to merge with one another. In such cases, cord grasses may grow between these patches. Reed grass is often associated with transition zone plants.

Associated Waterfowl and Wildlife: Provides cover and nesting area for wildlife but is of little direct food value.

Biting Flies and Mosquitoes: Because of the deep litter layer characteristic of this zone, both mosquito and biting fly production is low. Where the giant reed is found along the edge of a marsh, adult mosquitoes and flies may be present in considerable numbers.

Figure 23



ZONE IV REED GRASS MARSH Thousand Acre Marsh

ZONE V. Transition Marsh

Primary Flora: In general no single species dominates this zone but at the same time there is no sharp line of demarcation that separates it from the cordgrass zone or the arrow-arum-Pickerel weed zone. It occurs wherever drainage patterns extend far inland and water becomes essentially fresh.

Wetland Species:
Salt marsh cordgrass
Big cordgrass
Rush (*Juncus* spp.)
Three-Square (*Scirpus* spp.)
Switch grass
Groundsel bush
High tide bush
Marsh mallow
Cattail (*Typha* spp.)
Arrow-arum (*Peltrandra virginica* (L.) Kunth)
Pickerel weed (*Pontederia cordata* L.)
Tide marsh water hemp (*Acnida cannabina* L.)
Reed grass
Wild rice (*Zizania aquatica* L.)

Growth Habit: Highly variable depending on species present.

Primary Production:

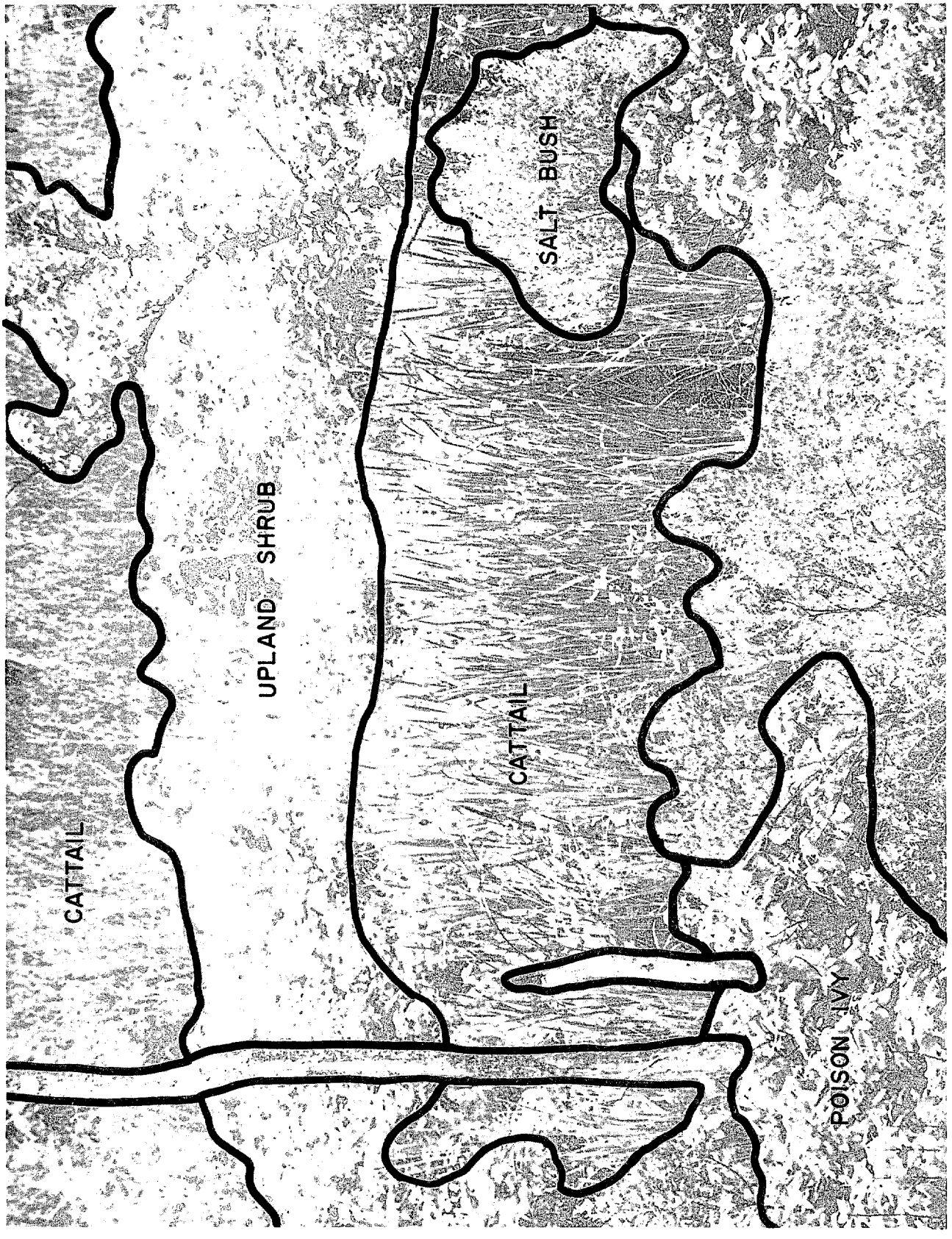
	Value	Measure	Locale	Source
Typha sp.	1565	$g(dry)m^{-2}yr^{-1}$	New Jersey	Jervis, 1969
Mixed	1246	$g(dry)m^{-2}$	Maryland	Johnson, 1970
S. cynosuroides	1110	$g(dry)m^{-2}$	Blackbird	Crichton and Fornes, 1973
Z. aquatica	1547	$g(dry)m^{-2}yr^{-1}$	New Jersey	Jervis, 1964
J. gerardi	180	$g(dry)m^{-2}$	Sussex Co.	Reimold and Gallagher, 1973

Physiographic Conditions: Very wet and still affected by tidal action. Salinity low. Peat substrate giving way to mud.

Associated Waterfowl and Wildlife: Provides excellent conditions for many ducks, rails and for the muskrat for both food, nesting and shelter.

Biting Flies and Mosquitoes: Production of the salt marsh mosquito *Aedes sollicitans* and of the greenhead flies is reduced in this zone because of decreased salinities. The production of other less obnoxious mosquitoes is increased, however.

Figure 24



ZONE V TRANSITION MARSH St. Jones River, Dover

ZONE VI. Arrow-Arum - Pickerel Weed Marsh

Primary Flora: Arrow-arum (Peltandra virginica (L.) Kunth)
Pickerel weed (Pontederia cordata L.)

Growth Habit: Erect closely spaced clumps of plants with broad heart or arrow shaped leaves and thick fleshy roots.

Primary Production:

	Value	Measure	Locale	Source
P. virginica	160	$g(dry)m^{-2}yr^{-1}$	New Jersey	Jervis, 1969
	230	$g(dry)m^{-2}yr^{-1}$	New Jersey	Jervis, 1969
P. cordata	63	$g(dry)m^{-2}yr^{-1}$	New Jersey	Jervis, 1969

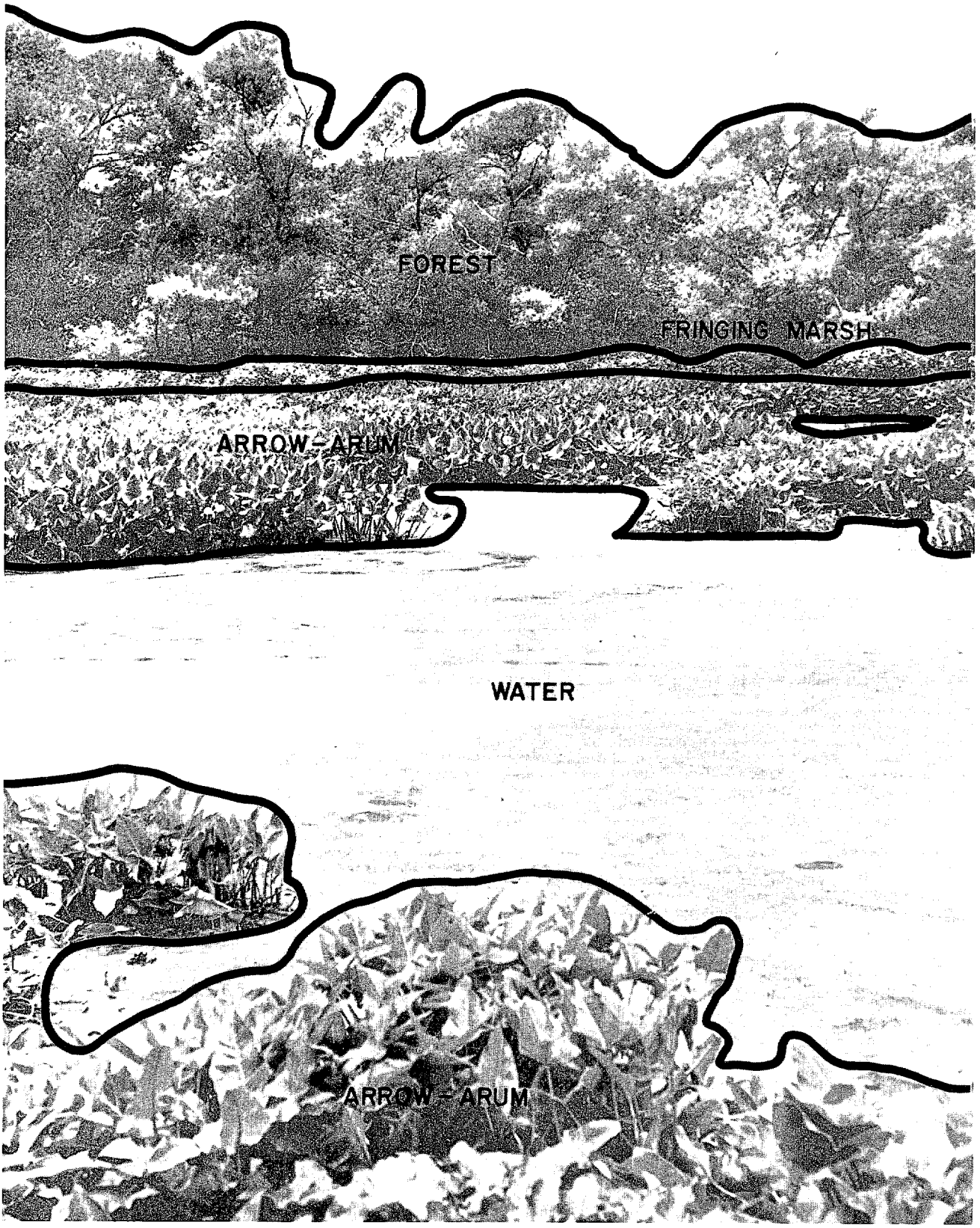
Physiographic Conditions: Tidal mud flats where the salinity is low and in freshwater.

Secondary Flora: Reed grass often growing as fringe that separates this zone from the uplands. Marsh mallow growing at higher elevations throughout the zone. Arrow-head (Sagittaria sp.) in freshwater areas. Wild rice in areas of brackish to freshwater. Cattails may occur throughout this zone.

Associated Waterfowl and Wildlife: Wild rice and arrow-head attract many species of ducks and the wood duck feeds extensively on arrow-arum seeds. Muskrats utilize cattails and arrow-head for food.

Biting Flies and Mosquitoes: Little information exists on the numbers of mosquitoes and biting flies in these areas. The information available suggests that production of greenhead flies and marsh mosquitoes is low in these areas.

Figure 25



ZONE VI ARROW-ARUM MARSH Augustine Creek

WETLANDS ATLAS (MAPS)

Following is a set of wetlands maps showing the distribution of the various wetland zones. The imagery used in mapping the wetlands of the state was derived from NASA Mission 247 Roll 120, flown August 29, 1973, for the tidal wetlands and NASA mission 144 Roll 20B, flown August 23, 1970, for the Nanticoke drainage area. The original photos are nine inch color infrared and provide optimal discrimination of vegetative types. Mission 247 photos approximate a scale of 1/240,000 and Mission 144 approximates 1/60,000.

In addition to the use of photographs, visits to field sites were carried out to obtain ground truth. This data was used to substantiate the interpretation made from the photos.

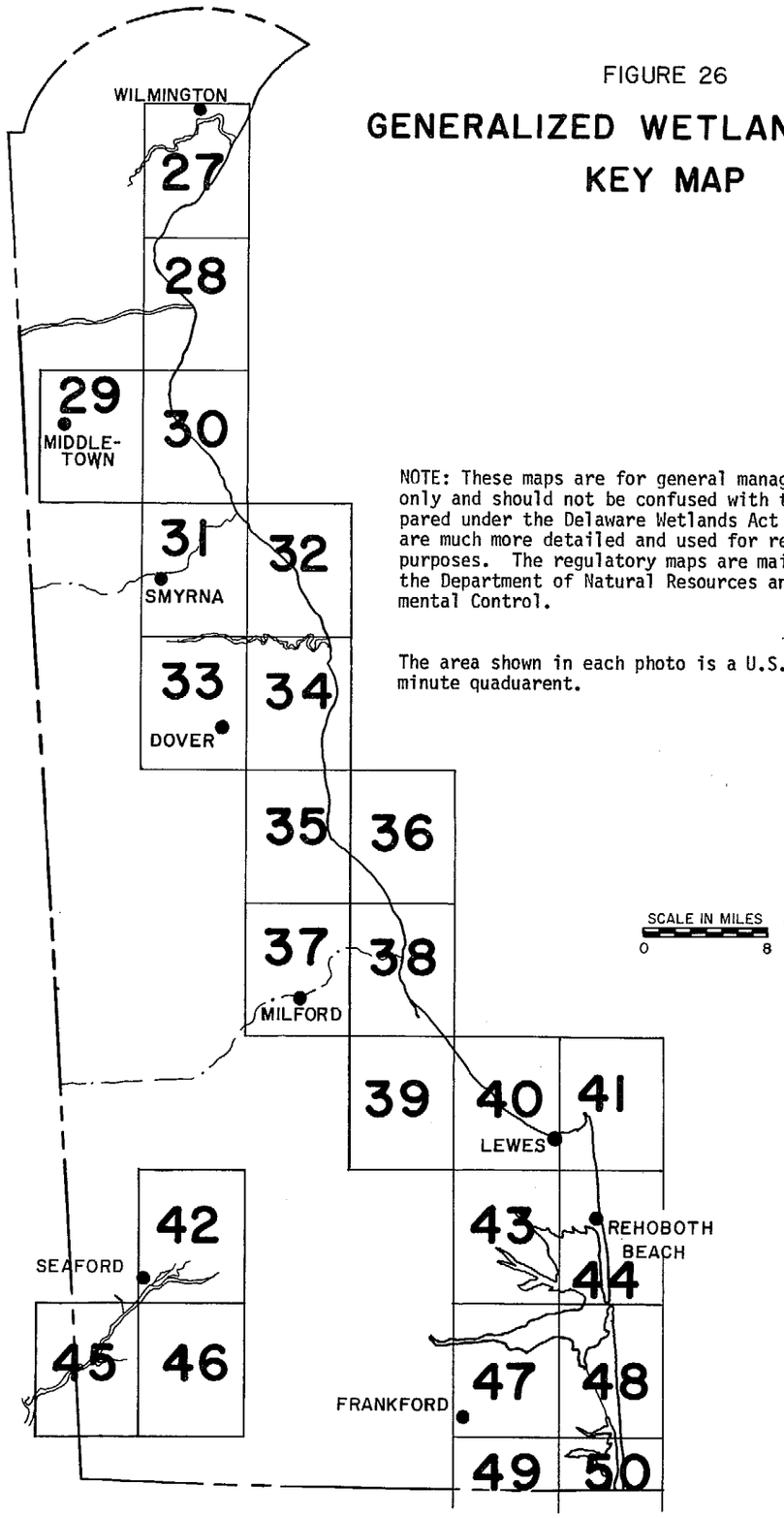
The classification zones as determined from the color infrared photos were outlined onto reproduced aerial photomaps of the state dated March 28, 1973. Each photo map corresponds to the standard U.S.G.S. topographic map quadrangle. Classification zones as distinguished on the photomaps were also numbered appropriately.

A word of caution must be raised regarding use of these maps. First, they are intended for management policy making, not regulatory use and should not be used for specific applications. Second, an official set of wetlands maps as required under the Delaware Wetlands Act of 1973 has been developed for the Department of Natural Resources and Environmental Control at a scale of 1"=200'. It is this set which has regulatory (permit) application. Finally, the data base is limited somewhat by the age of the infrared photographs (1970 and 1973) and the date of the photomaps developed for U.S.G.S. quadrangle mapping purposes (1973 vintage). Accordingly, recent land development activities may have eliminated or modified some wetlands areas through filling, diking, ditching or paving.

Wilmington South Figure 27 Generalized Wetlands Atlas

FIGURE 26

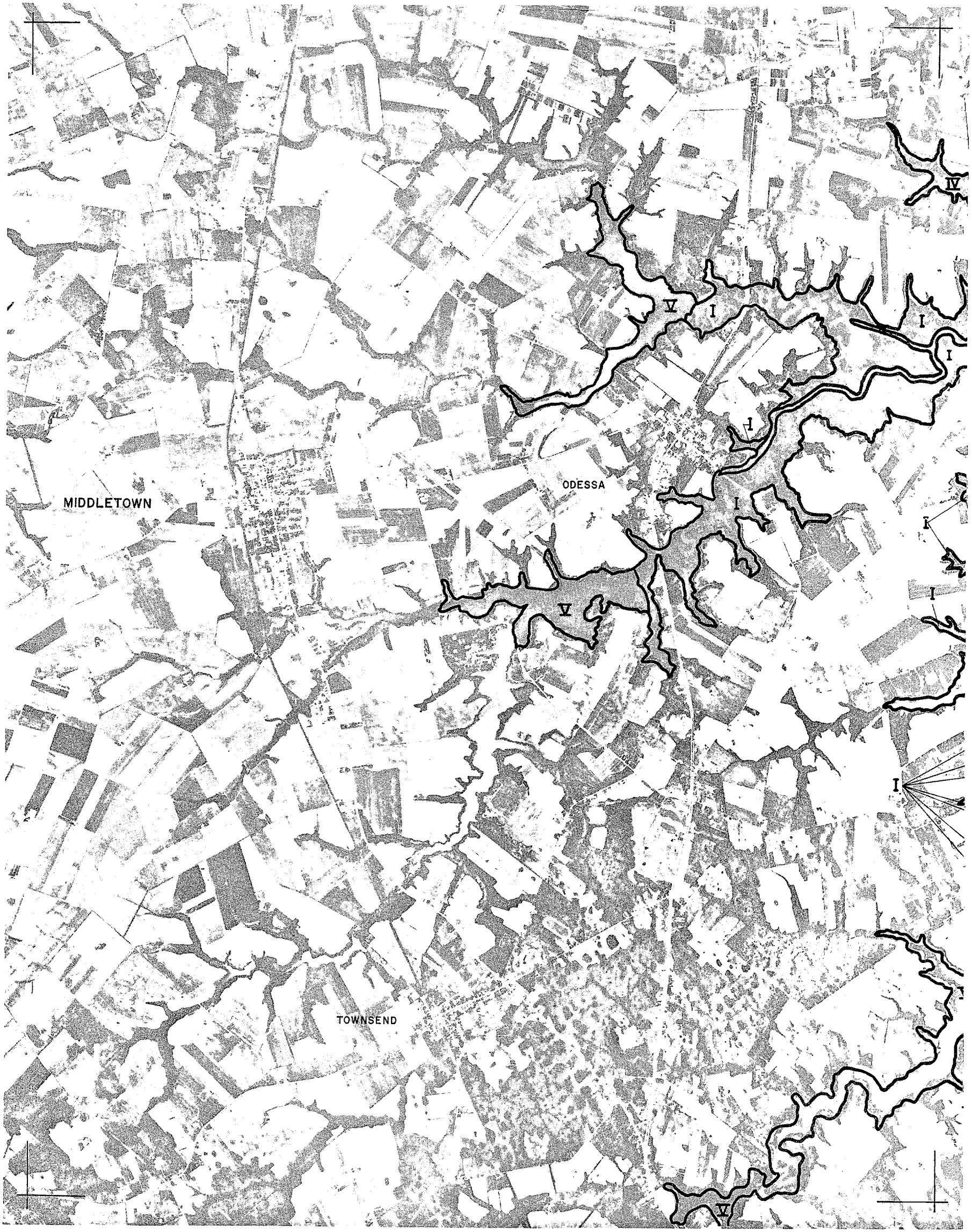
GENERALIZED WETLAND ATLAS
KEY MAP



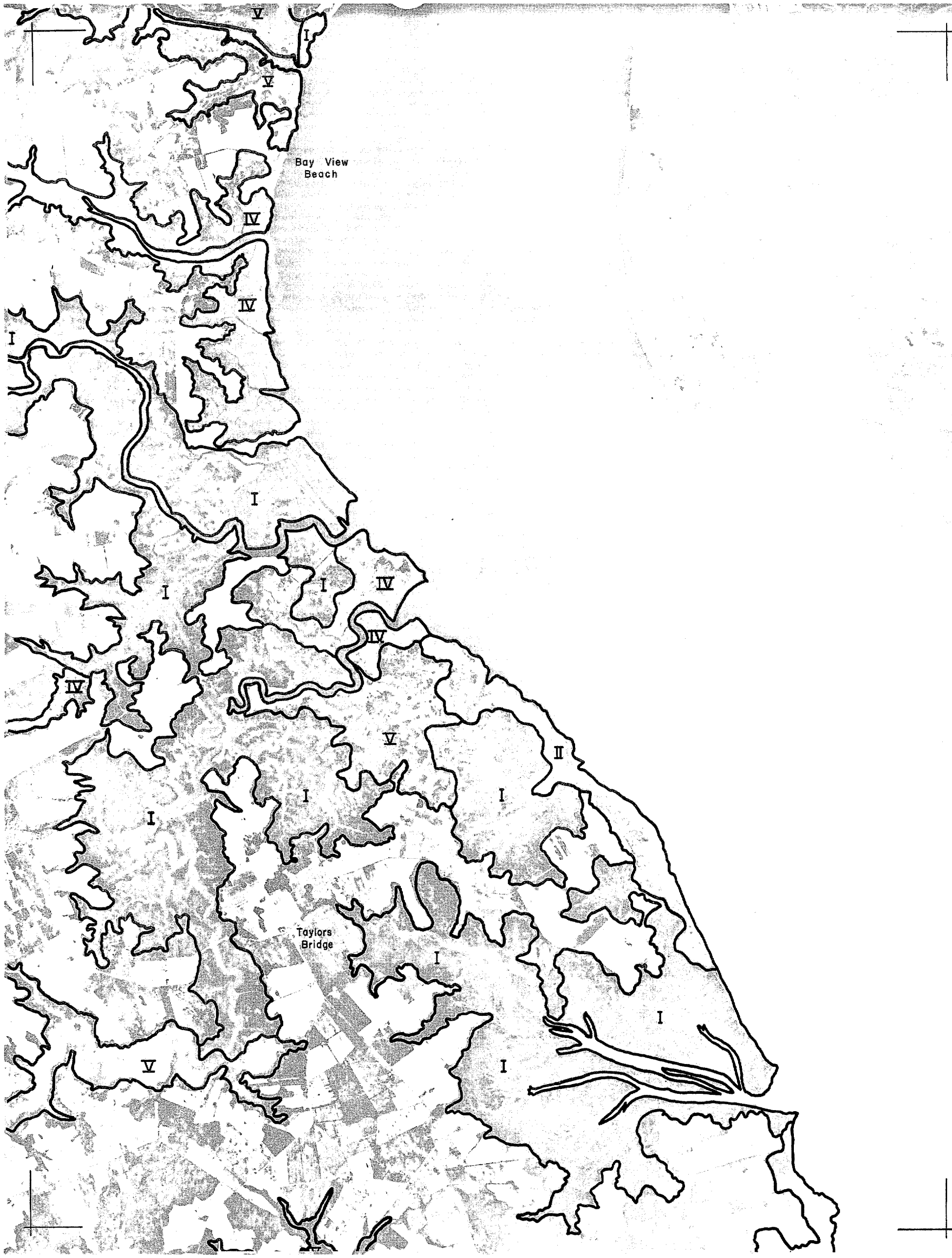
NOTE: These maps are for general management purposes only and should not be confused with the maps prepared under the Delaware Wetlands Act of 1973 which are much more detailed and used for regulatory purposes. The regulatory maps are maintained by the Department of Natural Resources and Environmental Control.

The area shown in each photo is a U.S.G.S. 7.5 minute quaduarent.

Delaware City Figure 28 Generalized Wetlands Atlas



Middletown Figure 29 Generalized Wetlands Atlas



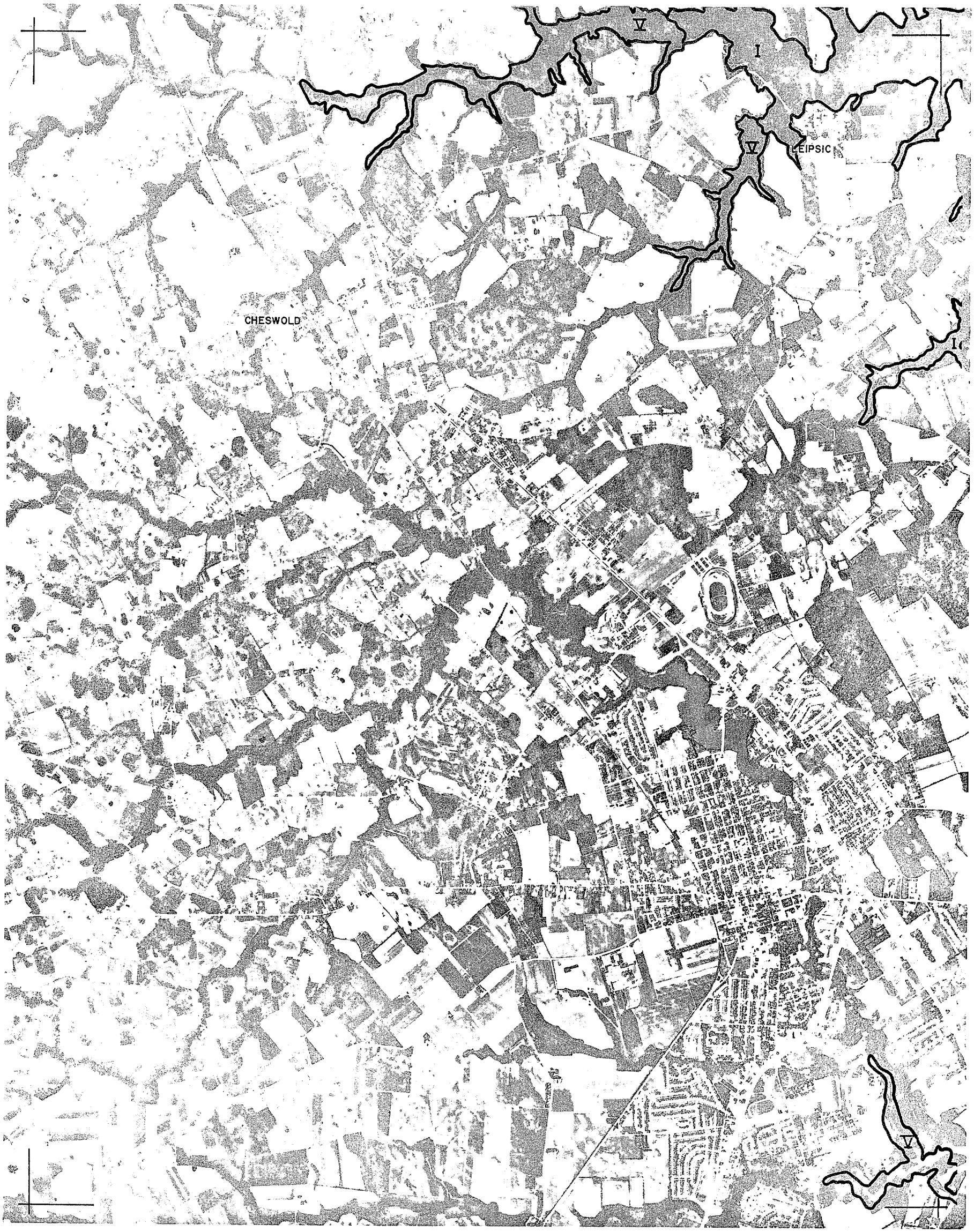
Taylors Bridge Figure 30 Generalized Wetlands Atlas

Smyrna

Figure 31

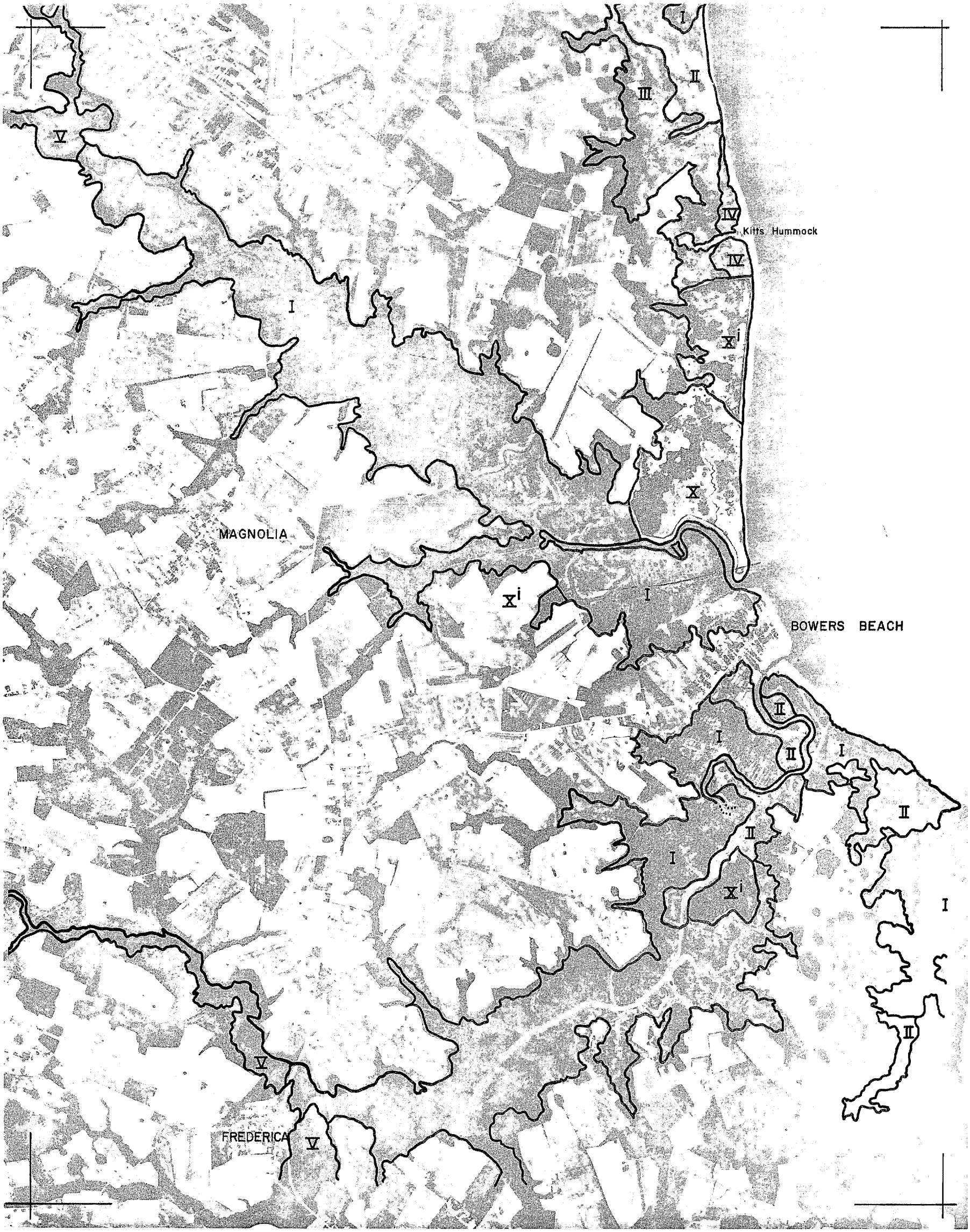
Generalized Wetlands Atlas

Bombay Hook Figure 32 Generalized Wetlands Atlas



Dover Figure 33 Generalized Wetlands Atlas

Little Creek Figure 34 Generalized Wetlands Atlas



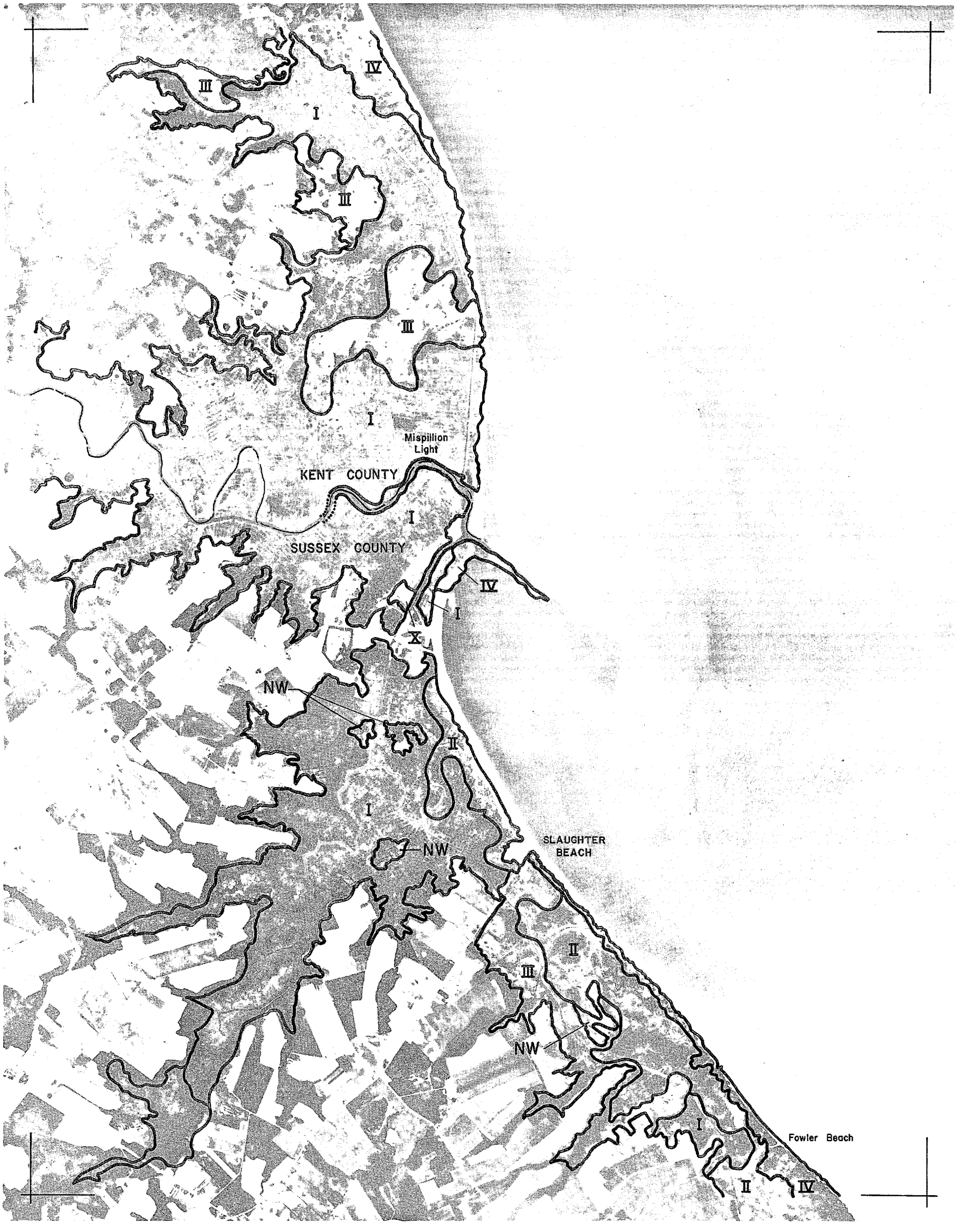
Frederica Figure 35 Generalized Wetlands Atlas

Milford Figure 37 Generalized Wetlands Atlas

Bennetts Pier

Figure 36

Generalized Wetlands Atlas



Mispillion River Figure 38 Generalized Wetlands Atlas

Milton Figure 39 Generalized Wetlands Atlas

Lewes Figure 40 Generalized Wetlands Atlas

Cape Henlopen Figure 41 Generalized Wetlands Atlas

SECTION II

ESTUARINE RESOURCES

SECTION II - ESTUARINE RESOURCES

INTRODUCTION TO ESTUARINE INHABITANTS - LIFE HISTORIES

The following section contains life histories of the more common estuarine and wetlands inhabitants of Delaware. It is not by accident that most of the species are fish, since they are the most numerous of the vertebrates with 15,000 to 17,000 total species compared to 4,500 amphibians.

THE "TYPICAL" FISH

Fish come in a great variety of sizes and shapes--from a couple of millimeters (one inch) to nearly 21 meters (70 feet) and in round, flat or angular shapes. Most of the species, except the flounders that inhabit the estuaries, are of "typical" fusiform (streamlined) shape. They are bilaterally symetrical (left and right sides are mirror images of each other), covered with scales, and have fins for propulsion and balance. Figure 82 depicts a typical fish.

Fins are the appendages of fish and are either paired or median. Median fins includes the dorsal fin(s) along the back, the caudal or tail fin and the anal fin along the lower edge of the body, just behind the vent. A fish can have one, two or three dorsal fins. Killifishes (Fundulus spp.) and herrings have one dorsal fin; striped bass (morone saxatilis) and sharks have two dorsals, while cod (Gadus spp.) have three. The single dorsal fin and the second dorsal fin in fish with two dorsals have soft rays. The first dorsal in fish with two dorsals is composed of stiff spines. The anal fin typically has soft rays preceded by one, two, or more stiff spines.

Paired fins include the pectorals and the pelvics (ventrals). Pectorals are located just behind the gill opening. Pelvic fins are located ahead of, beneath, or behind the base of the pectoral. These three locations are termed

FIGURE 82

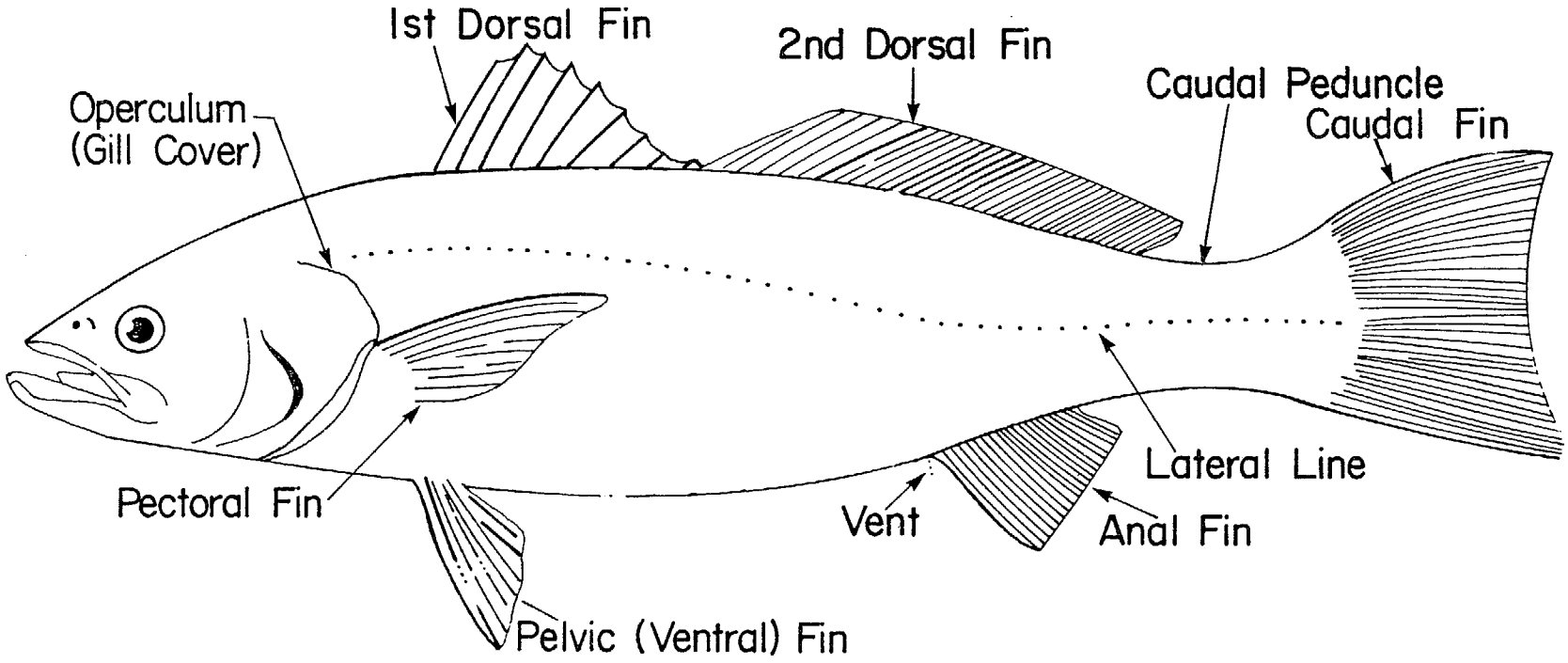


Diagram of typical fish with terms used in life histories

jugular, thoracic and abdominal, respectively.

The bodies of most common fish are covered with scales. Scales serve to protect the fish and to make the fish body impermeable to water and/or salt. In most fish a series of microscopic pores extending along each side from the head to the tail fin comprises the lateral line. The lateral line serves as a sensory organ responsive to chemicals and pressure changes in the water.

Fish must extract oxygen from the water and eliminate waste carbon dioxide from the blood. This typically occurs at the gills with water entering through the mouth, passing over the gills and leaving via the opercular or gill opening. The gill filaments are supported by bony gill arches and the gill area varies with the habits of fishes. Fast-swimming marine fishes such as menhaden (Brevoortia) possess more than five times the respiratory area per body weight found in sedentary fish such as toadfishes (Opsanus).

Gill rakers extend forward and inward from the gill arches and serve to strain food from the water. Those fish that eat zooplankton, such as herrings, silversides, anchovies, mullet, have numerous fine gill rakers, while the more carnivorous fish, such as bluefish (Pomatomus saltatrix), have fewer and shorter rakers.

These introductory comments on a "typical" fish will help in understanding the following life histories of fish. The accompanying diagram of a "typical" fish shows the characteristics described in the introductory comments.

SKATES

Raja erinacea, Raja eglanteria

Almost everyone who has fished in the Delaware area is familiar with the skates found here, for they are fairly common and very easily hooked. Most people consider them somewhat of a nuisance for there are very few baited hooks the skates will pass up, and fishermen often spend considerable time reeling in skates instead of more desirable species. Their desirability or lack of it is not shared by all, for people who know how to prepare the skates find them very delicious eating indeed.

Skates belong to a group of marine organisms known as the elasmobranchs, a group which also includes the sharks and rays. They are easily distinguished from the sharks by general body design and from the rays, whom they closely resemble, by features of the tail. It is long and whip-like in most rays, often without dorsal fins, but usually possessing a very prominent spine somewhere along the tail. This spine can be very dangerous since it is extremely sharp and often has poison or toxin associated with it. The skates, in contrast, have much reduced tails that are thicker in general form and which possess two dorsal fins near the end of the tail but no large spine. In addition, skates lay eggs while rays bear live young which are fairly well developed when born.

Unlike the true fishes which possess bony skeletons, members of the elasmobranch group have cartilaginous skeletons. Even the skull is made of this fibrous material. Elasmobranchs are also easily identifiable by the presence of at least five gill openings on each side of the head as opposed to the one found on each side of the bony fish. In the skates and rays these

gill openings are located on the ventral, or lower surface of the body. In sharks, the openings are on the sides of the body directly in front of the pectoral fins. The skin of the elasmobranchs is also very different from that of the fishes for it lacks true scales, being instead covered with scale-like studs, called denticles, that are very different in origin and appearance from the scales of the fish. As such, the skin of the elasmobranchs is usually very tough and leathery and feels rough to the touch.

Several species of skate are found in the Delaware area, two of which are very common -- the clearnose skate, Raja eglanteria, and the little skate Raja erinacea. All skates have the same general appearance in that they are flattened dorso-ventrally (from top to bottom), have eyes on the top surface, mouths and gills on the bottom, and pectoral fins that are large and wing-like in general design. These two common species, however, can be easily distinguished by a few prominent characteristics. The clearnose skate is fairly large, up to 70 centimeters (27 inches) in total body length and has a very angular shape to the body or disc as it is called, with bars of dark pigment being found on the dorsal surface. In addition, there is a row of spines running down the middle of the back and tail from the eyes to the first dorsal fin along with several rows of spines placed laterally to this row. Another characteristic, and one from which this skate receives its name, is the presence of two translucent areas, one on each side of the snout, which appear as clear areas in comparison to the rest of the body. The little skate, also known as the common skate, is usually somewhat smaller than the clearnose skate, growing to 50-60 centimeters (19 to 23 inches). It has a more rounded body, oval pigment spots on its dorsal surface instead of bars, and is missing the centrally placed row of spines along the back and tail.

Besides being very similar in appearance, these skates are very similar in their general habits, and they occupy similar positions, or niches, in the ecosystem of this general area. Each species prefers to live under slightly different temperature regimes, which serve to separate the niches of the two skates. The clearnose skate is typically a summer resident of Delaware coming inshore when the water temperatures rises above 9° or 10°C and moving offshore in the late fall when the water temperatures begin to drop. Their winter migration begins when water temperatures fall below 15°C, and they are completely gone from the area by the time the water returns to 9° or 10°C. The little skate follows an opposite pattern: moving inshore in the late autumn with falling water temperatures and offshore in the spring with rising temperatures. By early June, the population of little skates has usually completely disappeared from the Delaware Bay. However, they can be taken a short distance offshore where water temperature remains lower.

For most of the year, the two populations of skates are not occupying the same area so their interactions are few. There are times, however, during the migration periods, when these two species are occupying the same areas and do have much contact. Since they do exhibit very similar life styles (some aspects of which will be discussed later) these periods could possibly be periods of active competition between these two groups especially where food resources are concerned. How such competition affects these skates or the species of animals upon which they feed is not yet clear. More study is needed during the migration periods before scientists can fully understand such interactions and what they mean to the whole ecosystem.

Aside from the different temperature preferences exhibited by these two species, the clearnose skate and common skate differ in little else. When

present, their distributions in Delaware waters seem controlled mostly by salinity. Neither species is ever found in fresh or even brackish water and most individuals are found in water above 20‰ salinity. As an upper limit, they can tolerate water of 34‰ salinity which is above the salinity of the coastal and bay waters of Delaware and so not much of a controlling factor.

The feeding habits of these two species are also very similar. They are both considered opportunists for they will eat almost anything with which they come in contact. Several species of shrimp, crabs and other crustaceans, worms, molluscs, bivavles (especially the razor clam) and fish all have been found in the digestive systems of skates. While there are slight differences in the exact proportions of prey taken by each species, probably due in part to the prey availability during a particular season, it can be said that the two species of skates share the same food resources. Again, this could be important during the migration periods when these populations become intermingled.

All skates lay eggs which are deposited in characteristic egg cases familiar to most people who have walked along the beaches. Their cases are generally black or greenish in color, very leathery and rectangular in shape with horns and tendrils projecting from the four corners. There are slight differences in the egg cases of each species which allow one to identify each particular egg without too much difficulty. Production of the egg cases begins sometime before release of an egg from the ovary forming in a special gland, the shell gland, and are about two-thirds complete by the time a mature egg is deposited in them. After deposition, the cases become attached to some objects by the tendrils and the incubation period proceeds. While a good portion of the eggs develop successfully, some do not for they are

FIGURE 83
CLEARNOSE SKATE

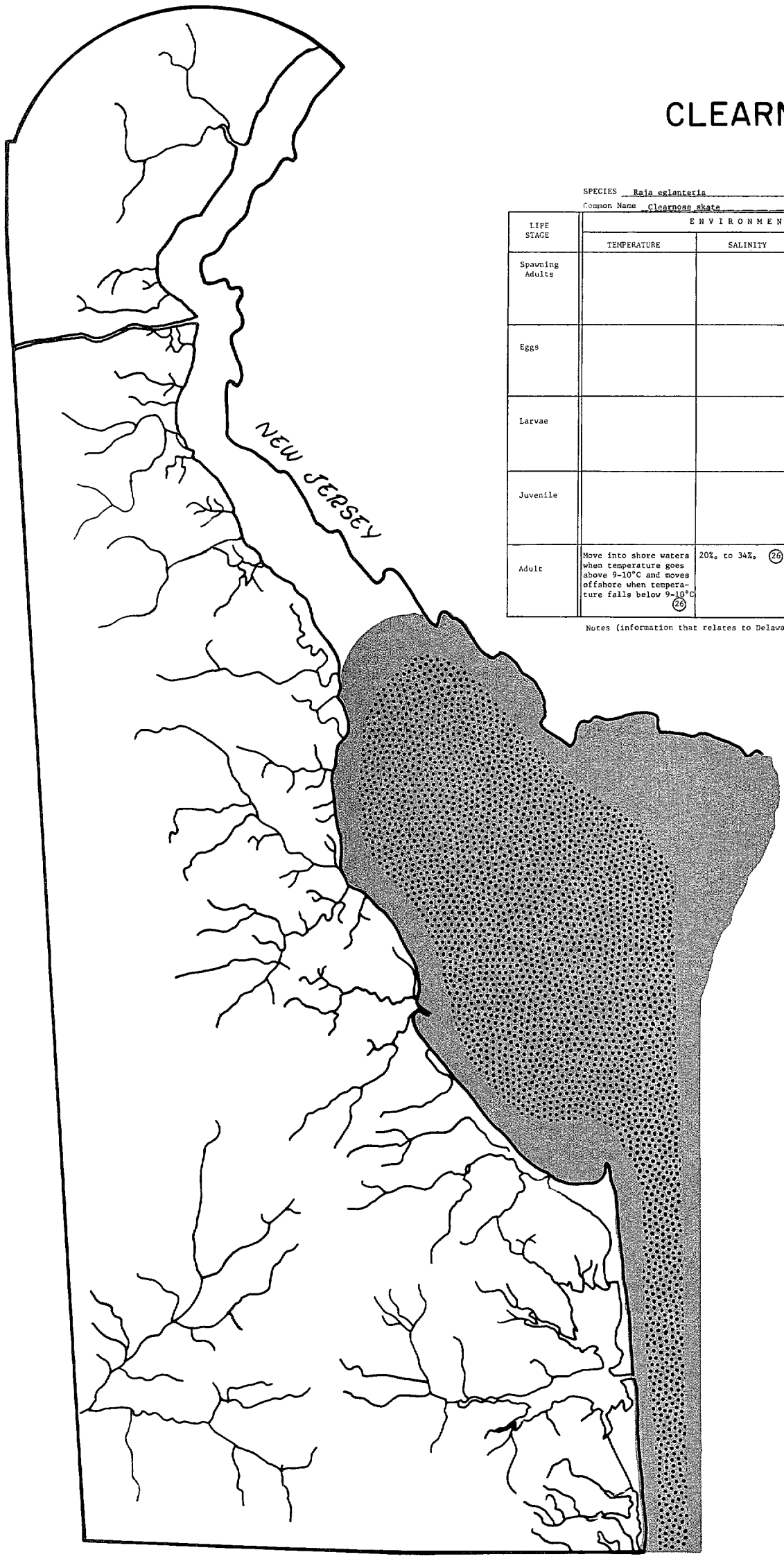
SPECIES Raja eglanteria

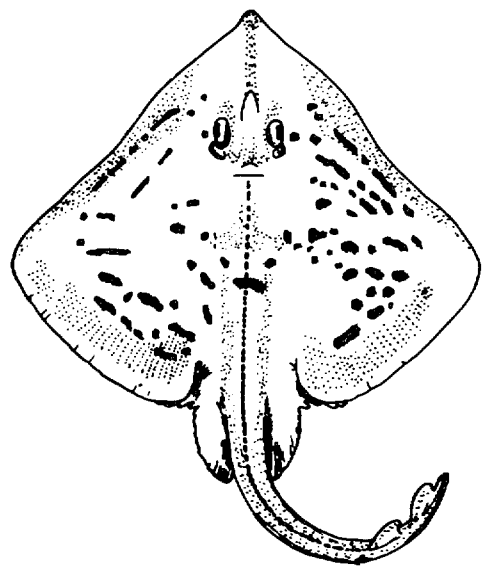
Common Name Clearnose skate

Spawning Period Spring

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults					
Eggs					
Larvae					
Juvenile					
Adult	Move into shore waters when temperature goes above 9-10°C and moves offshore when temperature falls below 9-10°C (26)	20‰ to 34‰ (26)			

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) Generally a summer resident of Delaware.





LEGEND

PROBABLE SPAWNING AREAS

GENERAL SUMMER DISTRIBUTION

often damaged by a predator -- crabs, oyster drills or even birds.

Little skates are three to four years-old here when sexually mature and the clearnose skate about four years-old. Eggs in some developmental stages are always found in the females but can be placed in generally one or two classes -- those eggs ready to be spawned and those in the reservoir group that will not be released until next season. The little skate appears to have two peak egg production and spawning periods, one in April and May and the other in November and December. The clearnose skates on the other hand have only one major egg production-spawning period, occurring in the spring.

The eggs incubate for three months for the clearnose skate and six months for the little skate before hatching. Hatching is accomplished through a slit in one end of the egg cases, the juveniles being 10-15 centimeters (4 to 6 inches) long at this time.

What is known of the growth rates of these organisms is based partially on speculation for there are some problems associated with age determinations of skates. Unlike the scales of fish which can be used for aging the animals, the denticles of the skates cannot, so age determinations have to be made by other means. Usually this involves examining large numbers of individuals of all sizes and numbers. There are problems with this method, for in the clearnose skate the growth rate is not constant throughout the year, and with the little skate there are two spawning periods each year complicating the procedures. Some estimates on growth rates have been made, however. The little skate seems to grow 8-10 centimeters (3 to 4 inches) the first year or two and somewhat slower thereafter, so at four years-old it might be 30-40 centimeters (12 to 16 inches) long. Berry (1965) in his study of the growth of the clearnose skate found six age classes of skates although newly hatched and yearling skates were not abundant. The clearnose skate grows about 15 centimeters (6 inches)

FIGURE 84
LITTLE SKATE

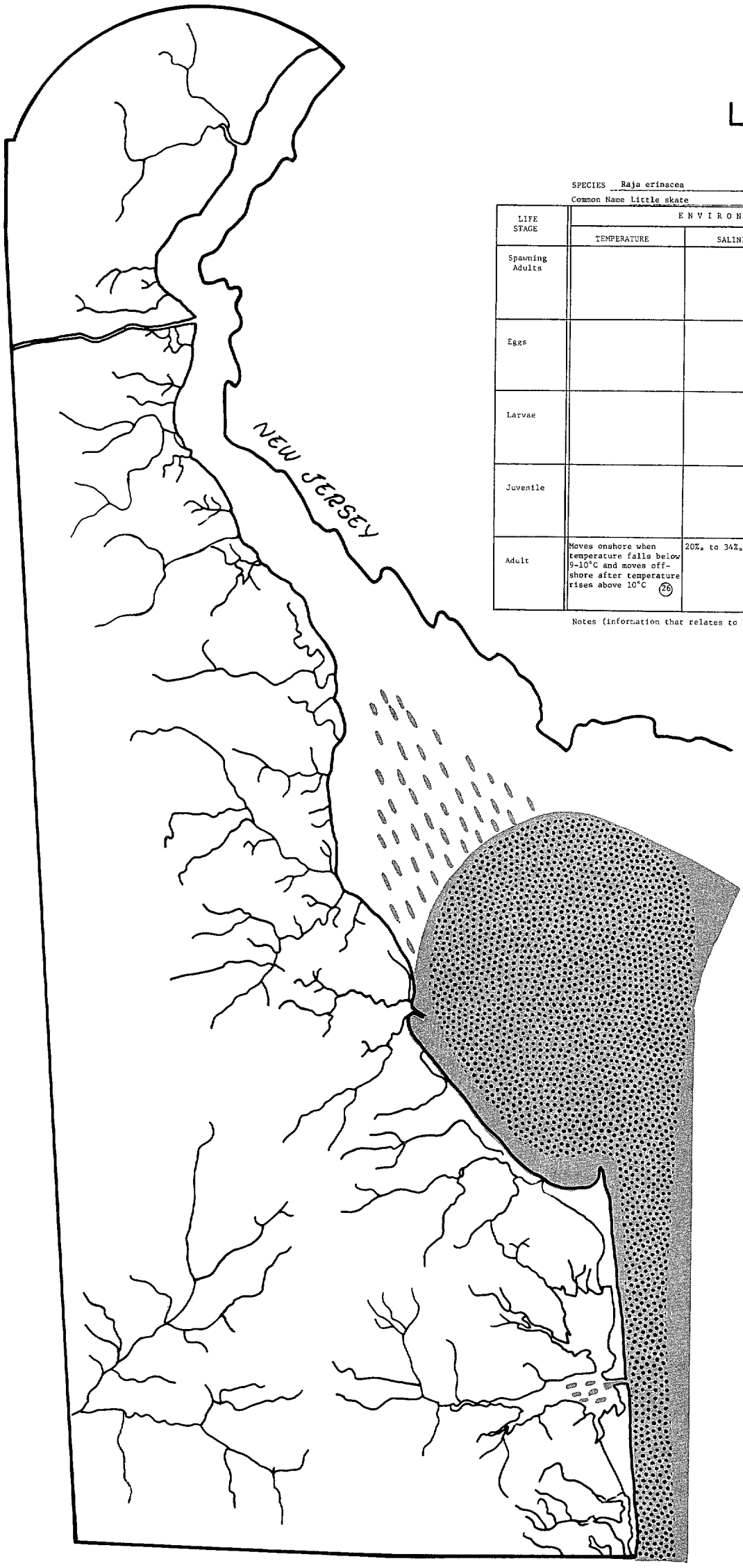
SPECIES Raja erinacea

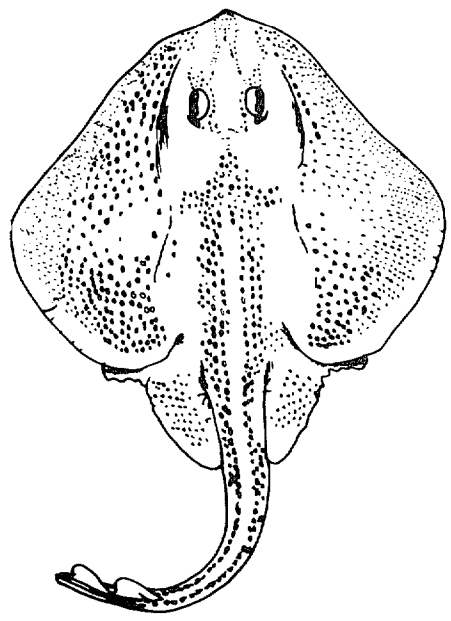
Common Name Little skate

Spawning Period April - May; November, December

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults					
Eggs					
Larvae					
Juvenile					
Adult	Moves onshore when temperature falls below 9-10°C and moves offshore after temperature rises above 10°C (26)	20‰ to 34‰ (26)			

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) Typically a winter species in Delaware.





LEGEND

PROBABLE SPAWNING AREAS

GENERAL ADULT DISTRIBUTION (WINTER)

the first year, 10 centimeters (4 inches) the second year and somewhat slower thereafter so that a five year-old individual will measure approximately 65-70 centimeters (25 to 27 inches) in length. The average growing season is 208 days per year. Individuals older than this are very infrequently found.

References

Berry, John, Jr. 1965. The use of vertebral rings to determine age and growth of Raja eglanteria, the clearnose skate, in Delaware Bay. M.S. Thesis, University of Delaware.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service. U. S. Government Printing Office, Washington, D. C.

Fitz, E. S. 1956. An introduction to the biology of Raja eglanteria Bosc 1802 and Raja erinacea Mitchell 1825 as they occur in Delaware Bay. M.S. Thesis, University of Delaware. 93 pp.

Fitz, E. S. and F. C. Daiber. 1963. An introduction to the biologies of Raja eglanteria Bosc 1802 and Raja erinacea Mitchell 1825 as they occur in Delaware Bay. Bull. Bing. Oceanog. Coll. 18(3): 69-97.

Hildebrand, S. F. and W. C. Schroeder. 1927. Fishes of Chesapeake Bay. Bulletin of the United States Bureau of Fisheries. U. S. Government Printing Office, Washington, D. C.

ATLANTIC STURGEON

Acipenser oxyrhynchus

The adult Atlantic Sturgeon, Acipenser oxyrhynchus, has an elongate somewhat pentagonal body, 8 to 12 feet in total length. The dermis of the sturgeon is armored, composed of five rows of boney shields or scutes. The head of the sturgeon is elongate with a narrow snout. The mouth is beneath the snout on the ventral surface. It is narrow, suckerlike and toothless with protractile lobed lips. Four pointed barbels protrude from the lower side of the snout in front of the mouth.

The dorsal fin, rather small and triangular in shape, lies far back on the body. The pelvic fins are also located quite far posteriorly. The pectoral fins originate near the opercular gill slit and are set almost as low as the belly. The caudal fin is asymmetrical with the upper lobe longer than the lower.

The overall coloration follows the counter-shading principle of disguise--a dark back (dorsal surface) with a whitish underside. The top of the head and the back are dark brown becoming progressively lighter lateroventrally, the entire lower surface being white. Contrasting sharply with the dark back are the dorsal row of shields which are white hence giving the appearance of whitish spots on a dark background. The lateral shields are dark dorsally but the central and lower parts of the shield appear whitish. The ventral shields are white in concert with the sides of the head, body and abdomen.

Females reportedly attain a length of 8 to 10 feet, but males are smaller, between 6 to 7 feet. Weights and lengths of some Atlantic sturgeons are: 7 feet, 176 pounds; 8 feet, 199 pounds; 14 feet, 811 pounds. In Delaware, a

Wilmington newspaper reported a 450 pound sturgeon landed in Delaware City in 1898.

The sturgeon is a fish of temperate waters and is found only in the northern hemisphere. They have been recorded from Labrador to St. John's River, Florida, including the Gulf of St. Lawrence, Nova Scotia, New Brunswick and the Hudson, Delaware, Susquehana, Potomac, James and St. Mary's (Georgia) Rivers.

The sturgeon feeds on mollusks and other bottom organisms which it searches for by dragging its barbels along the bottom. When the barbels locate food, the sturgeon roots the object out of the bottom with its snout, (if necessary), and then sucks up the food with its tubular mouth. In freshwater the sturgeon eats sludgeworms, isopods, amphipods and small pelecypods; in saltwater, they eat polychaetes, gastropods, shrimp, emphipods and isopods.

The Atlantic sturgeon is an anadromous species and migrates into brackish and freshwater in the spring for the purpose of spawning. Spawning generally takes place in water temperatures ranging between 56° and 64°F over a hard bottom of clay, rubble, gravel or shell in shallow running water of up to five fathoms deep. Migrations begin in February in Georgia; April in the Chesapeake; May and June in the Gulf of Maine, and in Canada the migrations may last into July. Apparently, little is known of the spawning behavior. A critical factor in the ecology of A. oxyrhynchus is that no females have been reported ready to spawn before reaching at least 150 pounds at an age of ten years. Males mature when approximately 69 inches and 70 pounds.

The eggs of the sturgeon are demersal (bottom dwelling) and adhesive, attaching to weeds, stones, shells, sticks and the like. Sometimes eggs are produced in stringy clusters. Ripe eggs measure approximately 2.6 millimeters in diameter. Typical of fish that produce large numbers of eggs, there is no

evidence of nest building or of parental care. One female generally will produce from 1,000,000 to 2,500,000 eggs; however, one specimen of 8 feet 9 inches weighing 352 pounds produced 3½ million eggs. The eggs hatch in about six days depending on temperature and the larvae are 11 millimeters in total length.

The Atlantic sturgeon is of value to man for several reasons. Primarily, the flesh of the large adult is valued by man and is of high quality. The roe from the Atlantic sturgeon is also highly prized for the production of caviar. The unripe eggs are removed from the female by an opening in the abdominal cavity. The eggs are freed from their membranes by rubbing the eggs on a screen. The freed eggs are then mixed with salt which extracts liquid from the eggs. The degree of salting and the resulting consistency of the eggs determines the quality and the price of the caviar.

In the late 1800's the Delaware River and the Chesapeake Bay supported a sizeable sturgeon fishery. In 1890, five million pounds of sturgeon were landed in the Delaware Bay and River area. In Maryland 141,000 pounds of sturgeon were caught in 1897. By 1940 no sturgeon were taken in Delaware Bay by commercial fishermen, and only 700 pounds were landed in Maryland.

Fishing pressure was probably the principal factor in reducing the sturgeon populations. Since there were no laws protecting the species, large numbers of mature individuals were taken during their upstream spawning migration, and consequently, very few were able to reach their spawning grounds. Damming large rivers such as the Susquehana stopped migrations, and municipal and industrial pollution further reduced the local populations.

Recent fishery statistics show that the population is relatively stable but marginal to say the least. The recovery from near extinction can be

SPECIES Acipenser oxyrhynchus

Common Name Atlantic sturgeon

Spawning Period Early spring

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	56° and above (78)	Fresh-brackish (22)			
Eggs					
Larvae					
Juvenile		Brackish moving to saline			
Adult	Wide range	Wide range			

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) anadromous

Figure 85

credited to creating a size limit, restricting the season of catch, limiting the type of gear used in sturgeon fishing and licensing fishermen. Sturgeon catches for 1970 for the United States eastern seaboard show that 175,000 pounds were caught at a value of thirty-one thousand dollars. In 1940, 1960 and 1970 there have been no sturgeon taken from the Bay by Delaware commercial fishermen, but this is a bit misleading for it is known that in the State of Delaware, sturgeon are being fished from the Bay by local fishermen. A resident recently caught nearly 200 sturgeons in a two week vacation period. Although the sturgeon is regaining a foothold along the Atlantic coast and in Delaware, it seems that they will remain a novelty to most 20th century fishermen when once they ruled the estuary.

References

Adapted from:

Thornton, Lawrence L. 1974. The life history of the Atlantic sturgeon, Acipenser oxyrhynchus. Bio. Dept. (Ichthyology, B-630). 10 pp.

Beck, R. A. 1973. Sturgeon: Alive and well. Delaware Conservationist, Vol. XVii, No. 2, pp. 4-6.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish. Bull. Fish and Wildl. Serv. 1953, Vol. 53, pp. 81-84.

Breder, C. M., Jr. 1948. Field book of marine fishes of the Atlantic coast. G. P. Putnam's Sons, N. Y. pp. 42-43.

Hildebrand, S. F. and W. C. Schroeder. 1927. Fishes of Chesapeake Bay. T. F. H. Publ., Inc., Neptune, N. J. pp. 72-77.

Vladykov, V. D. 1955. A comparison of Atlantic sea sturgeon with a new subspecies from the Gulf of Mexico (Acipenser oxyrhynchus de sotoi) J. Fisheries Res. Bd., Canada 12(5): 754-761.

Vladykov, V. D. and J. R. Greeley in Fishes of the Western North Atlantic. H. Bigelow, ed. Part 3. Sears Foundation for Marine Research, Yale Univ., New Haven, Conn. pp. 24-58.

THE AMERICAN EEL

Anguilla rostrata

Throughout history eels have been a source of speculation and mystery. Until recently little was known of the life cycles of species such as Anguilla rostrata, the American eel, because of their unique and elusive habits.

For instance, Aristotle felt that eels came "from what we call the entrails of the earth. These are found in places where there is much rotting matter, such as in the sea, where seaweeds accumulate, and in the rivers, at the water's edge, for there, as the sun's heat develops it induces putrefaction". Aristotle was, however, aware that adult eels migrated to the sea to spawn and youngeels returned to freshwater to mature. This is the life cycle for all members of the family Anguillidae.

A. rostrata's body configuration (anguilliform-named for the family of which it is a member) is long, slender and serpentine, a characteristic of eels in general. The color of the adult varies with location, substrate and illumination. Typically they are muddy brown to olive green above with traces of yellow or white on the lateral surfaces. The ventral area is lighter in color, varying from light yellow to beige. As in many of the fishes, the American eel can elicit color changes.

Anguilla rostrata is the most common and widespread eel species on the eastern coast of North America. Its general range extends from the streams and rivers of southern Greenland and Labrador south to the Gulf of Mexico, Panama, the West Indies and occasionally as far south as Bermuda and the northern coast of South America. Common in eastern streams, ponds and lakes, the American eel has been known to occur as far west as the Mississippi.

Anguilla rostrata is catadromous, that is, the adult form dwells in freshwater while spawning is facilitated in saltwater. Adult males are smaller than females, the average male being less than 46 centimeters long (18 inches), females 61 to 122 centimeters (24 inches to 47 inches), weighing up to 7.7 kilograms.

Color changes from drab green and brown to silver are noted as the mature fish transforms to the ocean spawning migration phase. During the freshwater portion of the ell's life cycle, the fish develops microscopic scales.

While in freshwater the adult form spends most of the day resting on the bottom, burrowed in the mud or hiding under an object. Nighttime is reserved for feeding on small animals such as insect larvae, fish, mollusks and crustaceans.

It should be noted that while most of the adult eels do in fact enter freshwater, many spend their adulthood in estuaries or coastal waters.

After spending from five to ten years (sometimes as high as twenty) in freshwater, the American eel returns to the sea to spawn. The seaward migration is thought to occur in the spring. As the eel begins its migrations, certain body changes occur. There is a pronounced color change to silver or bronze. Other changes include reduction in production of mucous, thickening of skin tissues, accumulation of fat, enlargement of the eyes and changes in the internal structure. These include: alteration of body flexibility and of locomotory behavior, pointing and narrowing of the pectoral fins, increased endocrine activity, development of gonads, cessation of food consumption, reduction of the digestive tract, increased numbers of chloride cells in the gills and changes in osmoregulatory activity. These changes are apparently essential for the transition of the eel from fresh to saltwater and the subsequent migration.

The obscure spawning ground of the American eel remained a mystery until 1922 when a young Danish oceanographer, Johannes Schmidt, reported its exact location, the Sargasso Sea, "between 22^{0} and 30^{0} latitude north and between 48^{0} and 65^{0} longitude west".

Migration to the spawning grounds begins from August to November as the eels move downstream towards saltwater. Eels have been reported crossing through damp grass, ditches, or even roads during this period, and initiation of the migratory sequence appears to be influenced by changes in the environment. A moon in first quarter accompanied by a high water level is the most favorable condition. Light intensity is most critical.

Spawning occurs in midwinter, leaving two to three months for the eels to reach their breeding grounds. The guiding mechanism of A. rostrata has not been determined, though it has been suggested that constant currents and olfactory stimuli may be important. Little is known of what happens to the marine form from the time it enters saltwater to the time it spawns. It is not known how deep they swim, but they most certainly journey beyond the continental shelf and into the oceanic basin before spawning. The previously cited spawning ground of the American eel in the Sargasso Sea may not be the only breeding ground of this species. It possibly breeds further north in deep water.

Each female eel produces from five to twenty million buoyant eggs which are about 1 millimeter in diameter. The eggs develop into the surface swimming leptocephali. These larvae resemble transparent willow leaves; the heads being small and pointed with jaws equipped with long teeth.

Very young larvae measure from seven to eight millimeters, increasing to four to five centimeters during the year of passive migration towards coastal

waters. As the digestive systems of these larvae are underdeveloped, it is believed they do not feed. In December or January of the following year the larval eels undergo a dramatic transformation upon approaching shore.

The metamorphasis to the glass eel stage includes a decrease in length and width with a corresponding transformation to cylindrical body form. At this phase in the eel's life cycle there is still no body pigment. Other changes include loss of the larval teeth and a total alteration of the anterior head regions, particularly in the jaws. When the eels enter coastal waters, pigmentation develops along the body surfaces and then the young are called elvers. Elvers average in size from two to three and one half inches long and begin their migration into the Delaware Bay in April or May. Further north the invasion of the elvers into freshwater occurs in May and June. The migration upstream is variable, requiring from a few days to a month for the elvers to pass. Water pipes, underground streams, and even sewers are utilized in the invasion to freshwater, but the young elvers generally do not enter cold water streams.

It should be noted that none of the adult eels return to freshwater after spawning. Like the Pacific Salmon, American eels apparently die after breeding, as no spent eels have ever been recorded in freshwater.

Eels can be taken year round in many places, except those areas in which they hibernate buried in the mud. Baited traps or pots are the major source of capture. Beam trawling in summer nights in estuaries has also proved of some commercial value. Net and weir fishing is utilized in many areas with peak catches occurring in September and October as the silver eels begin their downstream migration.

These eels are marketed locally, canned, or shipped fresh to various parts of the world, though in most cases the American eel is of only moderate human

FIGURE 86
AMERICAN EEL

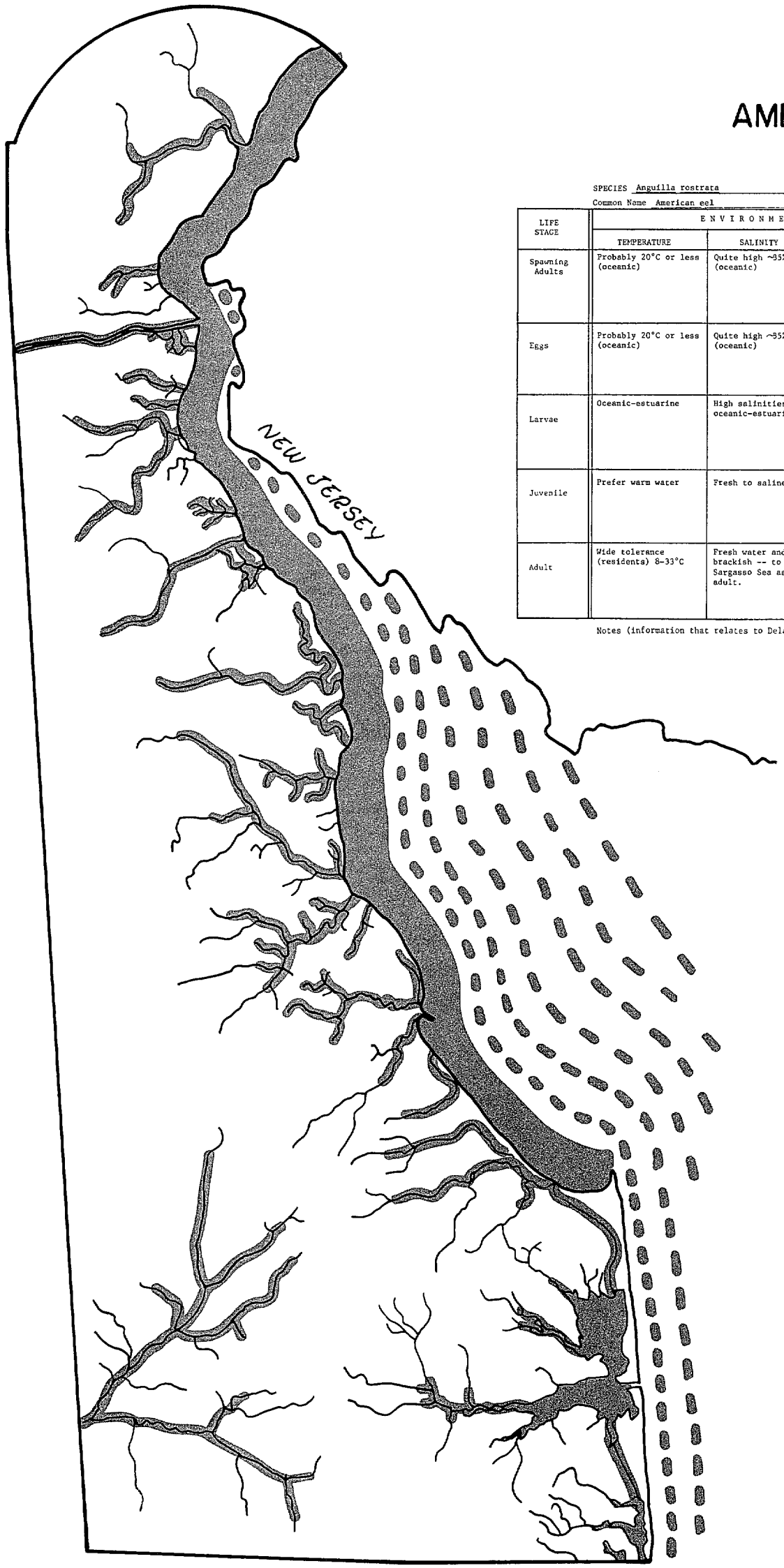
SPECIES Anguilla rostrata

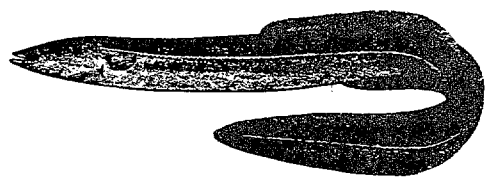
Common Name American eel

Spawning Period Moon 1st quarter, high water level, Autumn

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Probably 20°C or less (oceanic)	Quite high ~35‰ (oceanic)	~4 to 5 ml/l (oceanic)		
Eggs	Probably 20°C or less (oceanic)	Quite high ~35‰ (oceanic)	~5 ml/l (oceanic)		
Larvae	Oceanic-estuarine	High salinities oceanic-estuarine	5 ml/l oceanic-estuarine		
Juvenile	Prefer warm water	Fresh to saline	Presumably with increasing tolerance of low dissolved oxygen		
Adult	Wide tolerance (residents) 8-33°C	Fresh water and brackish -- to Sargasso Sea as an adult.	Presumably moderate to high tolerance of low dissolved oxygen		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) eggs buoyant; overwinter in mud.





LEGEND

GENERAL DISTRIBUTION

consumptive value when compared to other saltwater species. The majority of eels are smoked and eaten by Europeans or European immigrants. In Delaware, 58,000 pounds of eels were caught commercially at a net worth of $12,000, in 1970.

Though eels do compete with other species for available food and space, they represent a valid niche in the aquatic environment. Further, though eels are hardly considered the most desirable of fishes, their relatively high resistance to sewage, thermal and other pollutants assures them at present a continuing role in the limnetic environment. Dams and other barriers represent a potentially limiting factor in the distribution of North American Anguilla rostrata populations. Because of the long growing period in freshwater, reduction of eels in certain areas above such dams would not be visible for years.

Reference

Adapted from:

Washburn, Jan. 1974. Anguilla rostrata, the American eel. Biol. Dept. (Ichthyology, B-630), University of Delaware. 14 pp.

THE HERRINGS

(Alewife) - Alosa pseudoharengus
(American shad) - Alosa sapidissima
(Blueback herring) - Alosa aestivalis

The alewife, American shad, and blueback herring are all members of the herring family, Clupeidae. These three species are extremely similar in habit and appearance and it often requires an expert, or at least some practice, to distinguish between them. The alewife, which grows to 250-300 mm (10-12 inches) in length, usually has a greyish-green back with irridescent sides and occasional faint longitudinal stripes. The fins are yellowish-green. The American shad is one of the largest and most valuable herrings. It may reach 600 millimeters (24 inches) in length, and weigh 5.5 kilograms, although the average female is under 2.3 kilograms. Coloration is greenish to metallic blue, with some dark lateral spots and greenish fins. The blueback herring looks much like the alewife although it is generally more slender. It has a dark blue or grey-blue coloration above, with silvery sides. The fins are green or yellow. The average size of the blueback in commercial catches is about 300 millimeters (12 inches) and .2 kilogram.

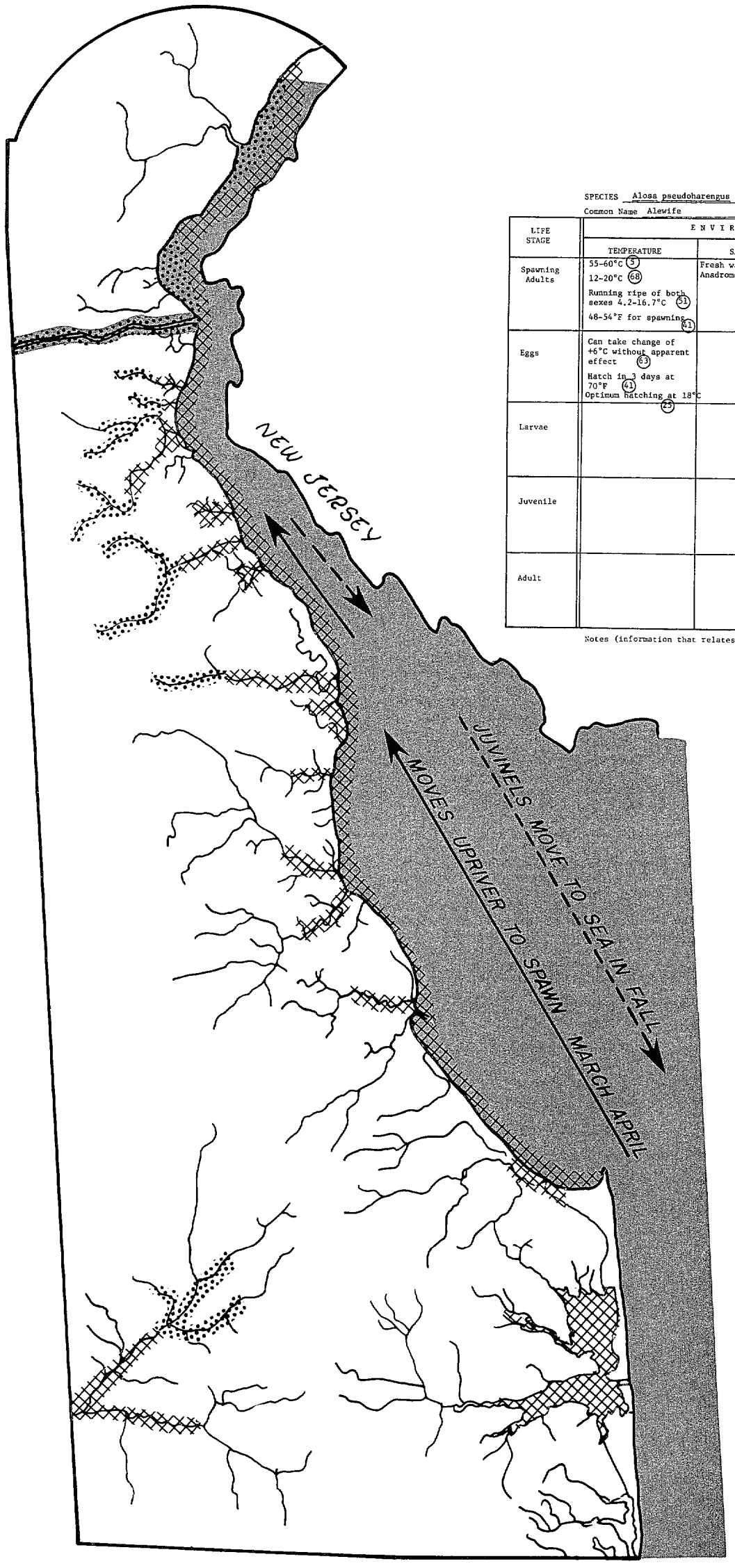
The ranges of these three herrings are similar. The alewife is found from Nova Scotia to North Carolina, up to 80 miles from shore. Some are also found in Lake Ontario and Lake Erie but these are of a smaller size. The American shad is found along the Atlantic coast of the United States from the Gulf of Saint Lawrence to Florida, although it is most abundant between Connecticut and North Carolina. Like the alewife and blueback, the shad is usually an open water fish, except when it migrates into freshwater to spawn. The blueback may be found schooling as far as 100 miles from the coast,

anywhere from New England to Florida. They are generally found further south than the alewife at any given time, indicating a preference for warmer water. This preference is reflected in its later spawning migrations.

The alewife, blueback herring and American shad all have similar migratory and spawning habits. They are anadromous in that they must return to fresh or brackish water to spawn. In the Delaware River, the alewife migration is the earliest of the three herrings, usually reaching a peak in early April. While the actual time of migration may vary from year to year, the alewife usually appears about one week before the shad, and a month before the blueback. The first alewives usually appear in the Chesapeake in February and in Maine water by April or May. The shad begin their spawning run when water temperatures reach 10-13^{o}C. In the Chesapeake this is between March and May. Upstream migrations may extend hundreds of miles and it is during these migrations that many are caught by commercial fishermen. In April or May the blueback migrates up the Delaware, but not quite as far as the other herrings.

The alewife prefers quiet waters for spawning that are about two feet deep, in streams, ponds, lakes, or near the mouths of creeks. Mating pairs swim together in spiral patterns. The externally fertilized, adhesive eggs are about 1.25 millimeters in diameter, and a female can lay from 60,000-100,000. The adults return to sea soon after spawning. There is no parental care for the eggs or larvae. The eggs hatch after about six days at 15^{o}C, or three days at 22^{o}C. The young alewives are about 15 millimeters long after one month, and by autumn, they may be 50-100 millimeters long. They return to saltwater in the autumn, although they may winter in the sheltered areas of bays. Sexual maturity occurs after three or four years when the alewives presumably return to their home stream to spawn.

FIGURE 87
ALEWIFE



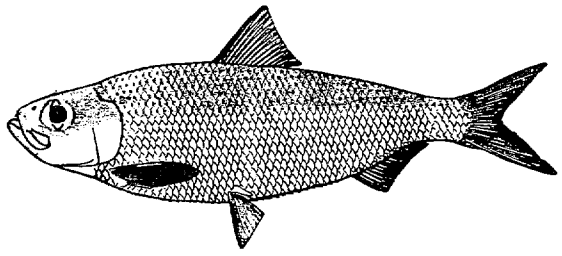
SPECIES Alosa pseudoharengus

Common Name Alewife

Spawning Period April to mid-May

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	55-60°C (5) 12-20°C (68) Running ripe of both sexes 4.2-16.7°C (51) 48-54°F for spawning (41)	Fresh water Anadromous (7)			
Eggs	Can take change of +6°C without apparent effect (63) Hatch in 3 days at 70°F (41) Optimum hatching at 18°C (23)			500 mg/l affected hatching success $p < 0.025$ (2)	
Larvae					
Juvenile					
Adult			Susceptable to low dissolved oxygen (21)		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) Spawn at Blackbird & Alloway.



LEGEND

SPAWNING AREAS

NURSERY AREAS

GENERAL ADULT DISTRIBUTION

The shad normally spawn over a sandy bottom in freshwater. Courtship and mating between pairs of shad have been observed most often after sunset near the surface of the water. The female may produce anywhere between 20,000-150,000 eggs. These eggs are large (3.5 millimeters in diameter), slightly heavier than water, and they may be held in suspension by water turbulence. Nests are built, but no parental care is given the eggs. Hatching occurs after twelve to fifteen days at 12°C, or six to eight days at 17°C. Soon after spawning the exhausted adult shad return to sea to feed and regain lost body weight. Juvenile shad (35-100 millimeters long) remain in fresh or brackish waters until Fall and probably spend their first winter in protected bays or estuaries. After one year, they reach 125-150 millimeters in length and after two years, 230-250 millimeters. Sexual maturity of the shad and the return to its native stream for spawning usually occur after four to five years.

The reproductive cycle of the blueback herring is similar to that of the other herrings. They usually wait for warmer water temperatures (21-24°C) to spawn but do not always migrate above brackish waters. Eggs of the blueback are demersal, adhesive, semi-transparent, and about one millimeter in diameter. Hatching occurs after about fifty-two hours at 23°C. Juveniles usually leave the spawning grounds by the first winter although they may remain in bays and estuaries for another year. Yearlings are 65-120 millimeters in length and sexual maturity requires about four years.

The feeding habits of the herrings vary with their age and habitat. While in freshwater the alewife feeds mainly on diatoms and copepods. When they move into saltwater, their diet shifts to mysid shrimp and small fish. The young shad feed on crustaceans, insects, insect larvae, rotifers, copepods and diatoms. Adult shad feed on shrimp, worms, small crustaceans, barnacles,

FIGURE 88
AMERICAN SHAD

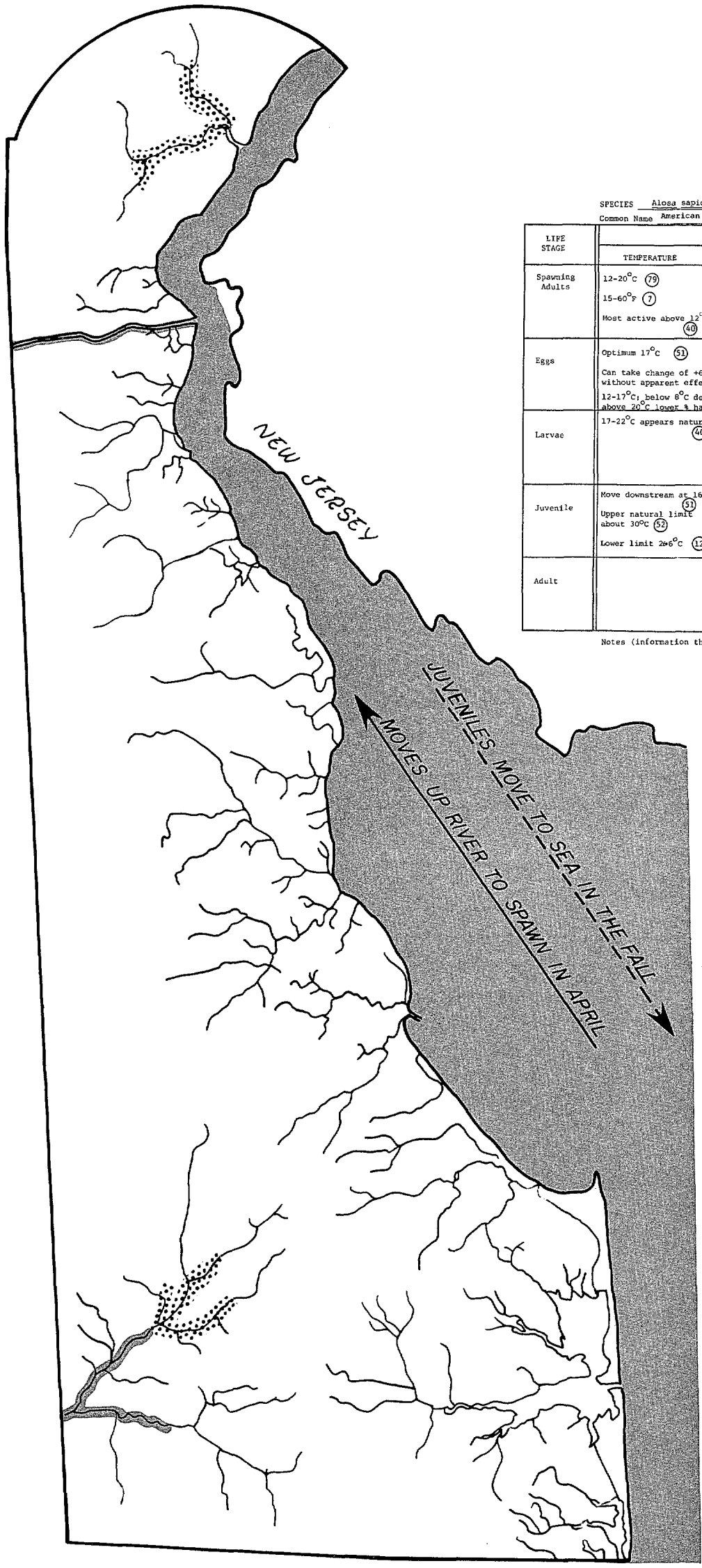
SPECIES Alosa sapidissima

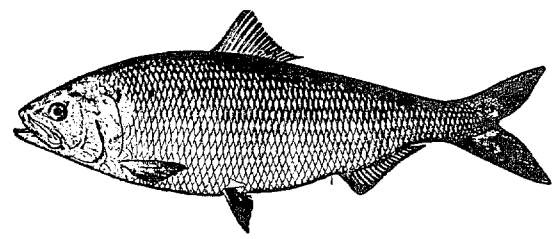
Common Name American shad

Spawning Period April through June

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	12-20°C (79) 15-60°F (7) Most active above 12°C (40)	Fresh (7) Tidal fresh (51)	Require 4.0 mg/l (16)		
Eggs	Optimum 17°C (51) Can take change of +6°C without apparent effect (63) 12-17°C, below 8°C death; above 20°C lower % hatched. (40)	Optimum 25°/oo (40)		Can take up to 1000 mg/l of sediment without apparent effect on hatching (2)	pH - no unfavorable effects 6-9 (40)
Larvae	17-22°C appears natural (40)	Fresh to brackish (51) Maximum 7°/oo (40)	High mortality and equilibrium loss at 1.28 mg/l (16)	500 & 1000 mg/l adversly affects survival A concentration of 100 mg/l had significant effect $p < 0.025$ on survival of shad. (2)	pH - no unfavorable effects 6-9 (40)
Juvenile	Move downstream at 16°C (51) Upper natural limit about 30°C (52) Lower limit 2-6°C (12)	Usually below 7°/oo (40) Abrupt increase from 0-30°/oo are not fatal. Abrupt decreases 30-0°/oo are fatal. (15) Gradual decreases are OK	Susceptible to low dissolved oxygen	.1 gm/100 cc common, not detrimental (40)	pH - no unfavorable effects 6-9 (40)
Adult		Mostly marine	Susceptible to low dissolved oxygen.		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

POSSIBLE SPAWNING AREAS

GENERAL ADULT DISTRIBUTION

FIGURE 89
BLUEBACK HERRING

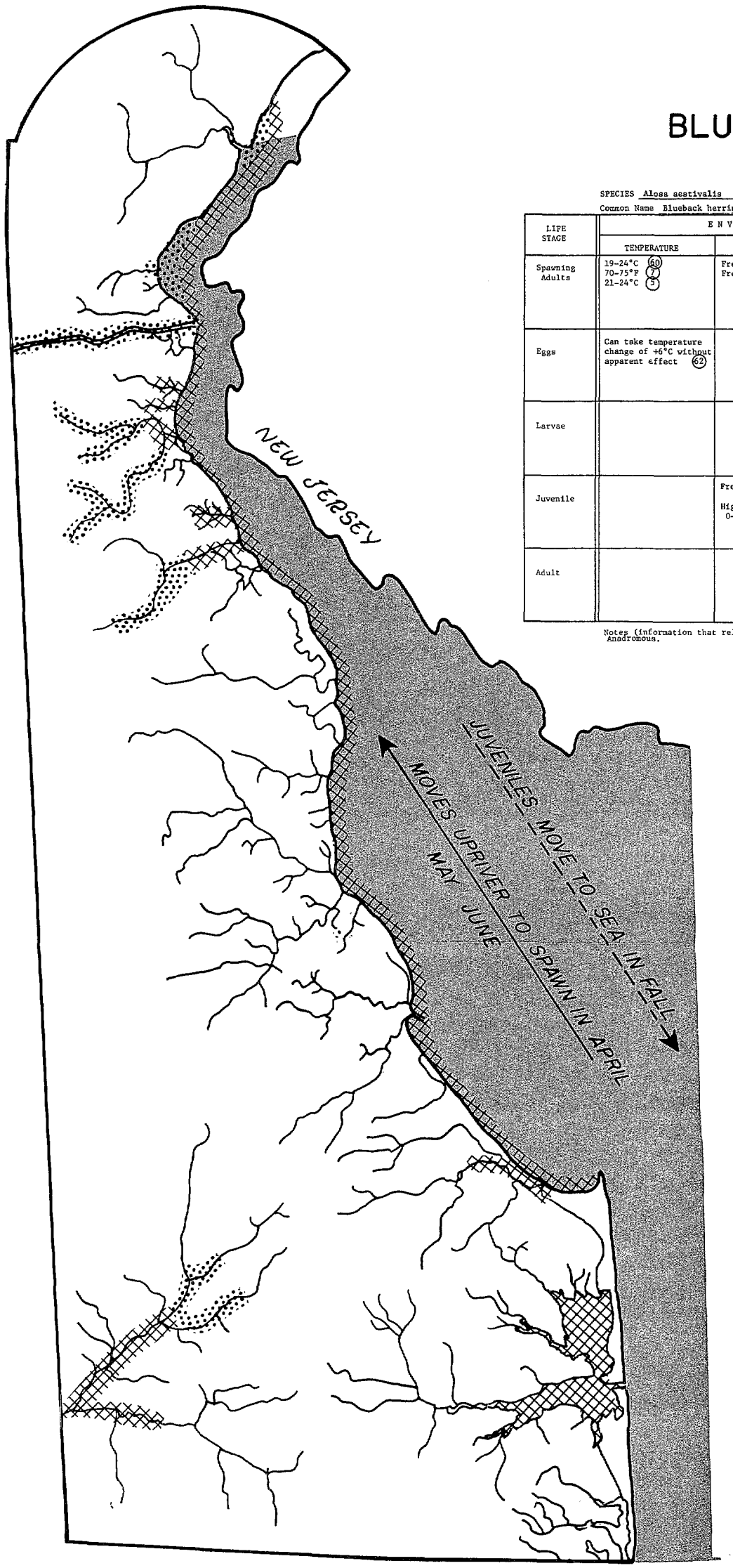
SPECIES Alosa aestivalis

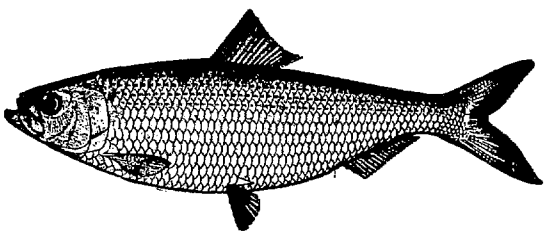
Common Name Blueback herring

Spawning Period Late April to mid-June

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	19-24°C (60) 70-75°F (7) 21-24°C (5)	Fresh water (68) Fresh to brackish (34)			
Eggs	Can take temperature change of +6°C without apparent effect (62)			Can take up to 1000 mg/l without apparent effect on hatching (2)	
Larvae					
Juvenile		Fresh (Great Lakes) High tolerance 0-28‰ (14)			
Adult			Susceptable to low dissolved oxygen (21)		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) Spawn in Blackbird & Alloway. Anadromous.





LEGEND

SPAWNING AREA

NURSERY AREAS

GENERAL ADULT DISTRIBUTION

and possibly some plants. The blueback herring feeds primarily on plankton.

If these species are to be preserved, their various habitats must be preserved. Herring are particularly vulnerable to alterations in their natural habitats. They require clear passage up rivers to spawn, clean streams to hatch, clean bays and tidal streams to develop and grow, and the open ocean to live as adults. American shad are turning back from their Delaware River migrations and moving further north. It is reported that many weakened, spent shad cannot physically make the return trip to the sea because of pollution pressures in the Delaware River. This illustrates the type of effect civilization can have on the natural life cycle of fishes.

The various stages in the life of the alewife, shad, and blueback are affected by environmental conditions. As explained earlier, the upstream spawning migrations are temperature stimulated. The herrings seem to return to their home stream, possibly through a "memory", reacting to chemical substances in a particular stream. These migrations may be hindered or prevented by low dissolved oxygen levels, chemical or thermal pollution. If the spawning migrations are inhibited, so is spawning. The eggs of these species require specific salinities for proper development. Even though these fish can tolerate a migration from salt to freshwater and back again, repeated or unexpected changes in salinity are usually fatal.

The preservation of these species should be of a high priority. They provide an important food source for many other species of fish and birds. Man also makes extensive use of these species, particularly the alewife and American shad, which are two of the most important food fishes on the Atlantic coast.

References

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. U. S. Govt. Print. Ofc., Washington, D. C. 577 pp.

Breder, C. M. and D. E. Rosen. 1966. Modes of reproduction in fishes. Natural History Press.

Chittenden, M. E., Jr. 1975. Dynamics of American shad, Alosa sapidissima runs in the Delaware River. Fishery Bulletin 73(3): 487-494.

Fishes of the Western North Atlantic. 1593. Sears Foundation for Marine Research. Part 1.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. Smithsonian Institution Press, Washington, D. C. 388 pp.

Leim, A. H. and W. B. Scott. 1966. Fishes of the Atlantic Coast of Canada. Fisheries Research Bd. of Canada, Ottawa. 485 pp.

Mansueti, R. 1955. Natural history of the American shad in Maryland waters. Md. Tidewater News 11(11), Supp. #4, April 1955.

Mansueti, R. and H. Kolb. 1953. A historical review of the shad fisheries of North America. Ches. Biol. Lab. Publ. #97.

Maxfield, G. H. 1953. The food habits of hatchery-produced, pond cultured shad (Alosa sapidissima) reared to a length of two inches. Ches. Biol. Lab. Pub. #98.

Schuler, V. J. 1969. A report on the American shad and other anadromous fishes taken in drifted gill nets in the Delaware River in the vicinity of Artificial Island during March-June 1969. Ichthyological Assoc., Del. Mis. Rept. #2.

Tyrus, H. M. 1972. Notes on the life history of alewife, Alosa pseudoharengus, in North Carolina. J. Elisha Mitchill Sci. Soc. 88(4): 240-243.

ATLANTIC MENHADEN

Brevoortia tyrannus

The menhaden, or moss bunker, Brevoortia tyrannus, is a member of the herring family, Clupeidae. A large scaleless head distinguishes it from other herrings. Its back may be dark green, dark blue, blue-grey or blue-brown. The sides of the body are brassy colored, with a dark shoulder spot behind the gill cover. The abdomen is sharp edged and the tail fin is deeply forked. Adult menhaden may reach 550 millimeters (22 inches), although the average is 300-350 millimeters (12-14 inches) in length, and about .3-.5 kilogram in weight, males and females alike.

The menhaden is a euryhaline species (i.e., adaptable to a wide range of salinities) which is usually found in large schools comprised of thousands of fish, occurring from Nova Scotia to southern Florida. Schools of 50,000-200,000 menhaden move northward as waters warm, appearing when water temperatures reach about 10°C while preferring temperatures of 15-20°C. While schools of adults may be found as far as 130 kilometers off the coast, the species is dependent on bays and estuaries during the larval and juvenile stages of its life. All estuaries from Cape Cod to Cape Canaveral may be used as nursery grounds. In the Delaware area it becomes quite numerous in spring and fall, particularly in tributaries and tidal streams, which serve as nursery grounds.

The menhaden spawns at sea or in large bays (for example, the Chesapeake). The time of spawning varies with locality. In New York and New England spawning is from May to October while spawning occurs in March, April, September and October in the mid-Atlantic waters. In the south Atlantic spawning is from October to March.

Eggs are buoyant, non-adhesive and 1.3-1.9 millimeter (.05-.08 inch) in diameter. Hatching occurs about forty-eight hours after fertilization which is external. The larvae enter bays and estuaries when they are about 10-30 millimeters in length. There they metamorphose into juveniles. White Creek, a tributary of Indian River Bay, is an important nursery area where young menhaden are the predominant spring and fall migrant species. They usually concentrate just above brackish water toward the freshwater end of estuaries. Juveniles usually remain in the bays for six to eight months before returning to sea. In September or October the menhaden enter the ocean where they continue to grow. Eighty percent of the menhaden are sexually mature by age two, and all are mature by three years.

The menhaden has no teeth and is chiefly a filter feeder, straining planktonic organisms such as planktonic crustaceans or diatoms from the sea water. By swimming with its mouth open and gill covers flared, the menhaden can filter 24-28 liters of seawater in a minute.

The menhaden is sensitive in varying degrees to certain environmental conditions at various stages of development. Adult menhaden are usually found in waters of at least $10^{o}C$. Larvae are usually killed by temperatures of less than $3^{o}C$. Nursery areas have water temperatures of at least $9^{o}C$, and 1-5‰ salinity, although larvae can tolerate salinities up to 40‰, if necessary. A recent survey found larvae in temperature from 0^{o}-$25^{o}C$ and in salinities ranging from 29-36‰. Temperature tolerance seems to increase with salinity. The eggs, being pelagic, are usually found in waters of 25‰ salinity or more.

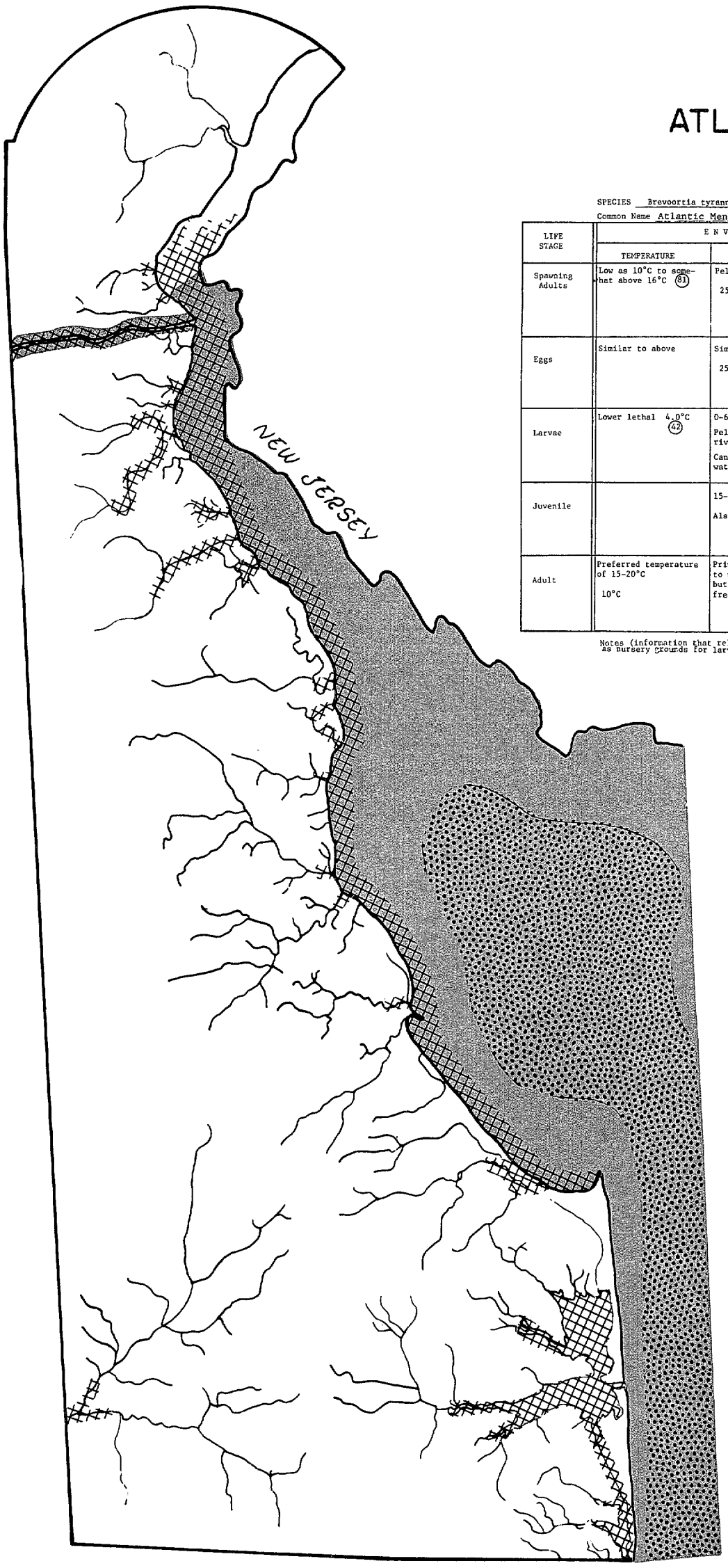
The menhaden is a very important prey species providing food for many other animals including whales, porpoises, cod, pollock, silver hake, sword-

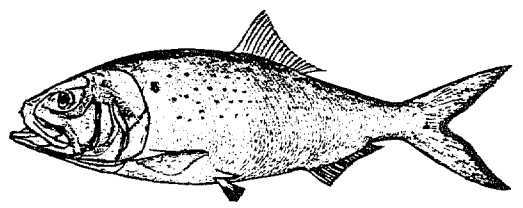
FIGURE 90
ATLANTIC MENHADEN

SPECIES Brevoortia tyrannus
Common Name Atlantic Menhaden
Spawning Period June to October

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Low as 10°C to somewhat above 16°C (81)	Pelagic (33) 25‰			
Eggs	Similar to above	Similar to above 25‰			
Larvae	Lower lethal 4.0°C (42)	0-6‰ (68) Pelagic to 2-3‰ in rivers (51) Cannot tolerate freshwater (43)			
Juvenile		15-40‰ (68) Also in fresh water	Susceptable to low dissolved oxygen (73)	No effect on survival even at 1000 mg/l (2) Highly sensitive to suspended sediments (66)	
Adult	Preferred temperature of 15-20°C 10°C	Primarily in brackish to marine salinities, but also found in fresh	Same as above		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) Spawning offshore; estuaries used as nursery grounds for larvae to juveniles.





LEGEND

PROBABLE SPAWNING AREAS

NURSERY AREAS

GENERAL ADULT DISTRIBUTION

fish, striped bass, flounder, weakfish, bluefish, sharks, ospreys and gulls. Bluefish are one of its worst enemies, as they will kill many more menhaden then they can eat. Since menhaden feed on plankton, they are in competition with many other filter feeders, such as the herrings, anchovies, mullets, oysters and mussels. As a commercial resource, the menhaden fishery involves a greater weight of fish than any other United States fishery, however, the menhaden fishery has been declining over the past decade. In 1953, Delaware landed over 360 million pounds of industrial fish (chiefly menhaden) with a value of close to four million dollars. Today, there are virtually no landings of menhaden in the State. This may be due chiefly to improved fishing techniques such as better methods of locating schools of menhaden (spotting boats, and surveys) which reduce the adult populations. However, another significant contributing factor in the decline of the menhaden fishery is undoubtedly the destruction or alteration of the nursery areas which are vital to the juvenile stages of development. If these nursery grounds become uninhabitable, through chemical pollution, thermal discharges, biological pollution, or other causes, the adult population of menhaden will be directly affected. Delaware's extensive wetlands, tidal streams and embayments are important contributors to the menhaden populations of the Atlantic Ocean.

References

Bigelow, H. B. and W. C. Schroeder, 1953. Fishes of the Gulf of Maine. U. S. Gov't. Printing Office, Washington, D. C.

Hildebrand, F. S. and W. C. Schroeder, 1928. Fishes of Chesapeake Bay. Smithsonian Inst. Press, Washington, D. C.

Kendall, A. W., Jr., and J. W. Reintjes, 1975. Geographic and hydrographic distribution of the Atlantic menhaden eggs and larvae along the middle Atlantic coast. From R.V Dolphin cruises, 1965-66. Fishery Bulletin 73(2). 317-335.

Lewis, R. M. 1966. Effects of salinity and temperature on survival and development of larval Atlantic menhaden, Brevoortia tyrannus.

McHugh, J. L., R. T. Oglesby, and A. L. Pacheco, 1959. Menhaden. Limn. and Oceanog. 4(2). 145-162.

Pacheco, A. L., and G. C. Grant, 1955. Studies of the early life history of Atlantic menhaden in estuarine nurseries. Part I-Seasonal occurrence of juvenile menhaden and other small fishes in a tributary creek of Indian River Bay, Delaware. 1957-58. U. S. Fish. and Wildlife Serv. Spec. Sci. Rept., Fish. #504.

Reintjes, J. W., 1969. Synopsis of biological data of the Atlantic menhaden, Brevoortia tyrannus. U. S. Fish and Wildlife Serv. Bur. Comm. Fish. Circular #320, 30 pp.

THE BAY ANCHOVY

Anchoa mitchilli

Anchoa mitchilli, the bay anchovy, is a member of the family Engraulidae; the superorder teleostei (the bony fishes); and the class pisces (the true fishes). It is occasionally confused with young herrings, smelt, or silversides. However, its larger eyes and mouth distinguish it from these species (Bigelow and Schroeder, 1953). The most striking characteristics of the bay anchovy are its projecting snout and its large jaw. It has a compressed body, with a straight dorsal and rounded ventral profile, with the abdomen having a sharp ridge extending the length of the ventral edge. The caudal fin is well forked, and the anal fin is long and low. The bay anchovy rarely exceeds nine centimeters (3.5 inches) in length (Bigelow and Schroeder, 1953).

The anchovy possesses an almost translucent body with a silvery lateral band which is slightly narrower than the eye. The fins are pale or yellowish, usually with dark spots. The striped anchovy -- *Anchoa hepsetus* -- with which *A. mitchilli* is sometimes confused, can be distinguished by its more brilliant silvery band, its larger size, and the relative placement of its fins (Hildebrand and Schroeder, 1912).

A. mitchilli is found along the Atlantic and Gulf coasts from Maine to Texas. It is a schooling fish, staying in deeper water when temperatures drop, but moving in toward shore and even into freshwater streams during the summer months. In Delaware, it is one of the most numerically abundant fish species. It has been found in the Delaware estuary from north of the Brandywine River to the mouth of Delaware Bay, in the middle of the bay, along the shores and in the Chesapeake and Delaware Canal.

Campbell (1975) ranked the bay anchovy fourth by number and eighth by frequency in the White Creek, a tributary of Indian River Bay, where it was present from June 15 to November 16. A study by Pacheco and Grant (1965) showed similar results. They also found positive associations between the bay anchovy and menhaden, mummichog, Atlantic silversides and tidewater silversides.

In the Rehoboth and Indian River Bays, A. mitchilli was ranked fifth in abundance by Derickson and Price (1973) being most abundant in spring and summer including all stages of development. In a study by Scotton (1970), A. mitchilli larvae comprised 71.6 per cent of the ichthyoplankton caught in Indian River and Rehoboth bays, where they were found from June to November. Their sizes ranged from four to thirty millimeters, and in temperatures from 5.5-30.5° and in salinities from 21.6-32‰.

Derickson (1970) estimated the total biomass of A. mitchilli in Rehoboth Bay for June, August and September to be 600 kilograms, 30 kilograms and 100 kilograms, respectively. Individuals were found in all stages of development, with greater abundances in spring and summer while being virtually absent in the winter months. The larger abundance of A. mitchilli in Indian River Bay is possibly due to its greater depths.

The bay anchovy is also predominant in Delaware Bay, especially during the summer months. deSylva, Kalber and Schuster (1962) found A. mitchilli from Penns Grove to Lewes, in salinities from 0-31‰. They migrate into shallower waters in spring and summer, and they may spend their first winter in the estuary, moving offshore as they grow older (Stevenson, 1958).

The spawning period for A. mitchilli is from May through September along the Atlantic coast. The older fish, the two year-olds, are usually

FIGURE 91
ANCHOVY

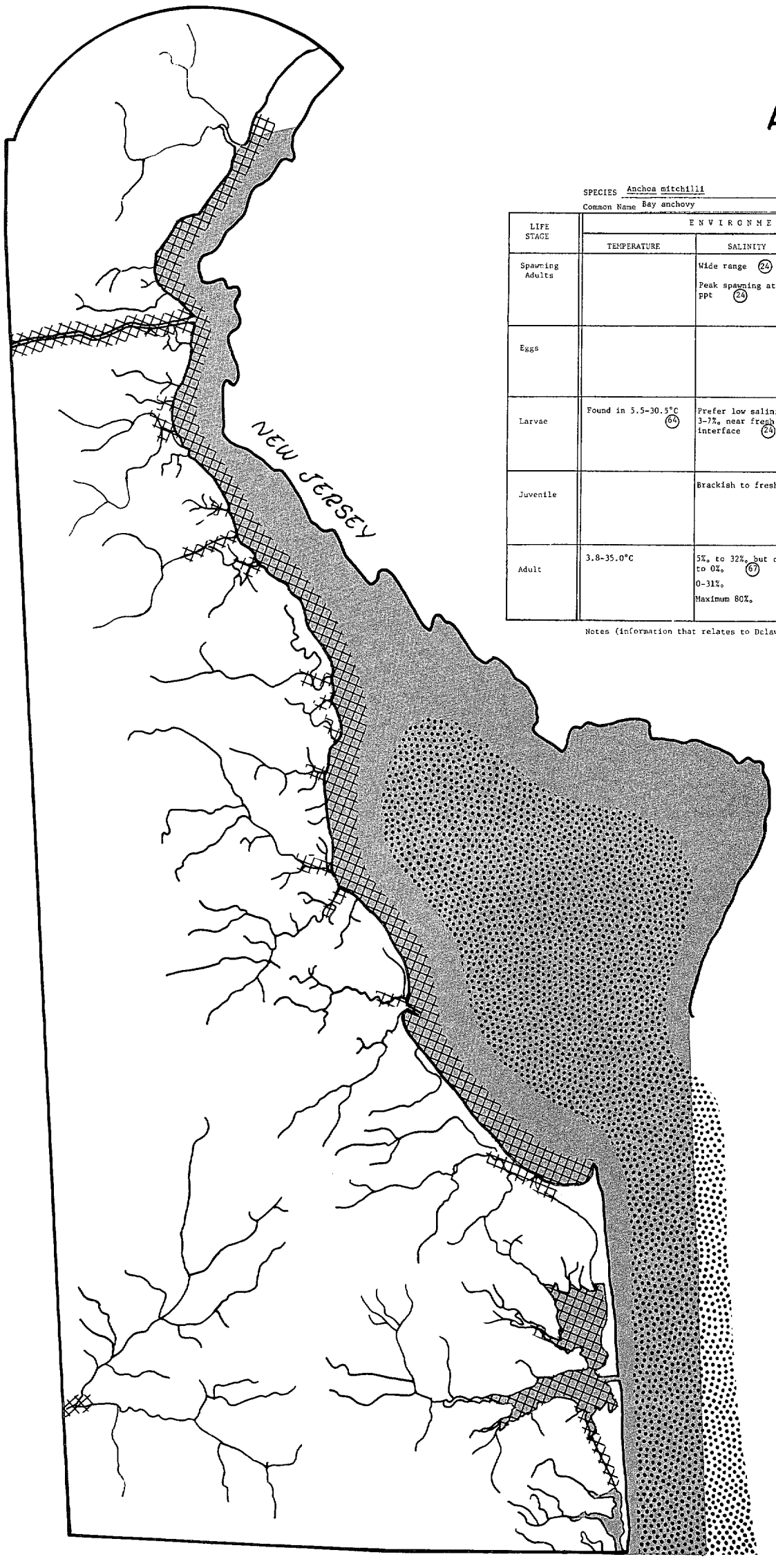
SPECIES Anchoa mitchilli

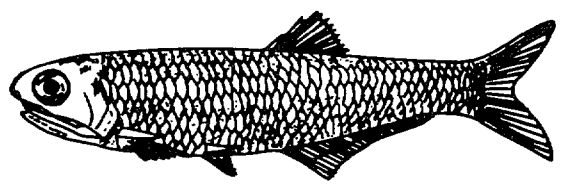
Common Name Bay anchovy

Spawning Period May - September

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults		Wide range (24) Peak spawning at 13-15 ppt (24)			
Eggs					
Larvae	Found in 5.5-30.5°C (64)	Prefer low salinity of 3-7‰ near fresh water interface (24)			
Juvenile		Brackish to fresh water			
Adult	3.8-35.0°C	5‰ to 32‰ but can go to 0‰ (67) 0-31‰ Maximum 80‰	Intolerant of low dissolved oxygen	Sensitive to suspended sediments (66)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

PROBABLE SPAWNING AREAS

NURSERY AREAS

GENERAL ADULT DISTRIBUTION

the first to spawn. Kuntz (1913) reports that the actual spawning act takes place in early evening.

The eggs are pelagic (live in the open sea) and slightly longer than wide when mature. The incubation period is about twenty-four hours and newly hatched larvae are about 1.8-2.0 millimeters (.07-.08 inches). After twelve hours, they attain a length of 2.6-2.8 millimeters (.10-.11 inches) and are still transparent. The mouth becomes functional after thirty-six hours (Kuntz, 1913). The body becomes deeper and more silvery with age. The terminal mouth of the juvenile soon gives rise to a projecting snout. Early growth is somewhat rapid -- 4 millimeters/week (1.6 inches) for the first month, 3 millimeters/week (.12 inches) for the rest of the summer. There is little or no growth in the winter. The yearling is about 60 millimeters (2.4 inches) long, and the maximum size is about 86 millimeters (3.4 inches). The mean length for summer populations in Delaware Bay is 56 millimeters (2.1 inches) (Stevenson, 1958). Sexual maturity occurs at 35-40 millimeters (1.4-1.6 inches) in nine or ten months (Stevenson, 1958).

The diet of the bay anchovy is composed mainly of copepods, shrimp, larval crabs, fish eggs, gastropods and diatoms. The young are principally planktonic feeders, while the older fish eat the larger foods.

The principle value of A. mitchilli seems to be as a food source for other fish as it has little economic value itself. In a survey by deSylva, Kalber and Schuster (1962), forty-one out of the sixty-six species studied in the Delaware Bay were "feeding heavily on small fishes (Anchoa mitchilli, Menidia spp.)". The anchovy should be examined further to determine the extent of its use by other fish as a food source. It is also desirable to know more about its spawning habits. Presently, its reproductive period is recognized by the presence of eggs and larvae in the water, but actual details as to what factors determine when and where it spawns are unavailable. Such information

would be helpful in gaining a more complete understanding of the ecology of the Delaware estuary and coastal environment and the role played by this small forage fish.

References

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. U. S. Govt. Printing Ofc., Washington, D. C.

Campbell, T. G. 1975. Fishes and hydrographic parameters of White Creek, Delaware: a description and comparison of 1973-74 to 1957-58. Master's thesis. University of Delaware.

Derickson, W. K. 1970. The shore zone fishes of Rehoboth and Indian River Bays of Delaware. Master's thesis. University of Delaware.

Derickson, W. K. and K. S. Price. 1973. The fishes of the shore zone of Rehoboth and Indian River Bays, Delaware. Trans. Am. Fish Soc. 102(3): 552-562.

deSylva, D. P., F. A. Kalber, Jr. and C. N. Shuster, Jr. 1962. Fishes and ecological conditions in the shore zone of the Delaware River estuary. University of Delaware Mar. Lab. Info. Series, No. 5.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. Smithsonian Inst. Press, Washington, D. C. 388 pp.

Kuntz, A. 1913. The embryology and larval development of Bairdiella chrysura and Anchovia mitchilli. Bull. U. S. Bur. Fish. No. 33.

Pacheco. A. L. and G. C. Grant. 1955. Studies of the early life history of Atlantic menhaden in estuarine nurseries; Part I. U. S. Fish and Wildl. Serv. Spec. Sci. Rept., Fisheries. No. 504.

Scotton, L. N. 1970. Occurrence and distribution of larval fishes in the Rehoboth and Indian River Bays of Delaware. Master's thesis. University of Delaware.

Stevenson, R. A. 1958. The biology of the anchovies. Master's thesis. University of Delaware.

FRESHWATER CATFISHES

Family Ictaluridae

Members of the family Ictaluridae are primarily freshwater fish which occasionally stray into brackish water. Their distribution was at one time limited east of the Mississippi, but they subsequently have been transplanted to the west coast as well. Three species--*Ictalurus catus* (Linnaeus), white catfish; *I. punctatus* (Linnaeus), channel catfish; and *I. nebulosus* (Lesueur), brown bullhead--have been reported in Delaware's wetlands in fresh to brackish water. All of the freshwater catfish except the channel catfish inhabit quiet, slow-moving waters such as ponds and pools in streams. The channel catfish, *I. punctatus*, prefer faster-moving waters. These members of the freshwater catfish family all have similar upper lethal temperatures and lethal salinities limits of 30-35^{o}C and 14-16‰, respectively. The sea catfishes, Ariidae, are a related, but separate family that can be recognized by having fewer barbels (four or six) and a deeply forked tail. They are found in the Atlantic from Cape Cod to Panama but are seldom found in Delaware's waters.

Members of the freshwater catfish family have distinctive morphological features. All have whisker-like barbels, an adipose (soft) second dorsal fin and a broad flat head. They are all scaleless and have a heavy first spinous ray in both the pectoral and first dorsal fins.

The catfishes reach sexual maturity after three to four years. The species found in Delaware spawn in the spring to early summer and exhibit parental care over their young. All are omnivorous feeders eating anything available to them on the bottom which they search with their barbels. Prey include amphipods, shrimp, dragonfly nymphs, isopods and small fish. Larger catfish eat larger but similar prey to that eaten by small catfish. All

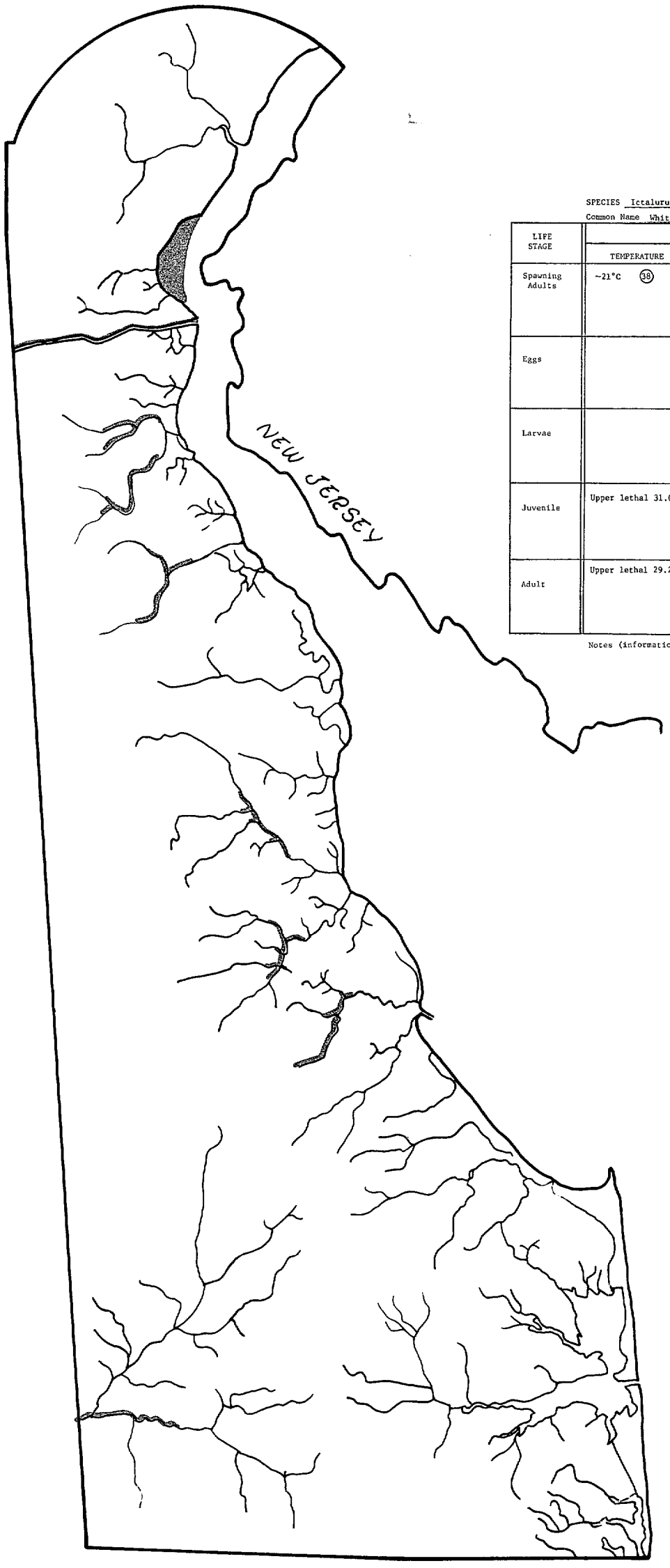
freshwater catfish are considered to be fair to good eating, yet in 1970 only 600 pounds of catfish at a value of ninety dollars were landed in Delaware. No doubt much more was taken by individuals fishing with hook and line.

The brown bullhead, Ictalurus nebulosus, is smaller than the other two catfish species, growing to a maximum length of only 46 centimeters (17-18 inches). Its back is brownish, belly gray to yellow; its sides and back often mottled. The bullhead's chin barbels are gray to black in color. Young of the year in the fall are 5-13 centimeters (2-5 inches) long; adults are 15-41 centimeters (6-16 inches) and 60-2270 grams (2-5 pounds).

The brown bullhead has an extremely well-developed sense of taste. Taste nerves are centered in the barbels which are used in food location and are also distributed over the head and flanks. Their ability to find food using taste was tested by blocking the other senses. Blinded bullheads found their prey with no difficulty as did those that were also without their sense of smell. Bullheads without sight or smell and without barbels and taste buds along one side were tested next. These fish circled toward their intact side and eventually found their food target using only the small amount of taste sense remaining.

The white catfish, Ictalurus catus, is generally found in quiet pools but can tolerate swiftly-moving water. Its upper lethal temperature limit (LC_{50}, 12 hours) following acclimation at 20°C was determined to be 31.0°C for smaller specimens of 19.4 centimeters (7.6 inches) mean length, and 29.2°C for larger specimens of 25.5 centimeters (10 inches) mean length. It is intermediate in size between the brown bullhead and the channel catfish. The white catfish is bluish above, silvery below; its caudal fin is forked with rounded lobes. It grows to a maximum length of 60 centimeters (about 24 inches) with adults

FIGURE 92
WHITE CATFISH



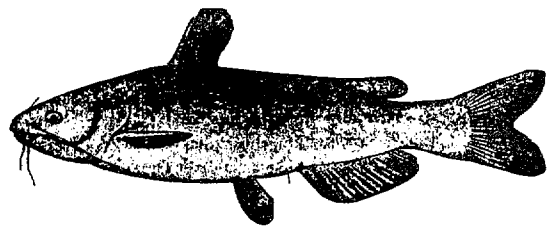
SPECIES Ictalurus catus

Common Name White catfish

Spawning Period May through June

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	~21°C (38)	<14‰			
Eggs					
Larvae					
Juvenile	Upper lethal 31.0°C				
Adult	Upper lethal 29.2°C	Lethal 14.8‰ — maximum 14.5‰ (71)			

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)



LEGEND

KNOWN GENERAL DISTRIBUTION

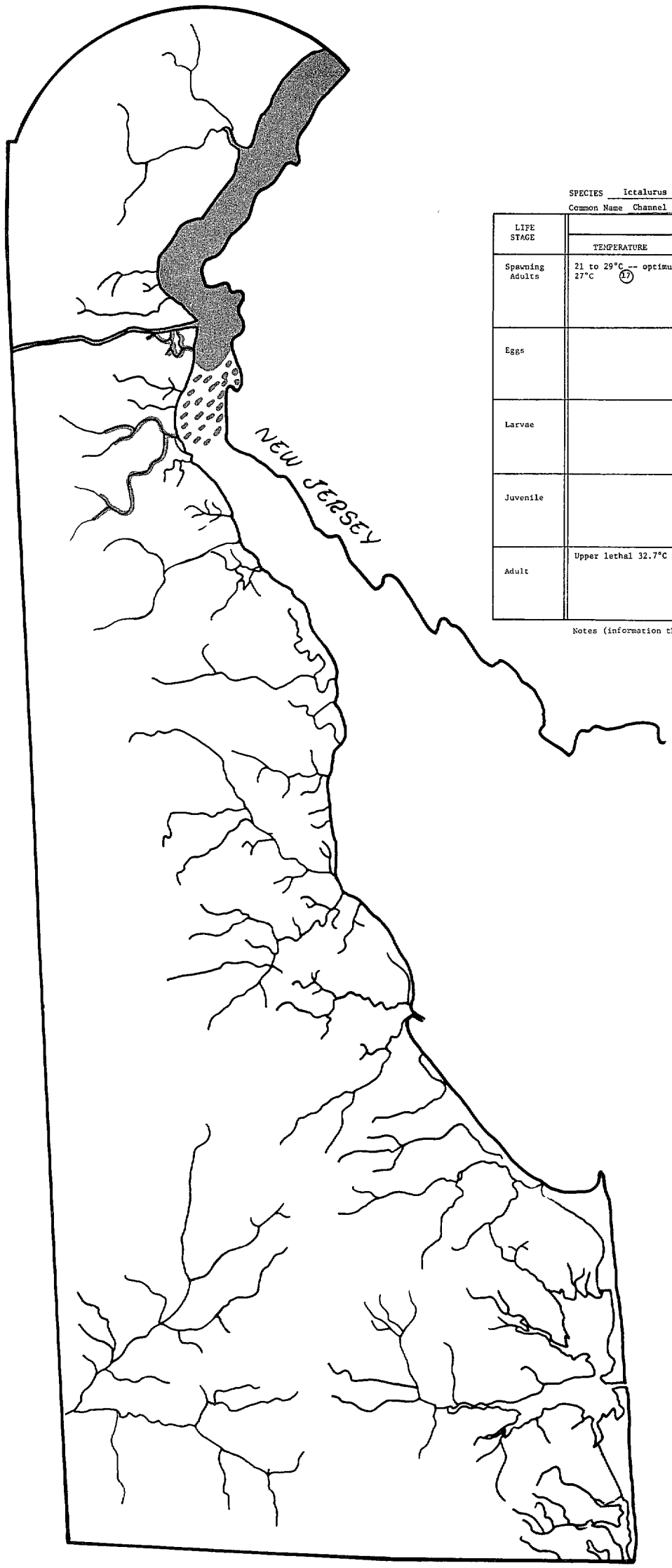


FIGURE 93

CHANNEL CATFISH

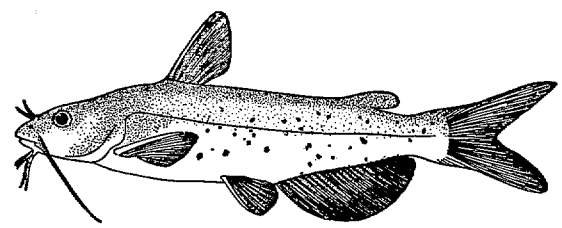
SPECIES Ictalurus punctatus

Common Name Channel catfish

Spawning Period April to September

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	21 to 29°C -- optimum 27°C (17)	Spawn up to 2.6-4.3‰ (50)			
Eggs		Tolerate up to 16‰ (60)			
Larvae		Tolerate up to 10‰ (60)			
Juvenile		Tolerate up to 12‰ (60)			
Adult	Upper lethal 32.7°C	Upper lethal 15.5‰, maximum 15.1‰ (71)			

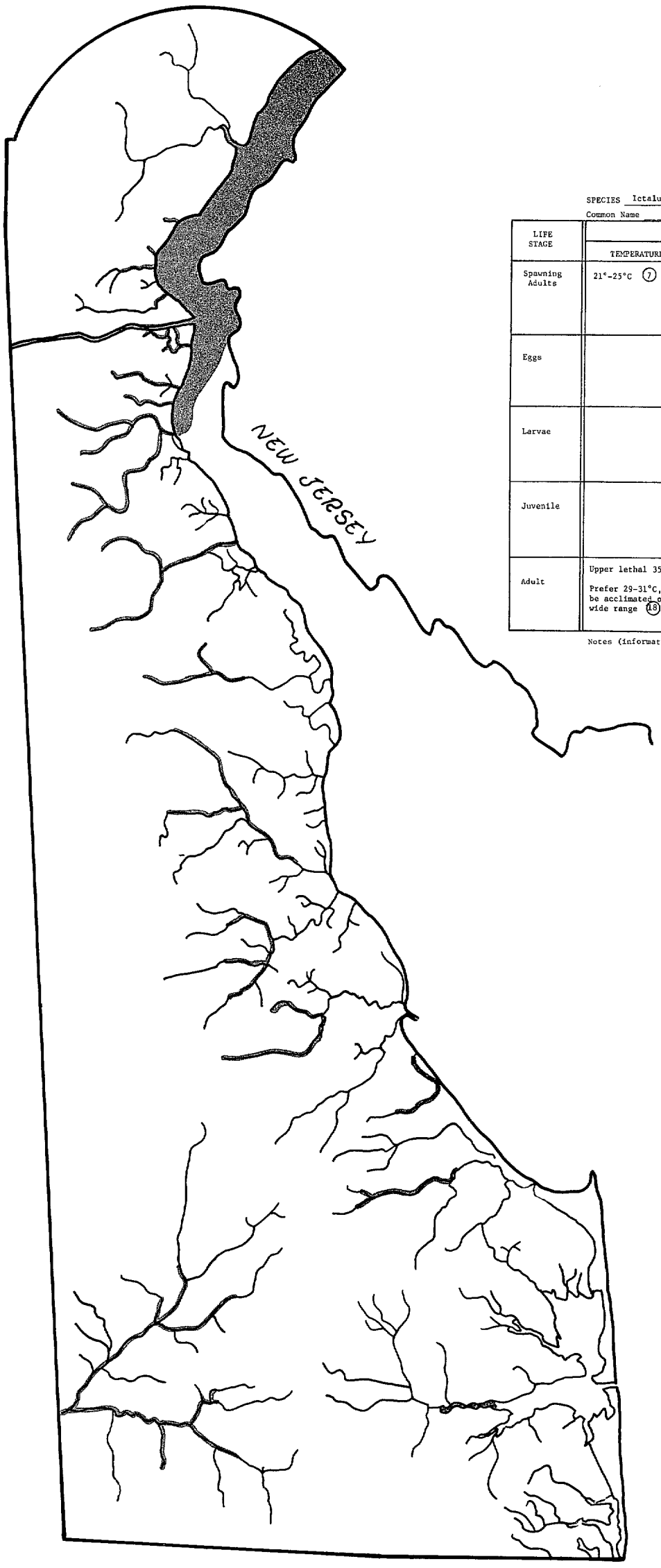
Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)



LEGEND

GENERAL ADULT DISTRIBUTION

FIGURE 94
BROWN BULLHEAD

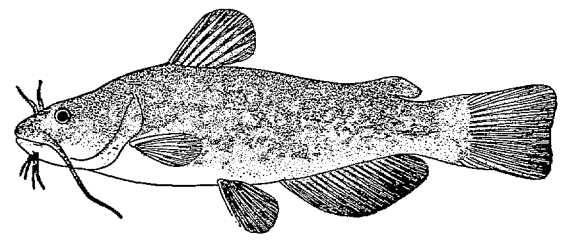


SPECIES Ictalurus nebulosus

Common Name Brown bullhead Spawning Period Spring

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	21°-25°C (7)	Low salinities, < 10‰ (68) Fresh (82)			
Eggs			Need water passed violently over heavy gelantenous egg cover (7)		
Larvae					
Juvenile					
Adult	Upper lethal 35°C Prefer 29-31°C, may be acclimated over wide range (18)	Maximum 7.6‰ (71) 14-16‰ upper lethal	Extremely tolerant of low oxygen (7)		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)



LEGEND

GENERAL ADULT DISTRIBUTION

usually 25-46 centimeters (9-18 inches), with weights of 220 to 1,020 grams (8 to 36 ounces).

The channel catfish, Ictalurus punctatus, is the largest of the three species found in Delaware. Although larger specimens can be found elsewhere, in Delaware adults are usually 28-76 centimeters (11 to 30 inches) with a weight range of 340-6,804 grams (12 ounces to 15 pounds). It has an upper lethal temperature of 32.7°C and a lethal salinity of 15.5‰. Specimens over 9.0 kilograms have been caught in the Great Lakes. It is bluish on its back, whitish below with mottled sides which have small irregular spots. Its caudal fin is deeply forked with pointed lobes. The channel catfish was at one time a commercially valuable fish in Lake Erie, but it is generally not recorded along the Atlantic coast. Its distribution is from the Great Lakes south to Mexico.

References

Bardach, F. E., J. H. Todd and R. Crickmer. 1967. Orientation by taste in fish of the genus Ictalurus. Science 155: 1,276-1,278.

Brown, B. E., I. Inman and A. Hearld, Jr. 1970. Schooling and shelter seeking tendencies in fingerling channel catfish. Trans. Amer. Fish. Soc. 99: 540-545.

Eddy, S. 1957. How to know the freshwater fishes. W. C. Brown Company, Dubuque, Iowa. 253 pp.

Hubbs, C. L. and K. F. Lagler. 1964. Fishes of the Great Lakes region. University of Michigan Press, Ann Arbor, Michigan.

Kendall, A. W., Jr. and F. J. Swartz. 1968. Lethal temperature and salinity tolerances of the white catfish, Ictalurus catus, from the Patuxent River, Maryland. Ches. Sci. (): 103-108.

Trautman, M. B. 1957. The fishes of Ohio. Ohio State University Press. pp. 415-426.

Turner, J. L. 1966. Distribution and food habits of Ictalurid fishes in the Sacremental-San Joaquin delta. Fish. Bull. Cal. 136: 130-143.

MUMMICHOG

Fundulus heteroclitus (Linnaeus)

The mummichog, Fundulus heteroclitus, is one of the hardiest and most common fish along the shore zone of the North Atlantic coast including Delaware. Coloration of the males is a dark green, the belly a yellowish orange; sides with numerous quite narrow ill-defined silvery bars, most distinct posteriorly; vertical fins dark; dorsal fin often with a blackish spot on its last ray; anal and ventrals yellow anteriorly. The females are nearly plain olivaceous, lighter below, without bars or spots; sides often with about fifteen dark cross bars or shades. The males have distinctly longer anal and dorsal fins. Adults are usually 6 to 10 centimeters (2 to 4 inches) in length and individuals may reach 15 centimeters (5-6 inches).

The mummichog seems to prefer brackish water, but they are well adapted to estuarine waters since they are able to tolerate a wide range of salinities, temperatures, dissolved oxygen levels and bottom types. In a comprehensive survey of Delaware Bay, deSylva et. al. (1962) found them in 0-35‰ salinity, 0-35°C temperature and 1-9 ml/l oxygen content. Mummichogs are typically found in tidal creeks and in coves rather than along open beaches. A statistically significant preference for muddy, vegetated bottoms by F. heteroclitus was seen by Briggs and O'Connor (1971) in the Great South Bay, Long Island. Under identical salinity, temperature, dissolved oxygen and tide stage, mummichogs chose mud bottoms over sand bottoms. Similar preference has been recorded in Delaware Bay, Indian River and Rehoboth Bays in Delaware.

F. heteroclitus has been described as a schooling fish by many authors. They are often found associated with Atlantic silversides, Menidia menidia and sheepshead minnows, Cyprinodon variegatus.

Mummichogs have been found to maintain a strict home range during the summer (Lotrich, 1975). The home range extends only 36 meters along the creek bank and only three meters away from the bank. At high tide the mummichog goes onto the marsh surface to feed.

The winter distribution of mummichogs has long been a matter of speculation. They have been observed burrowed into the mud of pools when the water temperature dropped. Recent observations of F. heteroclitus in Canary Creek, Delaware, revealed them moving upstream into lower salinity water. It has been theorized that they seek isotonic salinities so that they may minimize osmoregulatory metabolism during winter months. Other scientists find mummichogs associated with the bottom muds in the winter time in Canary Creek where they presumably lie semi-dormant, waiting for warmer weather. However, on high tides on the warmer winter afternoons, mummichogs have been observed in the tidal creeks apparently responding to the slight warming of the environment.

Food ingested by F. heteroclitus varies with availability due to season and prey size relative to mouth size. They have been called omnivores based on stomach analysis, but laboratory work reveals them as carnivores deriving almost no nutritional value from fresh plant material or detritus. However, mummichogs do ingest small bits of Spartina and small detrital consumers as fiddler crabs, Uca, and grass shrimp, Crangon. Stomach analysis also revealed sand and mud, probably the result of bottom feeding.

Seasonal trends in prey is evident from the following list. Prey in the spring includes copepods, insect larvae, horseshoe crab, Limulus, eggs; in the summer--copepods, decapods, horseshoe crab eggs and larvae, fish eggs and silversides, Menidia menidia, are found in the stomachs of large mummichogs. Also some cannibalism of their eggs and larvae have been reported.

FIGURE 95
MUMMICHOG

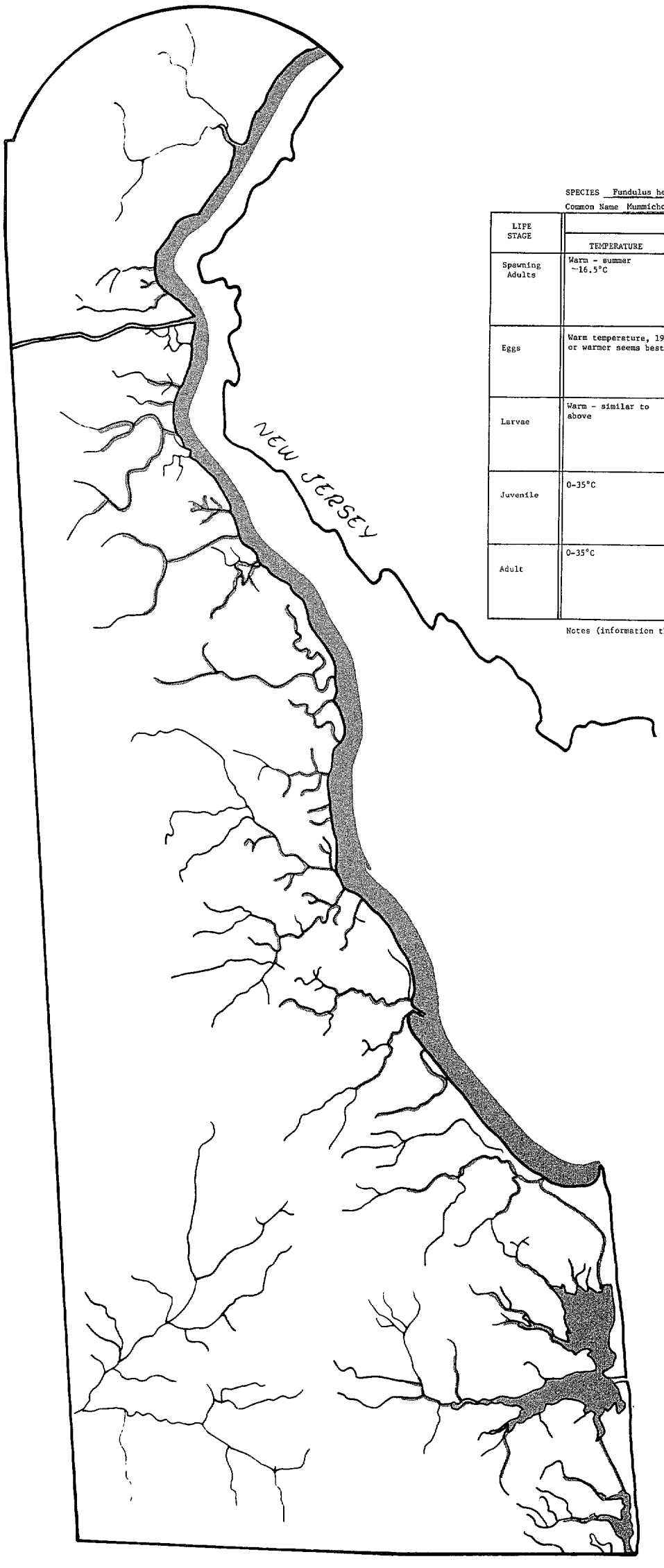
SPECIES Fundulus heteroclitus

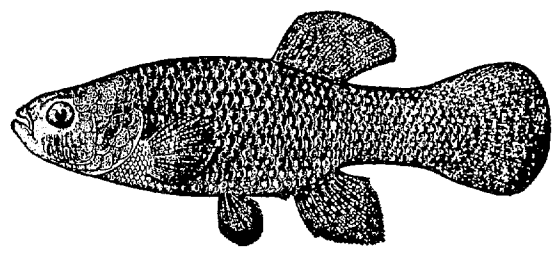
Common Name Mummichog

Spawning Period April to August

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Warm - summer ~16.5°C	Brackish			
Eggs	Warm temperature, 19°C, or warmer seems best	Brackish			
Larvae	Warm - similar to above	Wide range (68)			
Juvenile	0-35°C	0-70‰, prefer brackish	High tolerance to low dissolved oxygen to below 1 ml/l (73)		
Adult	0-35°C	0-70‰, prefer brackish	High tolerance to low dissolved oxygen to below 1 ml/l	Tolerant to high concentrations of suspended sediment LC_{10} = 23.000 mg/l (66)	Methoxychloride at .05/acre very toxic Abate ULV at 1 fl. oz./ acre produced no detrimental effects. (83)

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) Burrow in mud during winter.





LEGEND

GENERAL ADULT DISTRIBUTION

Mummichogs are oviparous (eggs develop and hatch outside the female's body) and spawn several times during the spring and summer. They are able to reproduce the first summer following their birth and are able to spawn for two more summers. Rising water temperatures initiate maturation of gonads. Consequently, beginning of spawning may vary from year to year, but the peaks of spawning activity throughout the summer are coordinated with the spring tides that occur every fourteen days.

It has long been suspected that F. heteroclitus spawns on the marsh surface. During the summer of 1975, confirming evidence was collected on Canary Creek Marsh in that mummichog eggs were observed inside of the primary leaf of cordgrass, Spartina alterniflora, on the marsh. Laboratory observations showed that the female stands on her head and places the eggs on a nearby vertical surface. The outer shell of each egg (chorion) is covered with many adhesive threads with which to attach to weeds and rocks.

Mummichog eggs are 1.8 to 2.0 millimeters (.07 to .08 inch) in diameter depending on the size of the female which can be as small as 2.8 centimeters (about 1 inch). Inside the chorion is a nearly transparent yolk that contains oil droplets and a very thin embryo. Each female can spawn 200 eggs per summer out of which an average of only one juvenile will survive.

Mummichog embryos hatch out of the eggs in seventeen days at a temperature of 19-21^{o}C; higher temperatures cause earlier hatching. The embryo carries the yolk sac with it for an additional one or two days after which it is considered to be a larvae. The larvae must now find its own food in order to survive. There is no parental care of the young.

F. heteroclitus is an important link in the food chain of the estuaries and because of their high production, represent a large store of energy for higher predators. They prey on copepods, insect larvae, decapods, eggs and

smaller fish. In turn, F. heteroclitus is preyed upon by the American eel, Anguilla rostrata; bluefish, Pomatomas saltatrix; white perch, Morone americana; and large crabs. Also, birds, mink and otters prey on F. heteroclitus in pools at low tide.

Life history studies have revealed the importance of these small forage fishes that are often considered useless. The mummichog is an important link in the estuarine food web that supports many valuable fish, crabs and mammals (see Principles of Wetland Ecosystems). They are commonly used as bait by sport fishermen. Finally, their role in controlling the salt marsh mosquito (Aedes sollicitans) through predation is exceptional.

References

Briggs, P. T. and J. S. O'Connor. 1971. Comparison of shorezone fishes over naturally vegetated and sand-filled bottoms in Great South Bay. N.Y. Fish Game J. 18(1): 15-41.

Derickson, W. K. and K. S. Price. 1973. The fishes of the shore zone of Rehoboth and Indian River Bays, Delaware. Trans. Amer. Fish. Soc. 102(3): 552-562.

deSylva, D. P., F. A. Kalber and C. N. Shuster, Jr. 1962. Fishes and ecological conditions in the shore zone of the Delaware River estuary, with notes on other species collected in deeper water. University of Delaware Mar. Lab. Publ. No. 5. 164 pp.

Lotrich, V. A. 1975. Summer home range and movements of Fundulus heteroclitus (Pisces: Cyprinodontidae) in a tidal creek. Ecol. 56(1): 191-198.

Schmelz, G. H. 1964. A natural history study of the mummichog, Fundulus heteroclitus (Linnaeus), in Canary Creek Marsh. M. S. thesis. University of Delaware. 65 pp.

STRIPED KILLIFISH

Fundulus majalis (Walbaum)

The striped killifish is a small, near-shore forage fish typically found along the shores of Delaware, Indian River and Rehoboth Bays. The adult male's back is dark olive shading into an off-white belly. On its sides are 15-20 vertical black stripes. The dorsal fin is dusky, often with a black spot on its last rays; caudal fin is also dusky; anal, ventrals and pectoral fins are lemon yellow. Adult females are similarly colored except that instead of vertical stripes, they have two or three longitudinal bars and several vertical stripes near the base of the tail. Young of both sexes are similarly marked with 7 to 12 vertical bands; sexual differentiation usually occurs at a size of 4-5 centimeters (1.6-2.0 inches). Maximum reported size is approximately 17 centimeters (6.5 inches) for females with males normally slightly smaller. For any given length, females are slightly heavier than the males. The striped killifish eats small mollusks, crustaceans, small fish, insects and insect larvae. Many of the stomachs examined contained considerable amounts of sand, probably ingested while eating along the beaches. The eggs of the horseshoe crab, Limulus polyphemus, are a favorite food during the crab's spawning season of late spring to early summer in Delaware.

Spawning of the striped killifish occurs from May through August at the times of new and full moon phases. The eggs are relatively large, averaging 2 millimeters (.08 inch) in diameter. As many as 500 eggs per female can be released at a spawning.

Fundulus majalis is commonly found in the shore zone of Delaware Bay, Indian River and Rehoboth Bays in coves, creeks and tidal pools. A study

in Great South Bay, Long Island (Briggs and O'Connor, 1971) conclusively showed that Fundulus majalis prefers a sandy bottom to a more muddy, vegetated bottom. A related species, Fundulus heteroclitus, (mummichog) showed a definite preference for the muddy bottom. Similar distributions relative to bottom type have been seen in Delaware Bay, Indian River and Rehoboth Bays.

Schools of the striped killifish are often seen in the shallow water right up against the beach. In a very early article by S. O. Mast (1915) the behavior of F. majalis stranded on the beach or in tidal pools is described. In a movement described as flopping or leaping they are able to return to the bay from the beach or tidal pool even when a sand bar must be traversed.

Aside from those sources listed, very little research has been done on Fundulus majalis. There are a few comparative studies on the chromosomes and on the morphologic and menistic characters of F. majalis and F. heteroclitus. Many questions about F. majalis remain to be answered: 1) its role in the food chain (primary prey i.e.--horseshoe crab eggs; primary predators); 2) its spawning behavior; 3) the reason for its observed distribution (preferred substrate) relative to F. heteroclitus.

It appears, based on the limited knowledge of the striped killifish, that it is a very hearty fish. It can tolerate a wide variety of salinities and temperatures, as it is found both in tidal creeks and in the near shore bay waters both in the summer and to a lesser degree in the winter. Also, its resting metabolism is quite low compared to other species like the menhaden and silversides. Finally, the striped killifish is capable of tolerating quite low dissolved oxygen levels.

References

Briggs, P. T. and J. S. O'Connor. Comparison of shore zone fishes over

FIGURE 96
STRIPED KILLIFISH

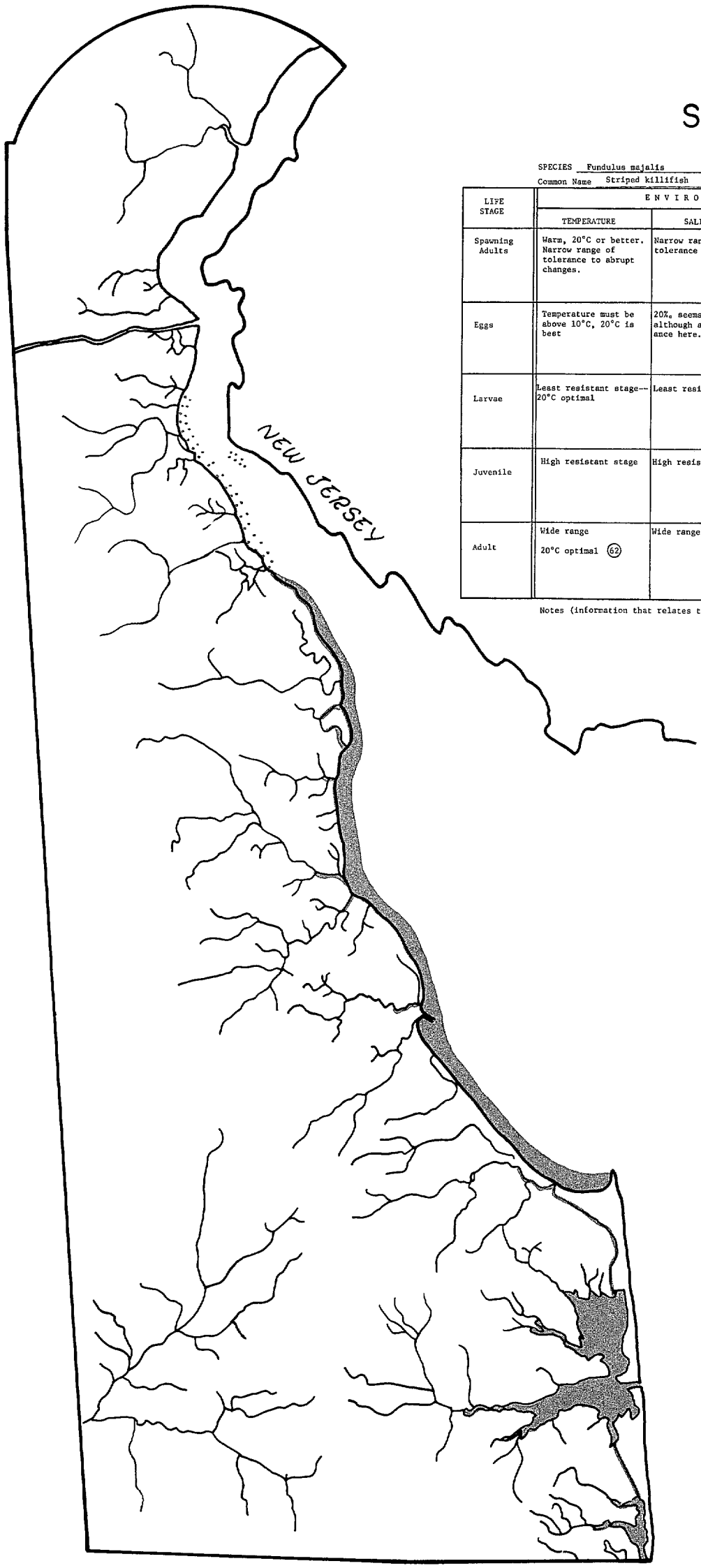
SPECIES Fundulus majalis

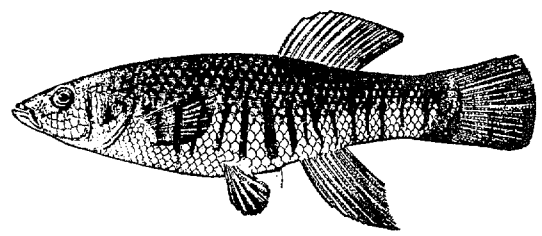
Common Name Striped killifish

Spawning Period April to September; New & full moon induces spawning

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Warm, 20°C or better. Narrow range of tolerance to abrupt changes.	Narrow range of tolerance to changes			
Eggs	Temperature must be above 10°C, 20°C is best	20‰ seems best although a high tolerance here.	High oxygen consumption rate		
Larvae	Least resistant stage--20°C optimal	Least resistant stage			
Juvenile	High resistant stage	High resistant stage	High tolerance to low dissolved oxygen below 1 ml/l (73)		
Adult	Wide range 20°C optimal (62)	Wide range	High tolerance to low dissolved oxygen to below 1 ml/l (73)	Tolerant of high concentration of suspended sediments LC_{10} = 23,000 mg/l (66)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

GENERAL ADULT DISTRIBUTION

naturally vegetated and sand-filled bottoms in Great South Bay. N. Y. Fish and Game Jour. 18(1): 15-41.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. U. S. Bur. Fish. Bull. 43(1): 365 pp.

Mast. S. O. 1915. The behavior of Fundulus, with special reference to overland escape from tide pools and locomotion on land. J. Anim. Behav. 5(5): 341-350.

Richards, S. W. and A. M. McBean. 1966. Comparison of postlarvae and juveniles of Fundulus heteroclitus and Fundulus majalis (Pisces: Cyprinodontidae). Trans. Amer. Fish. Soc. 95: 218-226.

Thornton, L. L. 1975. Laboratory experiments on the oxygen consumption and resistance to low oxygen levels of certain estuarine fishes. Master's thesis. University of Delaware. (unpublished.)

ATLANTIC SILVERSIDE

Menidia menidia

The Atlantic silverside, Menidia menidia, is a slender fish reaching four to five inches maximum length, possessing a small head but large eyes and a small mouth. There are two dorsal fins: the first with three to seven spines, and the second with seven to ten soft rays. The anal fin contains one spine and twenty to twenty-six soft rays. The body is covered with large scales and is faintly greenish above. There is a silver band running mid-laterally down the side of the fish outlined above by a narrow black line. The belly is white.

Although the Atlantic silverside is one of the most abundant shore zone fishes of Delaware, relatively little is known of its life history. The lack of information probably results from the fact that the species is of little direct use to man. Some silversides are caught for bait and even for human consumption, but the amounts involved are relatively small.

The species, however, deserves much more study than it has received for, while it is not directly used by man, it is still of great importance to the marine food web. Silversides are known to be one of the chief prey species of many of the commercially valuable food fishes of the area such as bluefish and founders. Without healthy silverside populations, it is probable that the predator fish species, and the recreational and commercial fishery industries developed around them, would suffer.

As shore zone inhabitants, the silversides reside in areas most likely to be altered by man. Since any changes that affect the silversides would eventually affect the more sought after species, it becomes imperative that

the environmental requirements of the species be determined and that managers try to keep any environmental changes within these limits.

All silversides are shallow water fish usually confining their movements to water 1-2 fathoms (6-12 feet) deep, at least in the spring, summer and fall. Although silversides appear to be year-round residents of Delawares' back bays and near shore communities, some parts of the population appear to seek deeper, warmer water in the winter. The adults are tolerant of low water temperatures approaching freezing and are able to exist in shallow areas in the winter; however, different winter studies undertaken in various areas of Delaware do not always indicate the presence of winter populations. So, there is still some confusion surrounding this point.

Silversides spawn only in the spring and summer months with most of the activity confined to the late spring. Some spawning does occur throughout the summer for small juveniles of all ages can generally be found throughout that time. Various secondary peaks in spawning activity also seem to occur but not enough data exist to decide what these peaks indicate about the possible existence of distinct silverside groups. Recently, it was found that the mean length of Menidia larvae was lowest in June and increased through August in the small bays.

Spawning takes place in water as shallow as an inch or so along the shores of the bays and tidal creeks. The fish spawn in schools often so large that the surrounding water is literally white from all the eggs and milt being deposited. Each female produces approximately 300 eggs which are about 1 millimeter in diameter and covered at one end by many long sticky filaments. Many eggs, then, stick together in rope-like masses and these clusters adhere to any object with which they come in contact.

The incubation period is as long as 10-12 days which means that many of these eggs do not survive to hatch. The longer the incubation, the greater are the chances that the helpless eggs will experience unfavorable environmental conditions or be consumed by predators. Survival rate is unknown. It appears, however, that a large adult population is present every year but there is little actual data to support these observations.

Once hatched, the larvae grow very rapidly increasing in length from about 5 millimeters (.2 inch) to 100-150 millimeters (4-6 inches) in several months. This is about as large as individuals get, as no significant growth occurs during the winter and it is doubtful that these fish live much longer than one year.

The silversides will eat almost anything smaller than themselves and in turn are consumed by a wide variety of predators. Silversides are opportunistic consumers although there are indications that they can be selective and that there are possibly significant diurnal rhythms in the feeding behavior. Researchers have found that in June and July the eggs and larvae of the horseshoe crab, Limulus polyphemus, and several species of amphipods account for most of the food of the silversides. In August, several isopods and fish larvae of various types become the most important items. The diet changes predominantly to mysid shrimps and amphipods in September and October, and mysid shrimps and copepods in November and December. Along with these food items, larvae of molluscks, crustacenans, vivalves, diatoms and other algae and even marsh insects have been consumed by silversides.

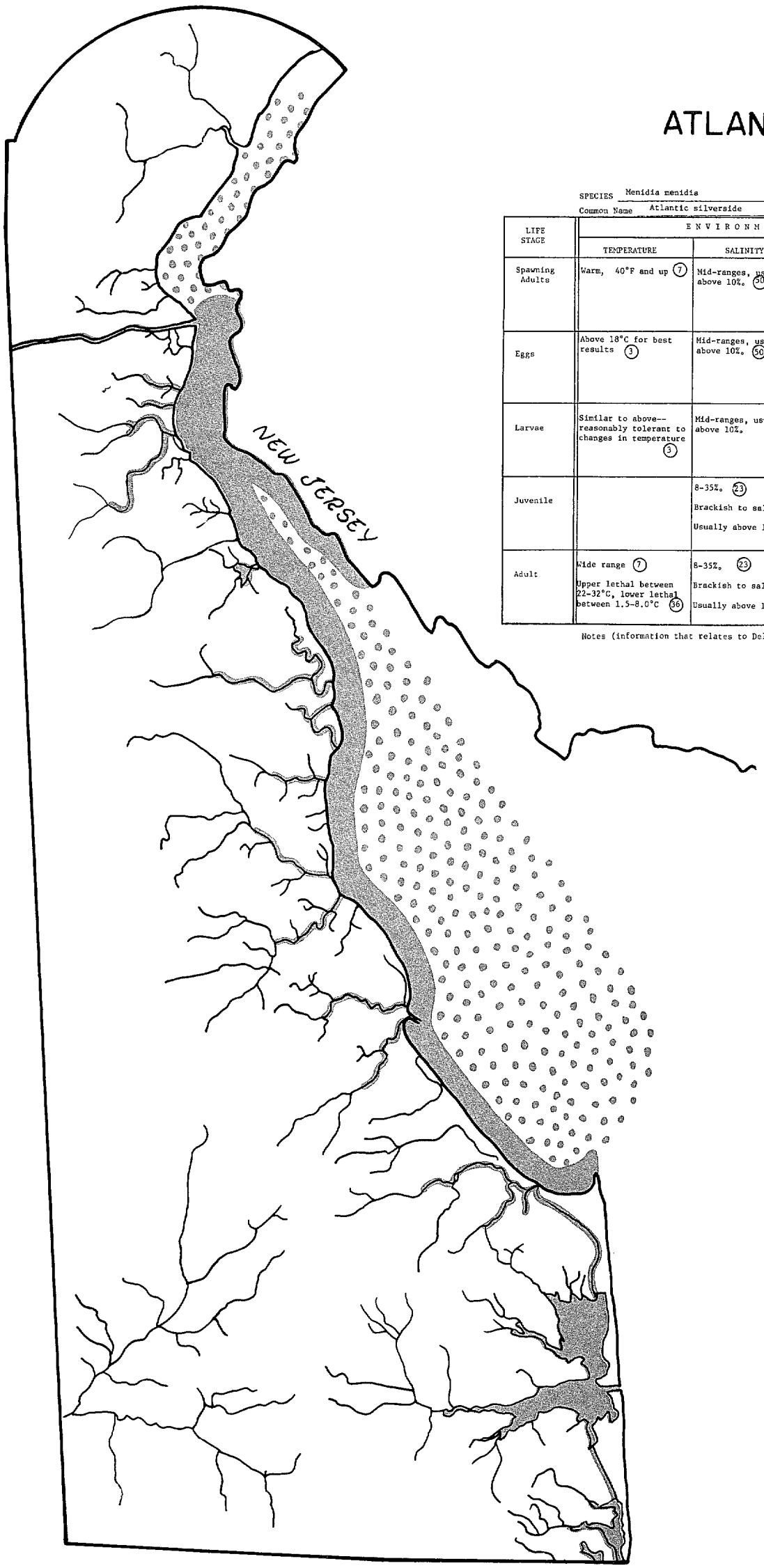
In turn, the silversides are preyed upon by bluefish, striped bass, eels, weakfish, black sea bass, scup, cunner and some of the flounders, as well as by any other predacious fish that happens into the estuary. Since silversides do not travel far offshore, their importance as prey is greatest when the

predator species come into the estuary and the shallow areas of the shore zone, such as during spawning periods. Besides the fish predators, silversides are also eaten by gulls, terns, herons and other shore birds which are adept at capturing the silversides as they school near the surface.

Many questions need to be answered about the silverside as predator and prey species: How important are the preferential feeding patterns of the silverside in the maintenance of the prey species?, What effect do the different food sources have on the silversides themselves?, What happens to the fish predators of the silversides if the numbers of silversides are reduced, especially in the shallow shore zone? Scientists really have very little data that could be used to answer these questions. Even less data is available concerning the role of the silversides in the food chain of the shorebirds.

Likewise, very little substantial data has been accumulated on the environmental requirements of the silversides. It is known that they are predominantly found in water above $10‰$ salinity, although occasionally they will stray into slightly fresher water. If the water is fresher, however, they usually are replaced by a closely allied, apparently ecologically similar species, Menidia beryllina, the tidewater silverside. Scientists also know that, as active fish, the silversides require well oxygenated water, much more so than other forage fishes found in Delaware. A good deal still needs to be learned about the oxygen requirements of the silversides, but since they are resident species of the area and important members in the food web of the estuary and apparently intolerant of the low oxygen conditions, it is imperative that such data be accumulated. Another area which should receive study concerns the spawning, egg and larval development periods which probably are the most critical periods in the maintenance of a particular population. Scientists

FIGURE 97
ATLANTIC SILVERSIDE



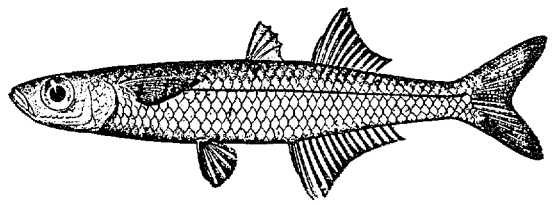
SPECIES Menidia menidia

Common Name Atlantic silverside

Spawning Period April to September

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Warm, 40°F and up (7)	Mid-ranges, usually above 10‰ (50)			
Eggs	Above 18°C for best results (3)	Mid-ranges, usually above 10‰ (50)			
Larvae	Similar to above--reasonably tolerant to changes in temperature (3)	Mid-ranges, usually above 10‰			
Juvenile		8-35‰ (23) Brackish to saline (4) Usually above 10‰ (50)	High susceptibility to low dissolved oxygen (73)		
Adult	Wide range (7) Upper lethal between 22-32°C, lower lethal between 1.5-8.0°C (36)	8-35‰ (23) Brackish to saline (4) Usually above 10‰ (50)	High susceptibility to low dissolved oxygen (73)	Highly sensitive to suspended sediments (66) LC_{10} = 580 mg/l (66)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)



LEGEND

GENERAL ADULT DISTRIBUTION

have accumulated data about spawning and egg development in laboratory situations, but little that is applicable to natural populations. While such data is hard to acquire, the fact that silversides are important species in the estuarine food web requires that such data be made available.

References

Bayliff, W. H., Jr. 1950. The life history of the silverside, Menidia menidia (Linnaeus). Che. Biol. Lab. Publ. No. 90. 28 pp.

Bigelow, H. R. and W. C. Schroader. 1953. Fishes of the Gulf of Maine. Fish. Bull., Fish Wild. Serv. Vol. 53. Washington, D. C.

Campbell, T. G. 1975. The fishes and hydrographic parameters of White Creek, Delaware: A description and comparison of 1973-74 to 1957-58 Master's thesis. University of Delaware. 96 pp.

Daiber, F. C., Don Aurand, Gillman Brenum, Richard Clarke. 1974-75. Ecological effects upon estuaries resulting from lagoon construction, dredging, filling and bulkheading. Report to Division of Fish and Wildlife. State of Delaware Project F-25-R-2. Job Numbers 1-2-4-5.

deSylva, D. P., F. A. Kalber, Jr., C. N. Shuster, Jr. 1962. Fishes and Ecological Conditions in the Shore Zone of the Delaware River Estuary. University of Delaware Marine Laboratories. Information Series, Publication Number 5.

Moore, J. M. 1968. The feeding and food habits of the silversides, Menidia menidia (Linnaeus). Master's thesis. University of Delaware. 62 pp.

Shuster, C. N., Jr. 1959. Delaware River Estuary. Information Series, Publ. 3. University of Delaware. Mar. Lab. 77 pp.

Thornton, L. L. 1975. Laboratory experiments on the oxygen consumption and resistance to low oxygen levels of certain estuarine fishes. Master's thesis. University of Delaware. 82 pp.

THE WHITE PERCH

Morone americana

The white perch, Morone americana, is not a perch, but a member of the sea bass family, Serranidae. It is somewhat deeper bodied and more flattened than its relative, the striped bass. Its head is low, with a pointed snout and small mouth, containing some small teeth. The upper body is usually colored olive, dark grey, grey-green, or silver-green. The sides are pale and silvery, with occasional blue reflections. Ventrally, it is white or silvery. Its fins are usually dusky colored. Like the striped bass, it has two dorsal fins, the front one being supported by stiff spines.

The white perch is found along the Atlantic coast from Nova Scotia to Georgia. When in coastal waters, it rarely strays far from river mouths. It is also found in brackish areas of bays, estuaries and tributaries, and in freshwater ponds and lakes. The white perch prefers shallow water, from six to twelve feet in depth, although it may spend the winter hibernating in deeper waters. It is found most often over flat clay or muddy bottoms. The Chesapeake and Delaware Bays, and the tidal creeks sustain sizeable populations of white perch.

The white perch is anadromous, migrating into fresh or brackish waters to spawn. These migrations usually take place in the spring in the Chesapeake Bay area, and progressively later further north. Spawning usually takes place just above brackish water, in shallow, weedy areas.

The average female white perch may lay as many as 40,000 spherical (about 0.7 millimeter (.03 inch) in diameter) demersal (sinking), and adhesive eggs. The incubation period varies with temperature: at 20°C, hatching occurs after

thirty hours; at 15°C, it occurs after 4 1/2 days. The larvae may remain in slightly brackish water or return to sea to complete their development. They grow most rapidly in the first three years. The average white perch is 21-23 centimeters (8 to 9 inches) long and .2-.5 kilograms in weight, although specimens 30 centimeters (12 inches) or more in length, and 1.3 kilograms in weight have been found. White perch usually live from six to seven years, although fifteen year-olds have been found.

Feeding habits of the white perch vary with age. Larvae and juveniles feed primarily on plankton. Young fish up to about ten centimeters long may eat annelids, amphipods, isopods and copepods. Adult white perch feed on insects (mayfly, caddis fly, dragon fly), fishes (smelt, yellow perch, white perch, anchovies, minnows), shrimp and crabs.

The white perch also supplies food for other fish such as salmon, trout, bass, and larger perch. Not all of these predators are present in Delaware, which is probably part of the reason for the local abundance of the white perch.

The distribution of the white perch is regulated by certain environmental factors. Temperature is important for successful spawning, which usually occurs between 10-15°C, although the adult white perch may be found in waters from 3°-25°C. The largest populations are usually found in brackish waters, with salinities ranging from 5-18‰. Some good sized populations are found land-locked in freshwaters. In Delaware, the tidal streams which support considerable white perch populations have salinities ranging from 1.8-28‰.

Considering the white perch's survival capacity and its good eating qualities, it is under-exploited. In Maryland, it used to be rated fifth in value and sixth in quantity. By maturing and spawning at an early age, there is assurance of a continuing supply of perch, particularly if it is intensively fished. The State of Delaware with its numerous creeks and bays which serve

FIGURE 98
WHITE PERCH

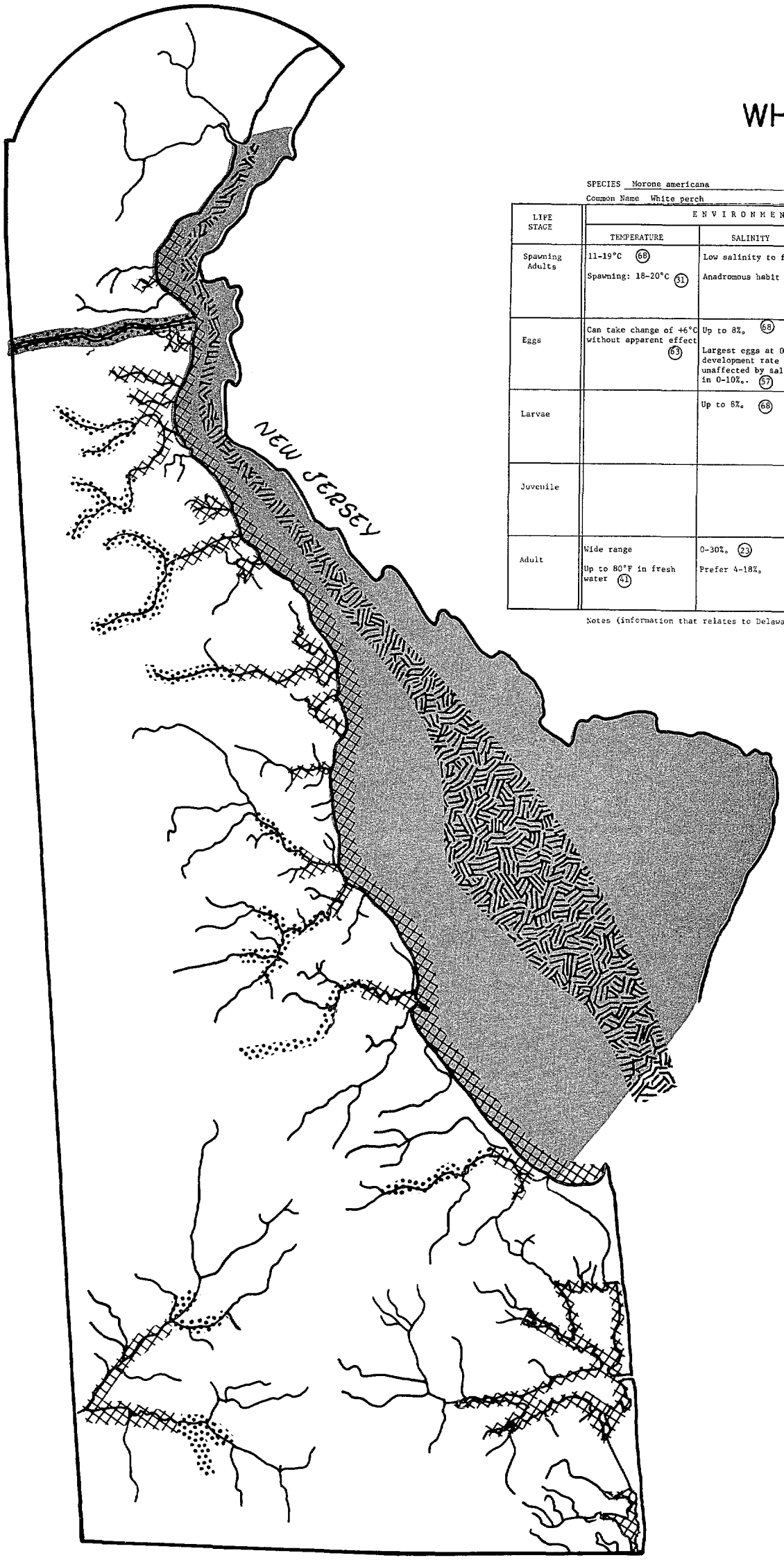
SPECIES Morone americana

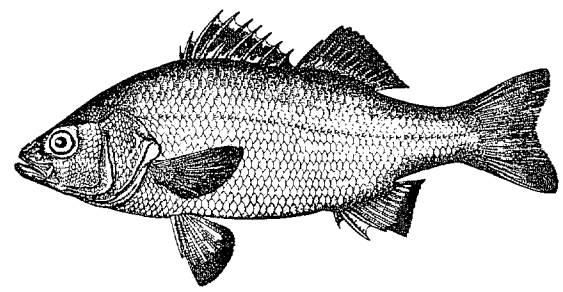
Common Name White perch

Spawning Period April and May

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	11-19°C (68) Spawning: 18-20°C (31)	Low salinity to fresh (7) Anadromous habit (41)			
Eggs	Can take change of +6°C without apparent effect (63)	Up to 8‰ (68) Largest eggs at 0‰, development rate unaffected by salinity in 0-10‰. (57)		1000 mg/l effects hatching success ($p \leq .005$) (2) LD_{50} (2 days) is 2680 ppm (57)	
Larvae		Up to 8‰ (68)			
Juvenile				500 and 1000 mg/l sediment had adverse effect on survival ($p \leq .05$) (2) Highly sensitive to suspended sediments. (66)	
Adult	Wide range Up to 80°F in fresh water (41)	0-30‰ (23) Prefer 4-18‰	Moderate tolerance to low dissolved oxygen (73)	Sensitive to suspended sediments. (66)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

- KNOWN SPAWNING AREAS
- NURSERY AREAS
- GENERAL ADULT DISTRIBUTION
- CONCENTRATED WINTER DISTRIBUTION

as nurseries and feeding grounds for the white perch, has a potentially important fishery. Care must be taken to preserve these nurseries and feeding grounds if this fishery is to persist.

References

Goode, G. B. 1888. A popular treatise upon the game and food fishes of North America. Standard Book Company, N.Y.

Henshall, J. A. 1919. Bass, pike, perch and other game fishes of America. Stewart Kidd Company, Cinn.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. Smithsonian Inst. Press, Washington, D. C. 338 pp.

Leim, A. H. and W. B. Scott. 1966. Fishes of the Atlantic coast of Canada. Fish. Res. Bd. Canada, Ottawa. 485 pp.

Mansueti. R. J. 1964. Eggs, larvae and young of the white perch, Roccus americanus, with comments on its ecology in the estuary. Ches. Sci. 5(1-2): 3-45.

Maryland Tidewater News. 1953. White perch studies. 10(1): 3-4.

Miller, L. W. 1963. Growth, reproduction and food habits of the white perch, Roccus americanus (Gmelin) in the Delaware river estuary. Master's thesis. University of Delaware.

Trautman, M. B. 1957. The fishes of Ohio. State Univ. Press of Ohio.

STRIPED BASS

Morone saxatilus

The striped bass, Morone saxatilus, also known as rock or striper has been an important part of the American fishery since the earliest times in American history. It is commonly found along the Atlantic coast and weighs from one to ten pounds and occasionally up to fifty pounds.

The striped bass is aptly named; it is greenish above, silvery on its sides and belly with seven or eight prominent longitudinal black stripes running above and below the lateral line. It has two dorsal fins; the first has long stiff spines. The caudal fin is forked; the anal fin has three strong spines. There is no difference in size or external appearance between the male and female.

One of the most prominent and most often studied aspects of the striped bass is its schooling and migratory habits. They travel in schools during a large part of their life span. The bass undergo migrations in large schools twice a year. Normally, the fish move north in spring and south in the fall. An elevation of water temperature to 8°C triggers a northward movement, and a drop in temperature and possibly the stronger tides of winter trigger a southward movement.

The striped bass are commonly distributed from Maine to northern Florida on the east coast. Seasonal variations in abundance are due to migrating stocks. However, many fish do not migrate south but instead overwinter from New York to Delaware.

Aside from the general north-south migrations, the bass also migrate upstream for spawning. At one time the striped bass spawned in all rivers along the Atlantic coast, and the eggs, larvae and young could therefore be

found everywhere along the coast. Suitable spawning grounds have dwindled over the years and today only the rivers of the Chesapeake and the Chesapeake and Delaware Canal provide productive spawning sites. At one time the Delaware River also provided a major spawning area; however, pollution has destroyed its value for producing striped bass in commercial quantities.

Spawning of striped bass usually takes place in swift freshwater although it has been recorded in brackish water. Males generally reach sexual maturity in two years, females in three years. The spawning itself is called "rock fights" and is a violent splashing at the surface by the female and the accompanying males (up to fifty per female).

The upstream migration and subsequent spawning occur in spring or early summer depending on latitude. The spawning act is related to warming temperature; most spawning has been noted at temperatures of 15.5o to 21oC. Development of embryo and larval stages is rapid; larvae are similar in appearance to adults after eight to ninety days their average length after one year is 11 centimeters (4 inches) and after two years, 35 centimeters (14 inches). A striped bass of one meter length and twenty-five pounds weight is approximately eleven years old.

Striped bass are carnivorous. They do not show much specificity toward species of prey, but do toward size, preferring as large and animal as they can swallow. Prey found in bass' stomachs include polychaete worms, squid, bloodworms, shrimp and fish. Fish such as herring, silversides, anchovies and killifishes become an important part of the bass' diet when it reaches a length of approximately 10 centimeters.

The striped bass is a valuable fish both commercially and recreationally. Catch statistics are scanty since the striped bass is a food fish only. It is generally caught by sport fishermen and and is sold fresh locally. It

FIGURE 99

STRIPED BASS

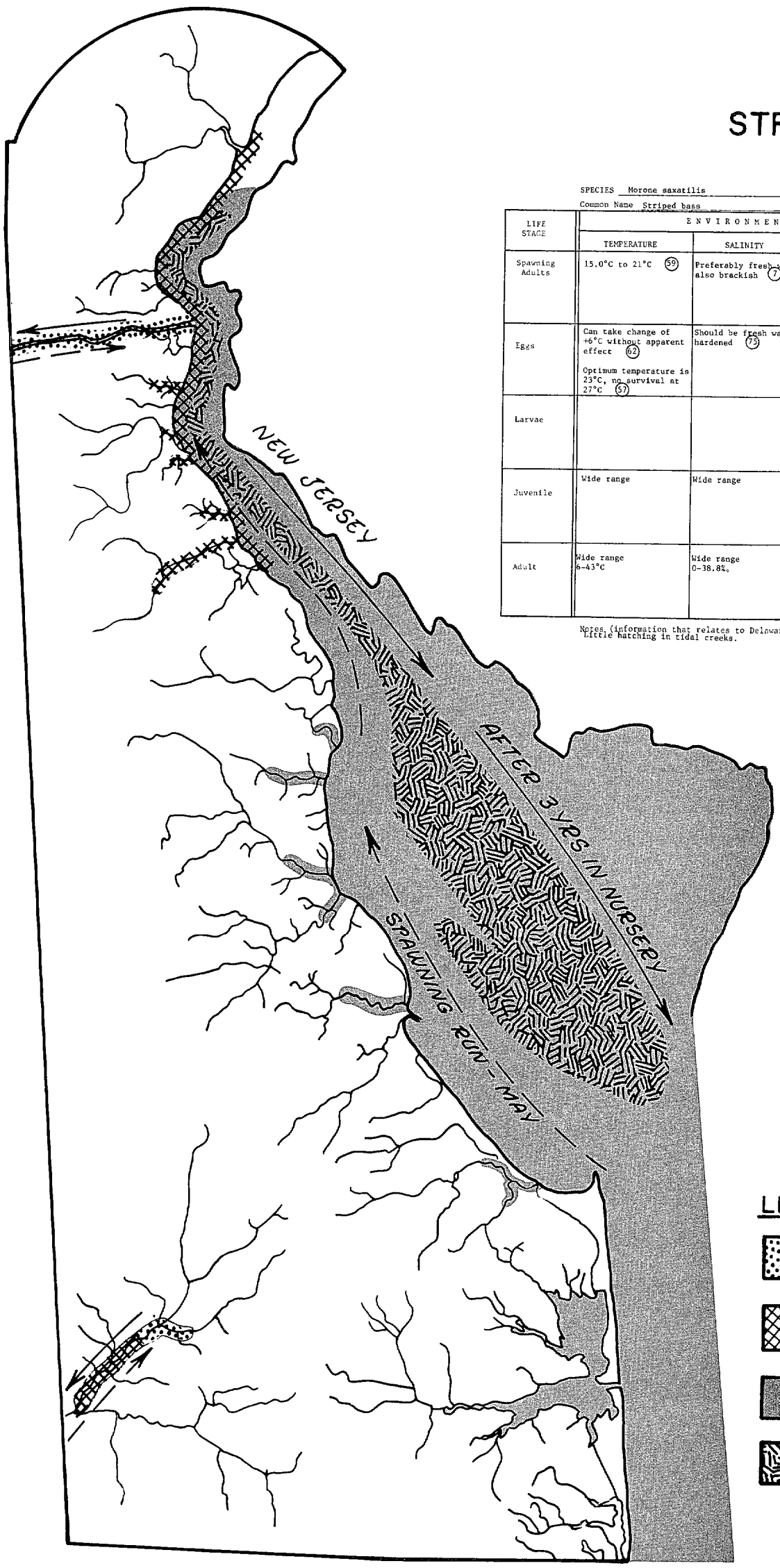
SPECIES Morone saxatilis

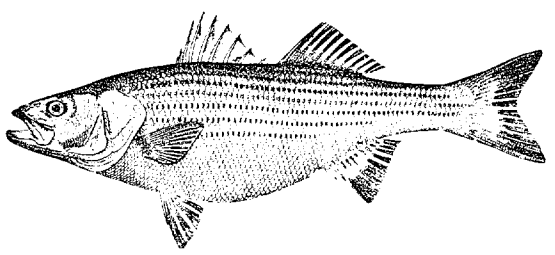
Common Name Striped bass

Spawning Period

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	15.0°C to 21°C (59)	Preferably fresh water, also brackish (7)			
Eggs	Can take change of +6°C without apparent affect (62) Optimum temperature is 23°C, no survival at 27°C (57)	Should be fresh water hardened (75)	4-5 mg/l reduces percent hatch (75)	1000 mg/l affected hatching success (2) LD_{50} (2 days) is 3411 ppm (57)	
Larvae			4-5 mg/l adversely affects larvae (75)	500 and 1000 mg/l affected survival $P \leq .005$ (2)	
Juvenile	Wide range	Wide range			
Adult	Wide range 6-43°C	Wide range 0-38.8‰	Moderate tolerance to low dissolved oxygen (73) 3 mg/l at 16-19°C is probably minimum permissible level (13)	Sensitive to suspended sediments (66)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) May overwinter in tidal creeks
Little hatching in tidal creeks.





LEGEND

- KNOWN SPAWNING AREAS
- KNOWN NURSERY AREAS
- GENERAL ADULT DISTRIBUTION
- CONCENTRATED WINTER DISTRIBUTION

appears, however, that the northern east coast commercial catch has declined while locally, in the Chesapeake, the catch is remaining high or is even increasing. The commercial gear used includes haul seines, otter trawls and pound nets. Values of the striped bass fishery for 1970 (latest available) show $11,700 in sales and 54,000 pounds landed in Delaware.

The overall decline of the striped bass fishery has been attributed to two factors: 1) the catching of two year-old fish and 2) the reduction of the spawning grounds. Two year-old striped bass have not reproduced yet, therefore their removal prevents them from contributing to the next generation. The number and quality of spawning grounds has declined largely due to pollution and dam construction. Experts fear that increased fishing effort would be detrimental to the remaining stocks, and they further recommend a fuller understanding of the biology of the striped bass.

References

Adapted from:

DiMichele, L. 1975. The life history of the striped bass, Morone saxatilus (Walbaum). Biol. Dept. (Ichthyology B-630). University of Delaware. 21 pp.

WINTER FLOUNDER

Pseudopleuronectes americanus

The winter flounder, Pseudopleuronectes americanus, is a "right-eyed" flatfish, that is, the eyes and coloring are on the right side of the body. The body is basically oval in outline, with a broad caudal preduncle and fairly small, terminal mouth. In general, the upper surface is dark olive green, with reddish brown spots scattered irregularly over the head and body; it is sometimes called the "blackback". The left or bottom side is nearly white. Male and female winter flounder are similar in appearance, and sex cannot usually be determined by external examination. The winter flounder seldom reaches a length of 600 millimeters (24 inches), or weight of 2.3 kilograms, with market-size fish generally 300 millimeters (12 inches) and .5 to 1.0 kilogram.

The winter flounder is a bottom-dwelling species, found in shallow waters of bays, harbors and estuarines and offshore to a 90-120 meter depth. It is generally agreed that winter flounder require fairly saline water for survival and reproduction. However, it was found that portions of two Rhode Island estuaries which had pronounced river influences were more important as nursery grounds for juveniles than the more marine areas. Substrate preference may be largely a reflection of food availability. The winter flounder's abundance on mud bottom as compared to sand and shell bottom areas in Long Island Sound has been related to the greater abundance of prey species in the mud.

The winter flounder is indigenous to the shoal bays and estuaries of the American North Atlantic coast, ranging from northern Labrador to North Carolina. It is generally considered a cold water species because of its abundance in the northern portions of its range. In the north, winter flounder may remain

in the shallows which stay cool throughout the summer, retreating to deeper waters in winter as the shallows become colder than the offshore waters. South of Cape Cod, including the Delaware region, winter flounder regularly move out of the bays and shallow waters in the spring and summer as these waters warm to above the preferred temperature of 12 to 15°C. Winter flounder remain in the deeper, cooler waters until fall, returning to the shallow waters when they cool.

The seasonal distribution of the juveniles is quite different from that of the adults. Like many other coastal and offshore species, the critical juvenile period (spring to fall for winter flounder) is spent in the protected foodrich estuaries, but as juveniles grow they tend to move seaward. Juvenile winter flounder remain offshore until their second or third year, when they are recruited into the adult population. The general pattern along the middle Atlantic coast is for the shore zone to be inhabited by juveniles in summer and adults in winter.

The diet of winter flounder varies with age, locality and seasonal availability of food. In general, the species is omnivorous, eating many kinds of animal and plant materials. Most food items are of relatively small size, owing to the small mouth of the winter flounder. Prey include polychaetes, isopods, amphipods, invertebrate eggs and phytoplankton, the small prey being consumed by the larvae and juveniles, larger prey by the adults. Winter flounder in Indian River Bay were found to consume primarily amphipods and isopods as juveniles but preferred polychaetes as adults.

Winter flounder are usually sedentary fish except during feeding when they prop themselves up on their dorsal and anal fins and await prey. They are capable of short bursts of speed to capture prey. High temperatures seem to inhibit

FIGURE 100
WINTER FLOUNDER

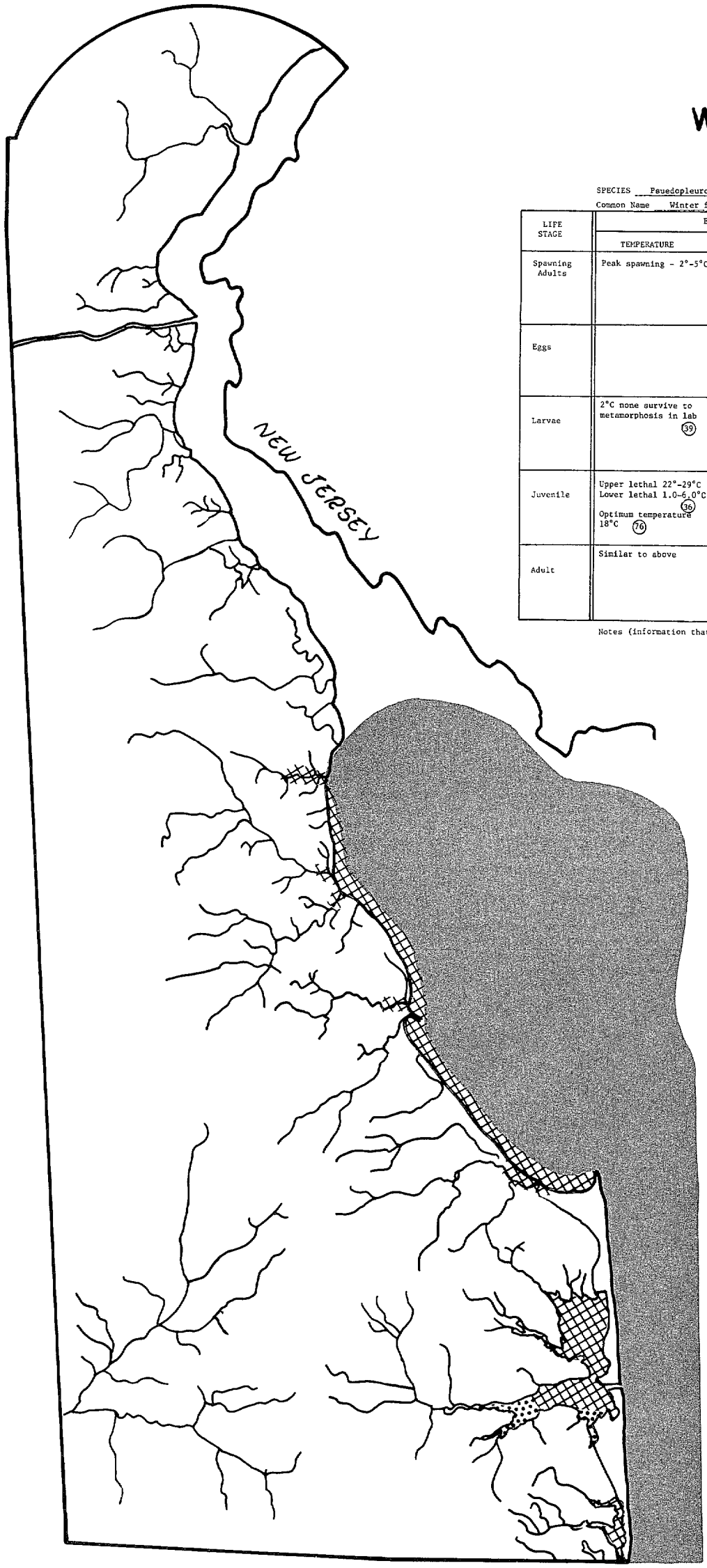
SPECIES Pseudopleuronectes americanus

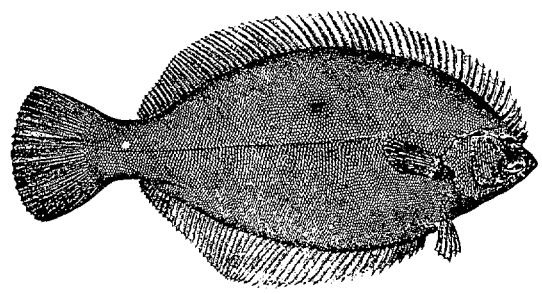
Common Name Winter flounder

Spawning Period Winter to early spring

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Peak spawning - 2°-5°C				
Eggs					
Larvae	2°C none survive to metamorphosis in lab (39)				
Juvenile	Upper lethal 22°-29°C Lower lethal 1.0-6.0°C (36) Optimum temperature 18°C (76)	Can tolerate low salinities			
Adult	Similar to above	8-30‰	High tolerance to low dissolved oxygen		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

KNOWN SPAWNING AREAS

NURSERY AREAS

GENERAL ADULT DISTRIBUTION

feeding behavior. Winter flounder appear to be nonselective feeders.

Most researchers agree that winter flounder reach sexual maturity at two to three years of age. They join the adult population and participate in the spawning migration at that time, having attained a length of approximately 20 to 25 centimeters (8 to 10 inches). The winter flounder is essentially a winter spawner, although the exact spawning period varies with location. In Delaware Bay, spawning occurs during a fairly long period beginning in December or January. Presumably, the spawning period is related to the water temperature. The peak spawning period corresponds to a water temperature of 2 to 5°C. Spawning usually takes place over sandy or muddy shoal waters.

Unlike most flounder eggs, those of P. americanus are not buoyant, but sink to the bottom, sticking to each other and to various objects in clusters. The distribution of these eggs is thus little affected by wind and tide forces resulting in a concentration of young near the spawning grounds. The eggs are small (approximately 0.75 to 0.96 millimeter in diameter), and are produced in great numbers. An individual female may produce as many as 3.3 million eggs; fecundity is greater for larger fish. Only about 1/10 of the eggs laid will hatch.

The larvae hatch after a short time (approximately 15 to 18 days at 3.3°C) and are approximately 2.3 to 3.5 millimeters in length. After approximately two months the larvae have grown to about 8 or 9 millimeters and metamorphosis consisting of development of the fins, twisting of the skull and migration of the left eye to the right side is completed. At this point the juvenile winter flounder is strictly a benthic animal, notably different from the larvae in morphology and habits. Juveniles grow rapidly during the first summer, but growth virtually ceases during the winter. After two years the winter flounder

is a sexually mature individual.

The winter flounder is a valuable food fish along the middle Atlantic coast, particularly since it occurs in winter when other fish are scarce. Its meat is considered somewhat superior to that of the summer flounder. Unfortunately, the fishery has markedly declined in recent years. In the 1960's the winter flounder was considered one of the dominant species of Indian River and Rehoboth Bays. More recent surveys, however, have failed to reveal winter flounder in as large numbers. Commercial landing of winter flounder in Delaware for 1970 was only 2,300 pounds and there is a moderate but persistent sport fishing effort during the winter months, particularly in Indian River Bay.

References

Adapted from:

Smedes, G. 1975. The life history of the winter flounder, Pseudopleuronectes americanus. Biol. Dept. (Ichthyology, B-630), Univ. of Delaware.

Other references:

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish. Bull. U. S. Fish and Wildl. Serv. 53(74). p. 577.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of the Chesapeake Bay. Bull. U. S. Bur. Fish, Vol. 43, Pt. 1. 388 pp.

Mielkana, M. S. 1966. The growth and feeding habits of juvenile fishes in two Rhode Island estuaries. Gulf Res. Repts. 2(2): 97-167.

Pearchy, W. G. 1962. Ecology of an estuarine population of winter flounder (Pseudopleuronectes americanus (Walbaum)). Bull. Bingham Oceanogr. Coll. 18(1): 1-78.

Perlmutter, A. 1947. The blackback flounder and its fishery in New England and New York. Bull. Bingham. Oceanogr. Coll. 11(2): 1-92.

Radle, E. W. 1971. A partial life history of the winter flounder (Pseudopleuronectes americanus) exposed to thermal addition in an estuary, Indian River Bay, Delaware. M.S. thesis, Univ. of Delaware. 74 pp.

Topp, R. W. 1968. An estimate of the fecundity of the winter flounder, (Pseudopleuronectes americanus). J. Fish. Res. Bd. Canada 25(6): 1,299-1,302.

YELLOW PERCH

Perca flavescens

The yellow perch, Perca flavescens (mitchill), is a member of the order Perciformes, and the family Percidae--the perches. Its natural range extends from the Hudson Bay region and Nova Scotia, south through the Great Lakes, South Dakota, Iowa, Illinois, Pennsylvania; in the eastern states to South Carolina, and from the northern Mississippi valley to the Red River Basin (Hildebrand and Schroeder, 1928; Hubbs and Lagler, 1958; Muncy, 1958). It is also the only member of the perch family found in California, where it was artificially introduced in 1891 (Curtis, 1949).

Its local distribution is determined by a number of factors. While preferring brackish waters, it migrates to fresher water to spawn. It is most often found in weedy shoals of shallow, brackish waters (Henshall, 1919), but it is still considered by many to be predominantly freshwater species. It is found in most streams and rivers in the Delmarva area, and is even found in some low salinity areas of the Chesapeake, and probably also the Delaware Bays.

The yellow perch is characterized by an elongate, moderately compressed body, with an arching back. Its head is long and low, with a pointed snout and a terminal mouth. The coloration is quite characteristic, the back being a dark olive color, the sides bright yellow, with a pale, pinkish belly. The back and sides are marked with six to eight dark black crossbars, and occasionally there is a black blotch on the posterior end of the anterior dorsal fin. The paired and anal fins are crimson colored (Henshall, 1919; Hildebrand and Schroeder, 1928; Smith, 1907).

P. flavescens is anadromous--that is, it migrates to freshwater to spawn.

These migrations may be triggered and directed by a number of stimuli. The return to freshwater is probably stimulated by a combination of increasing water temperatures, and a seasonal maturation of gonadal tissue. A study by Muncy (1962), in the Severn River of Maryland, found upstream migrations beginning in late February and early March, when water temperatures were 39-44°F. Collins (1952) demonstrated that once the migration had begun, differences in temperature, oxygen concentration, and turbulence all had an effect on the migratory paths of herring (Alosa). It is probable that these also aid in directing the migrations of P. flavescens.

Usually, the males arrive at the spawning grounds earlier, and in greater numbers than the females. At this time, they are also more vividly colored than the females. Spawning is usually in early spring--March or April--and in areas of less than 2°/oo salinity (Muncy, 1962). Higher salinities are detrimental to larval development. The water temperatures favorable for spawning are consistent between different investigations: 45-55°F (Coots, 1956), 44-50°F (Hildebrand and Schroeder, 1928), 44-54°F (Breder and Rosen, 1966).

The act of spawning occurs at night, in three to four feet of water. A gravid female is followed by several males, two of which keep their snouts against her belly. The others follow in a double row. The whole assemblage is composed of 15-25 fish (Harrington, 1942). The eggs are fertilized as they leave the female. They are released in amber-colored, adhesive strands which become water hardened a few minutes after release. The ribbons are two to six feet long, and one to four inches wide, and contain openings for improved water circulation. They become draped over submerged, or partly submerged twigs or branches in shallow water. The eggs, about 1/12" in diameter, hatch in 25-27 days (Henshall, 1919; Mansueti, 1964).

Newly hatched larvae have a total length of about 6 millimeters (.24 inch). Fin formation begins at 11 millimeters (.44 inch). There is little pigmentation until the larvae reach about 20 millimeters (.8 inch), when the body bands begin appearing. At the end of the first year, yellow perch in the Great Lakes are usually from 2.5-3.5 inches long; at two years, 4.5-6.5 inches; three years, 6-8 inches; four years, 7-9.5 inches; five years, 8-10.5 inches and six years, 10-12 inches (Lagler, 1956). Scale examinations show that some females reach eight inches in length by three years, and all females reach eight inches by four years. Some males, however, take four to five years to reach eight inches (Muncy, 1958). Six to eight years is the normal life span, but some may live to twelve years. The average length is less than one foot, and the average weight less than one pound, although the maximum recorded weight for a yellow perch is 4.5 pounds (Hildebrand and Schroeder, 1928). Sexual maturity for males occurs at 4.5 inches total length, and 6.8 inches for females (Muncy, 1962). These figures are for normal population densities. In cases of overcrowding, stunting of growth is apparent.

As with many other species, the egg and larval stages of the yellow perch are the most susceptible to environmental changes. The fact that spawning occurs in salinities of less than 2°/oo indicates that higher salinities are probably detrimental to early development. The fact that spawning takes place in water from 45-55°F also probably indicates a similar development advantage at lower water temperatures. Auld and Schubel (1974) determined the effects of suspended sedimentation on the developing eggs and larvae of yellow perch. Their results show that hatching success of eggs (60 per cent in nature) is not significantly affected by suspensions of fine-grained sediments up to 100 mg/l. Larval survival, however, was significantly reduced by concentrations in excess of 500 mg/l. This shows that even though eggs may be half buried in silt, and still hatch, the

larvae of the yellow perch are not able to survive well in water containing moderate quantities of suspended sediments.

The food of the yellow perch changes as it develops from larvae to an adult. The young feed primarily on plankton, small crustaceans and small insects. When they reach 40-49 millimeters, insect larvae become the principle food. When they grow to more than 50 millimeters, their diet becomes primarily chironomid larvae (Pycha and Smith, 1955). As they mature, they may add fish to their diet, namely sticklebacks, minnow and other smaller perch (Allen, 1935). Adults are quite predacious, actively feeding on minnows, young fish, crawfish, tadpoles and small frogs (Henshall, 1919). In brackish waters, food includes isopods, amphipods, fish, crabs, shrimp, insect larvae and snails (Hildebrand and Schroeder, 1928).

Hasler and Bardach (1949) have attributed patterns of movement of the yellow perch to its feeding habits. In Lake Mendota, Wisconsin, fishermen had noticed a nightly increase in perch catches in certain spots, Investigations showed that 1 hour and 40 minutes before sunset, at certain sites, perch appeared in spindle shaped schools of 50-200 fish of almost uniform size. The direction of movement was shoreward, near the lake bottom. These patterns of movement are probably due, in part, to the feeding behavior.

In some areas, the prolific and hardy nature of perch has caused it to be considered a pest, for it can, when introduced artificially in numbers, out compete other more desirable fishes as trout, striped bass and white perch.

Man is an important predator of the yellow perch. Fishermen use worms, salmon eggs, small crayfish, grasshoppers and flies as bait. Animals which feed on the yellow perch are birds (mergansers, steelheads) and fish (gars and pikes).

FIGURE 101
YELLOW PERCH

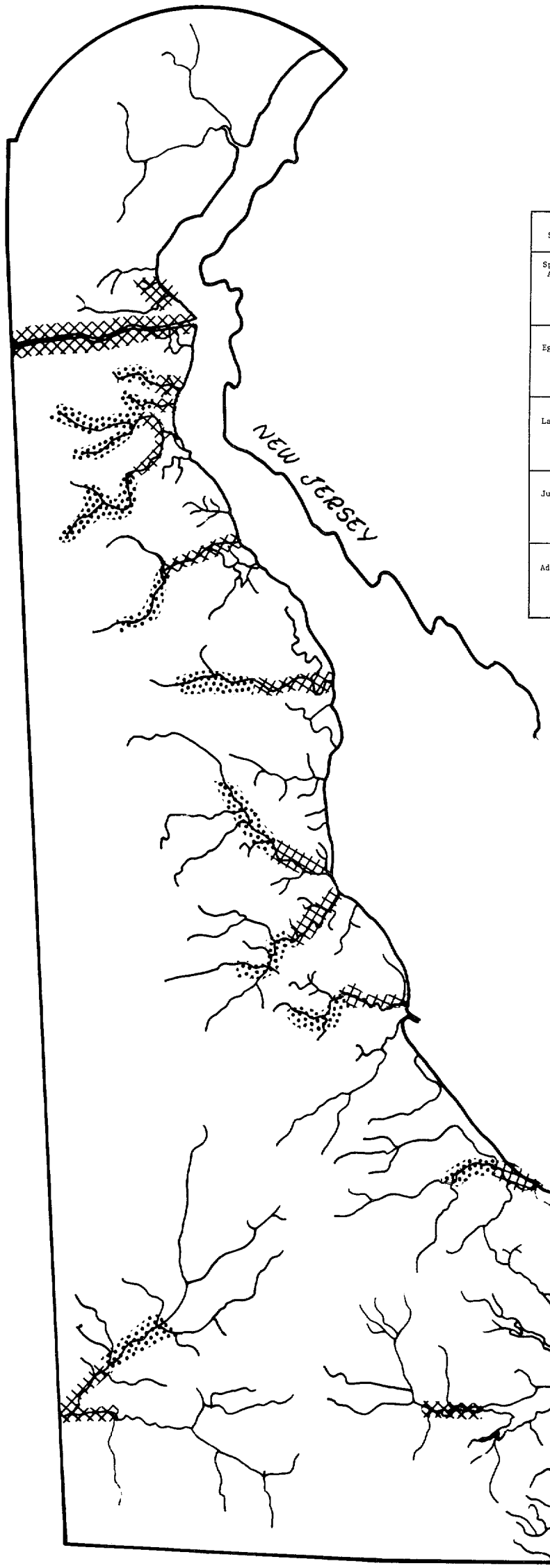
SPECIES Perca flavescens

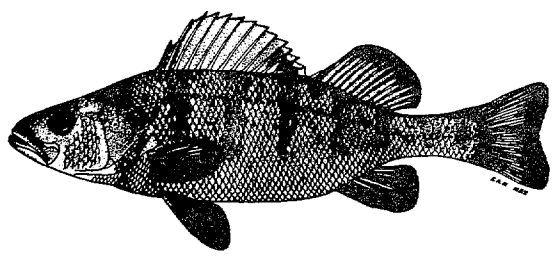
Common Name Yellow perch

Spawning Period Spring

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	6-12°C (68) 44-54°F (7) 44-50°F (35)	Fresh water to slightly brackish < 2‰ (58)			
Eggs		Fresh to slightly brackish (58)		Can take up to 1000 mg/l or more with no effect (2)	
Larvae		Fresh to slightly brackish (58)		500 and 1000 mg/l affected survival $p \leq .005$, adversely. (2)	
Juvenile	Prefer 20.0-23.0°C (54)	Up to 12‰			
Adult	Prefer 17.6-22.1°C (54)	Up to 12‰	Lethal level - 1 ppm (22°C) (61)		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.) Anadromous





LEGEND

SPAWNING AREA

NURSERY AREA AND ADULT DISTRIBUTION.

Evidence so far seems to indicate that the yellow perch is a hardy, adaptable fish, somewhat euryhaline and preferring cold water. Its most vulnerable part of the life cycle is the larval stage, where certain environmental requirements of temperature, salinity and suspended sediment must be met. The fact that it has good eating qualities--sweet meat, and few bones--make it a desirable little fish.

References

Allen, K. R. 1935. Food and migration of perch in Windermere. J. Anim. Ecol. 4(2): 264-273.

Auld, A. H. and J. R. Schubel. 1974. Effects of suspended sediment on fish eggs and larvae. Ches. Bay Inst., Johns Hopkins Univ. Spec. Rept. 40.

Breder, C. M. and D. E. Rosen. 1966. Modes of reproduction in fishes.

Collins, G. B. 1952. Factors influencing the orientation of migrating anadromous fishes. Fish. Bull., Fish and Wildl. Serv. 73(52): 375-396.

Coots, M. 1956. The yellow perch, Perca flavescens, in the Kalmuth River. Ca. Fish and Game 42(3): 219-228.

Curtis, B. 1949. The warm water game fishes of California. Ca. Fish and Game 35(4): 255-273.

Harrington, R. W., Jr. 1947. Observations on the breeding habits of the yellow perch, Perca flavescens. Copeia (3): 199-200.

Hasler, A. D. and J. E. Bardach. 1949. Daily migrations of perch in Lake Mendota, Wisconsin. J. Wildl. Mgmt. 13(1): 40-51.

Henshall, J. A. 1919. Bass, pike, perch and other game fishes of America. Stewart Kidd Co., Cinn., Ohio.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. Smithsonian Inst. Press, Washington, D. C.

Hubbs, C. L. and K. F. Lagler. 1958. Fishes of the Great Lakes region. Univ. Mich. Press, Ann Arbor, Mich.

Lagler, K. 1956. Freshwater fishery biology. Dubuque, Wm. C. Brown Co. 360 pp.

Mansueti, A. J. 1964. Early development of the yellow perch, Perca flavescens. Ches. Sci. 5(1-2): 46-66.

Muncy, R. J. 1958. Growth of yellow perch in tidal waters. Md. Tidewater News 14(3): 11-12.

Muncy, R. J. 1962. Life history of the yellow perch, Perca flavescens, in estuarine waters of the Severn River, a tributary of Chesapeake Bay, Maryland. Ches. Sci. 3(3): 143-159.

Pycha, R. L. and L. L. Smith, Jr. 1955. Early life history of the yellow perch, Perca flavescens, in the Red Lakes, Michigan. Trans. Amer. Fish. Soc. 84: 249-260.

Smith, H. H. 1907. The fishes of North Carolina. N. Car. Geol. and Econ. Survey.

BLUEFISH

Pomatomus saltatrix

The bluefish, Pomatomus saltatrix, has gained a reputation, not unfounded, as one of the most ravenous and blood-thirsty of the predatory fish species. Traveling in schools sometimes numbering in the thousands, the bluefish will attack and devour a wide variety of fish species. Some of the most exciting sport fishing, for estuarine anglers, can be found where blues run into harbors and estuaries along the east coast. Because of the sport they provide and because of their fine-tasting flesh, bluefish have always been an important recreational fish in the Delaware area.

The bluefish is a moderately stout-bodied fish with a body about one-fourth as deep as it is long. It has a moderately pointed nose, a lower jaw which projects in front of the upper jaw and very large canine teeth. There are two dorsal fins present, the first consisting of eight to ten spines, the second consisting of twenty-three to twenty-six soft rays. The anal fin is similar to the second dorsal. The ventral fins are placed directly under the pectoral fins, both sets of which are of moderate size. Characteristically, bluefish are sea-green or greenish-blue in color above and silvery below with most of the fins being of the general body color. Maximum length for blues runs about 3½ feet although larger blues are said to have roamed the Atlantic waters in the 18th century.

Bluefish are oceanic in nature but are seasonal inhabitants of Delaware waters, being found here in the spring, summer and fall. Large schools appear off the Delaware coast in April or May but do not come in close to shore until later in the spring and summer. The adults usually are preceeded by the fry and snapper blues as the smaller fish are known, both of which apparently run well up into the Bay. Some of the best bluefishing occurs in the early fall.

As the water temperature begins to drop, the population moves offshore and most individuals are gone by November.

The destination of the fish as they move offshore is unknown. Some scientists propose that along the entire Atlantic coast, there might be as many as five distinct populations of bluefish which are distinguishable only by some very specific body characteristics. As the water along the coast grows colder, each one of these populations is thought to move offshore into deeper warmer water to spend the winter. Other scientists believe that there might only be two large populations of bluefish on the Atlantic coast, one of which winters south of Florida and then moves northward to North Carolina in the summer and one that spends its winters around Florida and migrates to New England in the summer. More study will have to be done to determine which if either of these concepts is correct.

Much speculation also surrounds the spawning habits of these fish. The age at which bluefish reach maturity and the place and time of spawning are not known. Actual cases of spawning fish have never been reported although males with sperm and females with roe are occasionally found in Delaware waters during late spring and summer. It is possible that they move offshore to spawn. Yet, because large numbers of fry are present along the coast, it has been proposed that their spawning grounds are not far removed from shore.

Spawning bluefish produce buoyant eggs. The eggs hatch about forty-five hours after spawning with the larvae in a very primitive stage of development. The small larvae feed from an attached yolk sac for approximately five days until functional jaws, gills and digestive system have developed. In no time, they are preying upon everything smaller than themselves with the ferocity of an adult. Apparently, they grow as large as four to nine inches by their first fall and achieve twelve inches by the following spring.

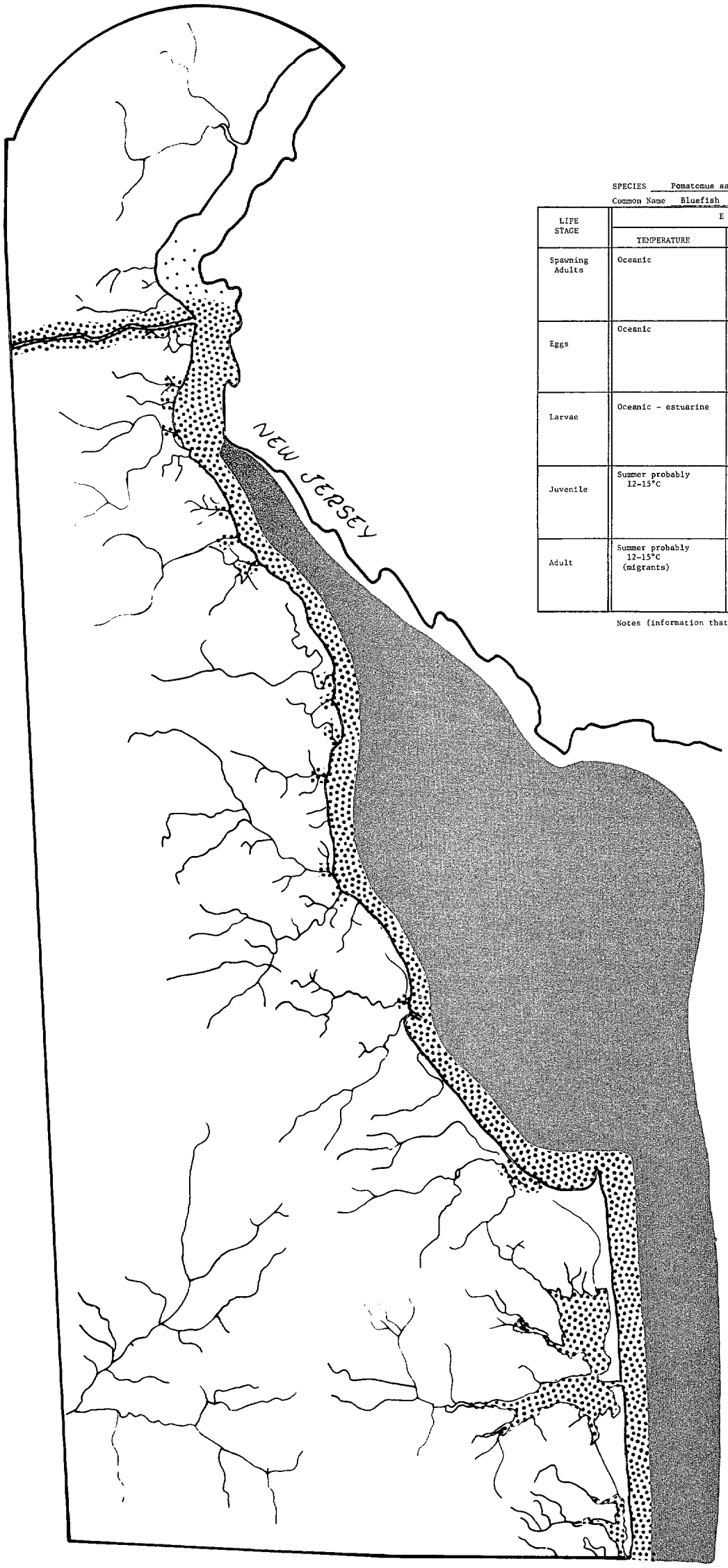


FIGURE 102
BLUEFISH

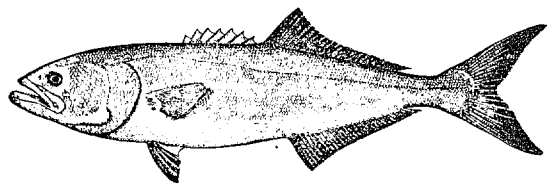
SPECIES Pomatomus saltatrix

Common Name Bluefish

Spawning Period Spring to summer; coastal waters

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Oceanic	Oceanic	Oceanic		
Eggs	Oceanic	Oceanic	Oceanic		
Larvae	Oceanic - estuarine	Oceanic - estuarine	Oceanic - estuarine		
Juvenile	Summer probably 12-15°C	0-37‰	Highly susceptible to low dissolved oxygen (73)	Highly sensitive to suspended sediments (66)	
Adult	Summer probably 12-15°C (migrants)	10‰ and up	Highly susceptible to low dissolved oxygen		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)



LEGEND

SNAPPER BLUES

GENERAL ADULT DISTRIBUTION

As noted, there is little that the bluefish does not include in its diet. They do prefer, however, such fish as the menhaden, herring, alewives and mackerel. Blues will also feed upon squid, scup, hake, butterfish and cunners as well as on some crustaceans and worms as adults, and on copepods and mollusks, crustacean larvae and any fry smaller than themselves, as juveniles. The movements and cycles of these prey species might influence to a large extent the cycles exhibited by the bluefish themselves. The movements of the blues south in the winter might be as much in response to the movements of the prey species south as it is a response to the decreasing water temperature.

Like many other species of fish, bluefish often exhibit fluctuating populations over the years. Certain year classes are extremely successful due presumably to mating success and favorable environmental conditions. Sometimes population fluctuations coincide with fluctuations in the populations of the prey species, but an obvious correlation is not always apparent. Although not a commercially important fish in Delaware, it is harvested in great numbers in New Jersey and New York. However, the sport fishermen value the bluefish most highly. They catch ten times as many bluefish along the East coast as the commercial fishermen.

References

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish and Wildl. Serv., U. S. Govt. Printing Ofc.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. Fish and Wildl. Serv., U. S. Govt. Printing Ofc.

Lineoweaver, T. H., III. 1965. The bluefish. Sea Frontiers 11: 14-22.

SPOT

Leiostomus xanthurus (Lacepede)

The spot, Leiostomus xanthurus, is a moderately sized fish of up to 34 centimeters (13 inches) and 2.8 kilograms that is found in Delaware Bay below the Chesapeake and Delaware Canal, in most rivers flowing into the Bay, and in Indian River-Rehoboth Bay area. The spot is distinguished by a black spot just behind the upper corner of each gill cover and 12-15 oblique yellowish bars on the sides. Its color is bluish gray with golden reflections on the back and silvery underneath. The fins are mostly pale yellow; dorsal and caudal fins are more or less dusky. The dorsal fin is subdivided into a spiny forward section and a longer but half as high soft-rayed section. The caudal fin is concave; anal fin has two stiff spines.

The mouth of the spot is located low on the head in good position for bottom feeding. The spot has been observed to be a bottom feeder, slowly swimming down and scopping up a mouthful of bottom material. This is sorted over in the mouth as the spot continues swimming. This feeding behavior differs from that of the croaker that dives into the bottom and pulls out large mouthfuls of material. No difference was found in the diet of spot due to season, locality or size of fish--large fish simply had more in their stomach. Found in the stomachs of spot were: nemoatodes, annelids, crustaceans, plecypods, small fish and plants.

Spot are evident in Delaware and Maryland during the spring, summer and fall. They have been caught in salinities from 0-60‰ and water temperatures of 6-36°C; low lethal temperature is reported to be near 5°C. In the fall spot move south and offshore. A large winter population is found off the

South Carolina coast. A spot tagged in Delaware Bay in October and caught off North Carolina in December shows the extent of migration possible.

Spawning of spot takes place over an extended period, October to March, with most spawning in December and January. Spawning occurs in moderately deep water off the Carolinas with mature females producing up to 90,000 eggs. In the spring the larvae and spent adults reappear in the bays. Growth during their first summer is rapid. Data from South Carolina shows spot of 14-16 centimeters (5-6 inches) in length by the end of their first year. Some young of the year do not migrate south in the fall, but instead over-winter in deep portions of local bays.

The spot is another commercially valuable fish that is commonly found in Delaware's estuaries and bays. Despite its common occurrence, no spot are now commercially caught in Delaware. In fact, less than 500 pounds were landed in the Middle Atlantic region during 1970. During the 1950's the spot ranked in the top one-third of U. S. fin-fisheries in both value and weight caught. The center of the spot fishery is in the neighboring Chesapeake Bay region which in 1922 recorded the largest seine haul at 90,000 spot weighing 50,000 pounds. Commercial fishing for spot begins in July but is best in the early fall when the fish begin their southern migration. Spot are a good-tasting marketable fish that could be fished in Delaware waters if their numbers increased.

FIGURE 103
SPOT

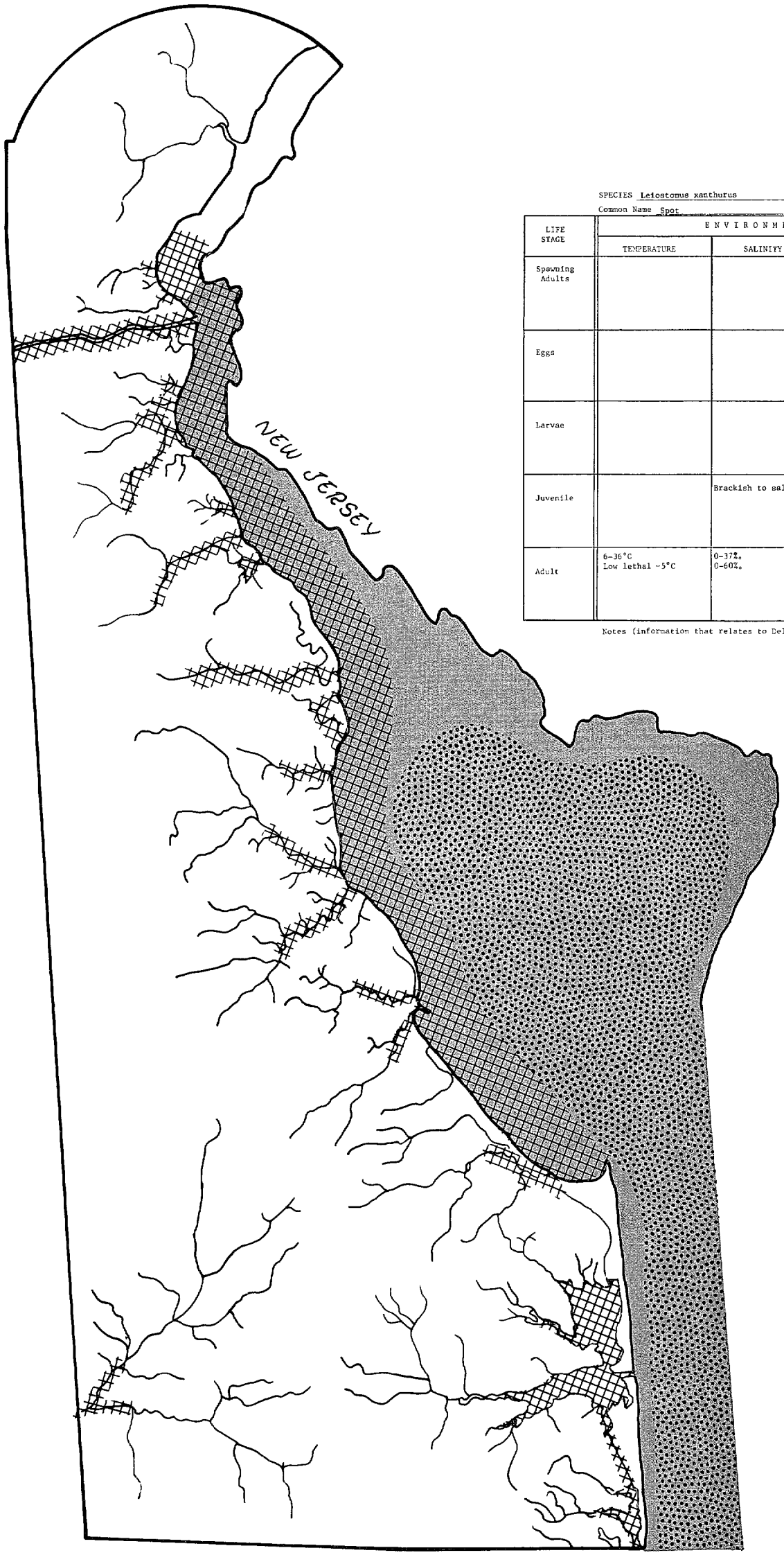
SPECIES Leiostomus xanthurus

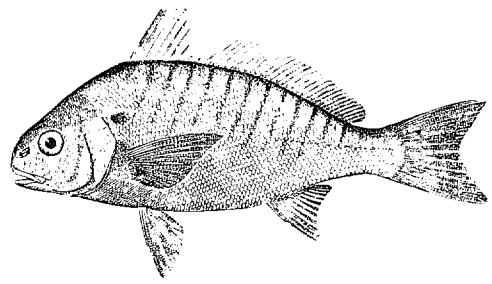
Common Name Spot

Spawning Period December through March

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults					
Eggs					
Larvae					
Juvenile		Brackish to saline	Moderate tolerance to low dissolved oxygen (73)		
Adult	6-36°C Low lethal ~5°C	0-37‰ 0-60‰	Moderate tolerance to low dissolved oxygen (73)	Relatively tolerant of concentrations of suspended sediment. (66)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

PROBABLE SPAWNING AREAS

NURSERY AREAS

GENERAL ADULT DISTRIBUTION

References

Dawson, C. E. 1958. The study of the biology and life history of the spot, Leiostomus xanthurus (Lacepede) with special reference to South Carolina. Bear's Bluff Lab. Contrib. 28. 48 pp.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. T. F. 11. Publications, Neptune, N. J. 588 pp.

Pacheco, A. L. 1962. Age and growth of spot in lower Chesapeake Bay, with notes on distribution and abundance of juveniles in the York River system. Ches. Sci. 3: 18-28.

ATLANTIC CROAKER

Micropogon undulatus (Linnaeus)

The Atlantic croaker, Micropogon undulatus, is one of the most abundant members of the drum family, Sciaenidae. It is also known as simply "croaker", "hardhead" or "King Billy". The Atlantic croaker gets its name from its ability to produce a croaking or drumming sound. The sound is apparently caused by the rapid contraction of a pair of special "drumming" muscles along either side of the air bladder which acts as a resonator. Both sexes of the Atlantic croaker are able to produce the 300-600 Hz. sound. The exact purpose of the croaking is unknown but it has been closely associated with both feeding and spawning behavior.

M. undulatus is readily recognized by its inferior mouth (located low on the head, in good position for bottom feeding) and the series of short barbels on each side of the chin. The adult is green or grayish silver on its back and silvery-white on its belly. It is highly irridescent when in the water. The dorsal fin appears to have two sections--one spiny and one soft-rayed, but it is actually a single, continuous fin. The third and fourth spines of the spiny section are the highest of the entire dorsal fin. The pelvic fins occupy a thoracic position, inserted under and slightly behind the rather long pectorals. The croaker has an anal fin with two strong spines; the lateral line extends along a stout caudal peduncle and onto the slightly concave or rounded caudal fin. External appearance is essentially identical for both sexes. The largest recorded croaker was 67 centimeters (26 inches) and 3.6 kilograms while the average size is 27-30 centimeters (10 to 12 inches) and 200-300 grams.

The Atlantic croaker is found from Texas to Massachusetts. However, it is most numerous from Virginia to New Jersey. M. undulatus or a related species, M. opercularis, has been reported as far south as Uraguay. The croaker is found in water that ranges from fresh to hypersaline (60‰). Observed distributions of the croaker indicate that the fish usually enters freshwater only as a juvenile.

Although food preference is somewhat influenced by the availability of food items, studies indicate that the croaker is a carnivorous bottom feeder, and show that the preferred prey are annelid worms. The feeding behavior of the croaker helps explain the predominance of annelid worms in its diet. The fish swim just above the bottom, searching for food. Periodically, it dives to the bottom and grabs a mouthful of bottom material and hopefully, some food. The mouthful is sorted out, the sand being spat out and the prey swallowed. This feeding behavior results in a diet consisting of prey typically found burrowing in the bottom rather than the copepods and decapods normally found on the bottom surface.

Several studies indicate that the croaker reaches sexual maturity at the end of its second year. However, a recent study along the Gulf Coast indicates that sexual maturity is reached after just one year. In the mid-Atlantic region spawning takes place offshore from August through December. The collection of fish in March ranging from 3.2 to 6.4 centimeters (1.2 to 2.5 inches) supports the idea of a protracted spawning season. Croaker fry have been collected in the Chesapeake during the fall as they move into the Bay toward fresher water with the aid of a subsurface up-bay current where they grow until the following year. Yearling croakers move out of the estuaries and into offshore waters in the late summer and early fall. Adult croakers move into Chesapeake Bay

FIGURE 104
CROAKER OR HARDHEAD

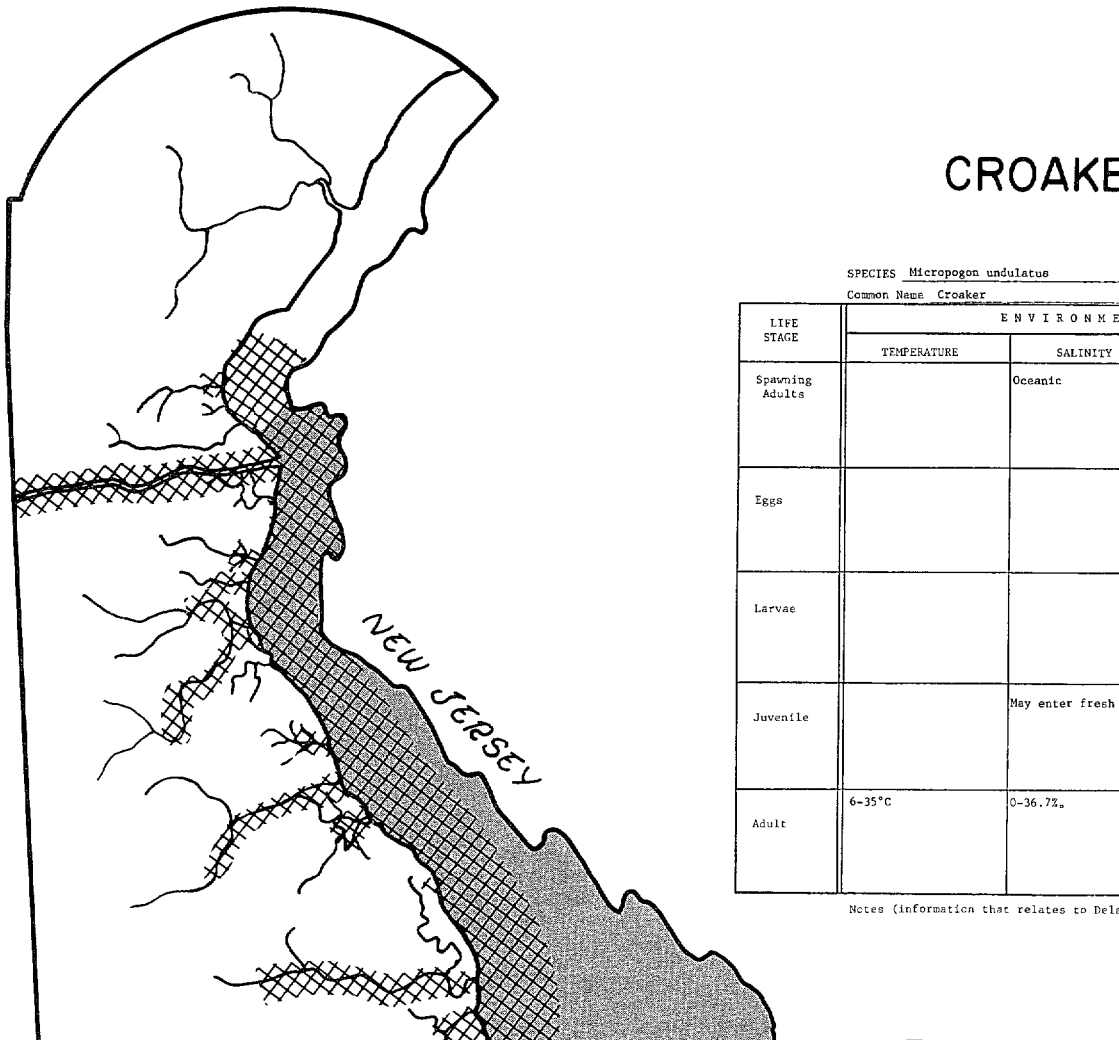
SPECIES Micropogon undulatus

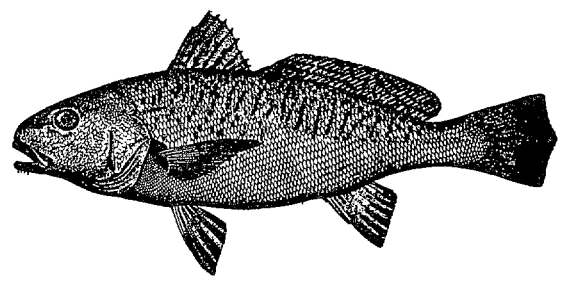
Common Name Croaker

Spawning Period August to December

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults		Oceanic			
Eggs					
Larvae					
Juvenile		May enter fresh water			
Adult	6-35°C	0-36.7‰		Sensitive to suspended sediments (66)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

PROBABLE SPAWNING AREAS

NURSERY AREAS

GENERAL ADULT DISTRIBUTION

in the spring and return to the sea in the fall to spawn.

Although the actual courtship and spawning behavior has not been described, it is believed to be rather non-elaborate. Fertilization of the eggs by the sperm is external. Increased levels of croaking by both sexes of the croaker are also characteristic of the spawning act.

Data on growth rates for the Atlantic croaker is practically non-existent because of the long spawning period of the species. Further complicating the situation is the observed distribution of larger croakers in more saline water which some investigators have interpreted to mean that croakers grow faster in higher salinity water. Observations in a Gulf of Mexico estuary indicate that the growth rate is greater in warmer waters. One group of female croakers ranged in length from 10.1 and 14.5 centimeters (4 and 6 inches) at the end of their first year.

The croaker has been a commericially valuable food fish on the east coast throughout the 1900's. In the late 1920's the marketable fish ranged from 1/2 to 1 1/2 pounds and from five to twenty cents per pound. Because of its abundance it was generally recognized as being inferior to the weakfish and the spot.

Since 1920 the croaker fishery has been characterized by wide fluctuations in abundance. Since 1945 the Virginia landings have declined from about 55 million pounds to only 3.5 million pounds in 1965. However, increasing numbers of small croakers have been taken in recent years. Croakers are primarily captured by pound nets and haul seines in the Chesapeake Bay and by trawls in the ocean.

While croaker landings have declined, the striped bass landings have significantly increased. It has been suggested that the trend toward lower

water temperatures have forced the two fish species into closer proximity, thus accentuating the predation of young croakers by the stripped bass. It has also been suggested that the decline in croaker landings is reflective of a natural long-term cycle. A more thorough understanding of croaker population dynamics is needed for a more complete answer to the problem of the fluctuating croaker landings.

References

Dobroski, Charles J., Jr. 1975. A report on the life history of the Atlantic croaker, Micropogon undulatus. Dept. of Biol. (B-630), University of Delaware.

Dovel, W. L. 1968. Predation by striped bass as a possible influence on population size of the Atlantic croaker. Trans. Am. Fish. Soc. 97: 313-319.

Fish, Marie P. and W. H. Mowbray. 1970. Sounds of the Western North Atlantic Fishes. Johns Hopkins Press. p. 106.

Hansen, D. J. 1970. Food, growth, migration and abundance of Pinfish, Lagodon rhomboides, and Atlantic croaker, Micropogon undulatus near Pensacola, Florida. 1963-1965. Fish. Bull. Fish Wildl. Serv. U. S. 68: 135-146.

Haven, D. S. 1959. Migration of the croaker, Micropogon undulatus. Copeia 1959: 25-30.

Massmann, W. H. and A. L. Pacheco. 1960. Disappearance of young Atlantic croakers from the York River, Virginia. Trans. Amer. Fish. Soc. 89: 154-159.

Roelogs, E. W. 1954. Food studies of young sciaenid fishes, Micropogon and Leiostomus, from North Carolina. Copeia 1954: 151-153.

WEAKFISH

Cynoscion regalis

One of the most important commercial and sport fishes found in Delaware waters has always been the weakfish or sea trout, Cynoscion regalis. The size of the weakfish population in the Bay has fluctuated widely over the years; however, particularly large numbers have been caught during the summers of 1970 through 1975. Like many other fish in this region, weakfish are only seasonal residents of the Delaware area, being found here from April or May until October. During the summer months they provide quite a bit of excitement for the sport fishermen and a large part of the income of Delaware's commercial fishing industry.

Weakfish are members of the family Sciaenidae, commonly called the Drum or Croaker family, as a result of the sounds these fish often make. The males of many of the Sciaenids, including the spot, sand perch, spotted trout, croaker and black drum, possess special muscles which lie along the air bladder. Contraction of these muscles creates vibrations which resonate through the bladder producing a quite distinct and often very loud drumming noise.

Weakfish are one of the more colorful species in the area since the olive green color of the upper body is usually mixed with purple, blue, gold, green or copper tints and marked with spots of black or bronze. The lower body is silvery white and the fins somewhat yellowish for part or all of their length. The body of the weakfish is about four times as long as it is wide with the head usually about one-third the length. There is a projecting lower jaw and two distinct canine teeth in the upper jaw. Two dorsal fins are present. The first dorsal is triangular and slightly higher than the second dorsal, which is rectangular and more than twice as long as the first dorsal. Pectoral and

ventral fins are very similar in size and appearance with the pectorals inserted almost directly above the ventrals. A relatively small anal fin and a broad caudal fin completes the body.

The weakfish is predominantly a schooling fish with the schools often being quite large. There is some evidence that for at least part of the summer the sexes run in separate schools, intermingling for breeding and for extended migrations only. The schools seem to prefer relatively shallow water and some move well up into the bays and the tidal creeks of Delaware. Depending on food availability and weather conditions, weakfish can be found either along the bottom or at the surface.

While the adults are found throughout the Bay and tidal creeks, apparently only certain portions of the Bay are used for spawning. Most of the spawning activity is concentrated in the southwest portion of the Bay in an area south of the Mispillion River and west of the Ship Channel. However, spawning does occur in other portions of the Bay as eggs and larvae have been found as far north as the Smyrna River.

Spawning takes place throughout the spring and summer months, but there are two peak spawning periods in the Delaware Bay. The first occurs during the latter part of June and the second during the latter part of July. The salinity and temperature ranges over which spawning, egg hatching and development take place are really quite variable as eggs and larvae have been found in waters of 12-31‰ salinity and 17-27°C. Much of the spawning though appears to take place when water temperatures approximate 19°C.

It has been estimated that approximately 450 billion eggs are produced during the average spawning periods of the Delaware Bay weakfish. Of these some 1.5 million survive to the fry stage, quite a reduction but still a

FIGURE 105
WEAKFISH
(SEA TROUT)

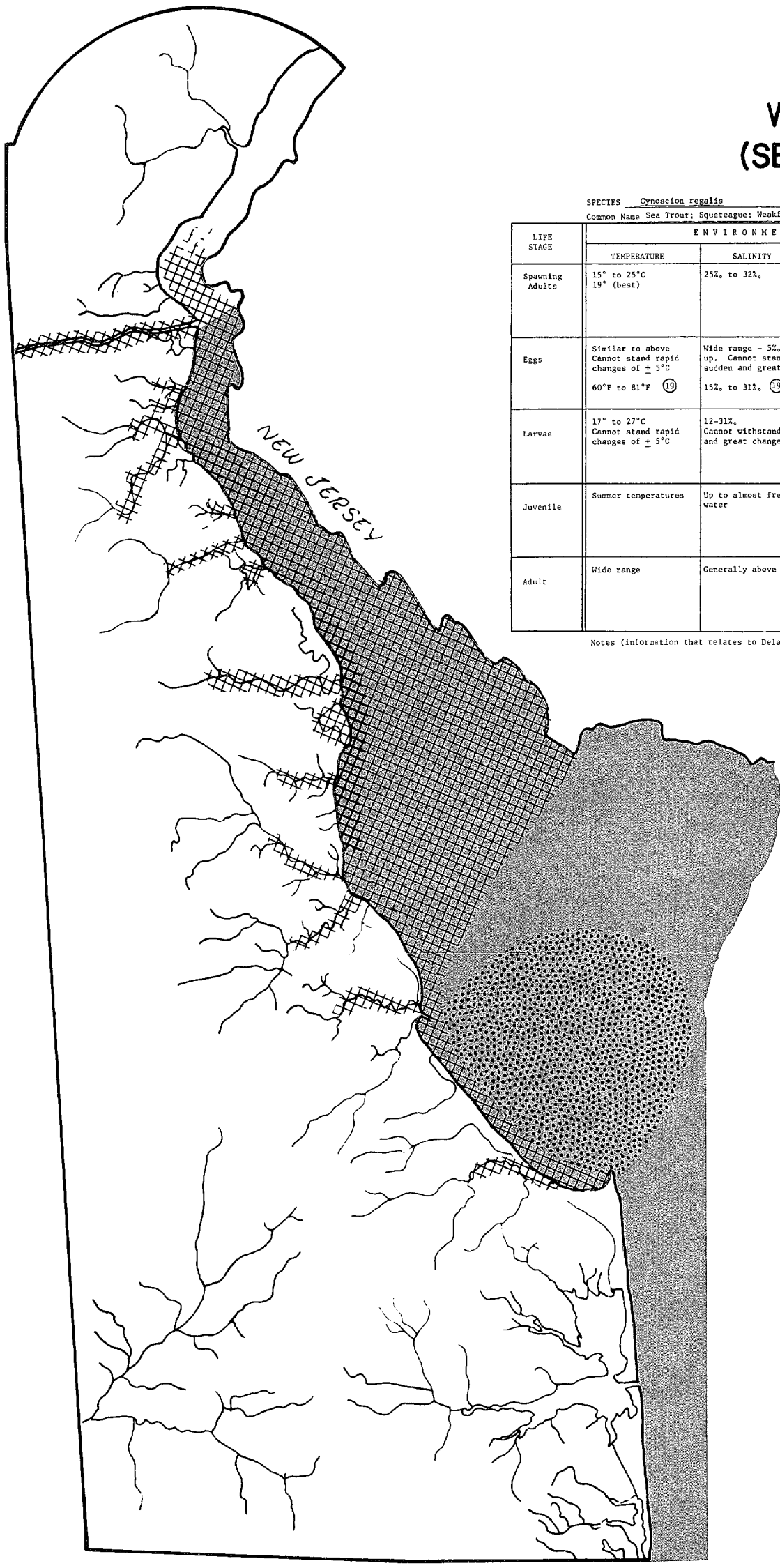
SPECIES Cynoscion regalis

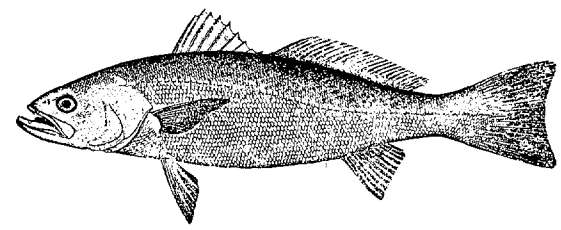
Common Name Sea Trout: Squeteague: Weakfish

Spawning Period Late May to early August

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	15° to 25°C 19° (best)	25‰ to 32‰	~5 ml/l		
Eggs	Similar to above Cannot stand rapid changes of ± 5°C 60°F to 81°F (19)	Wide range - 5‰ and up. Cannot stand sudden and great changes 15‰ to 31‰ (19)	>5 ml/l		
Larvae	17° to 27°C Cannot stand rapid changes of ± 5°C	12-31‰ Cannot withstand sudden and great changes	Moderately high concentrations needed		
Juvenile	Summer temperatures	Up to almost fresh water	Moderately high concentrations needed		
Adult	Wide range	Generally above 10‰	Moderate tolerance to low dissolved oxygen	Sensitive to suspended sediments (66)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

SPAWNING AREAS

NURSERY AREAS

GENERAL ADULT DISTRIBUTION

considerable number. The eggs produced are small, buoyant, transparent and have several oil globules associated with the yolk sac. They are fairly delicate, so that great amounts of water turbulence often cause serious damage to the eggs. Some turbulence though is necessary to keep the water well oxygenated as oxygen levels below 5 ppm (3.6 ml/l reduce successful hatching greatly and levels below 2.5 ppm (1.8 ml/l) prevent hatching altogether. The eggs and larvae also cannot withstand sudden changes in either salinity or temperature, especially the later as a 5°C change in either direction can prove fatal.

Hatching under Bay conditions usually takes two to three days, and the larvae produced are small and spend their early hours upside down due to the position of the yolk sac. As the yolk is used up, the larvae right themselves and move to the bottom where they complete their larval development.

Growth rates of young fry are very variable so that by the first fall they can be anywhere from 10 to 15 centimeters (4 to 6 inches) long, and by the next spring up to 20 or 25 centimeters (8 or 10 inches) in length. After this initial period, the growth rate is much slower, for a two year-old fish will be only about 30 centimeters (12 inches) long; a four year-old fish about 38 centimeters (15 inches); a six year-old fish 46-56 centimeters (18-22 inches), and a 12 year-old fish about 76 centimeters (30 inches) long and weigh 4.5-5.4 kilograms. Most of the weakfish caught in Delaware Bay are in the 1-5 pound class (.4 to 2.3 kilograms).

Weakfish are mainly fish eaters, although they do prey upon a large assortment of other organisms, and some of these fish such as the menhaden have themselves undergone very drastic population changes in recent years. The decline in menhaden through the 1950's and early 1960's also saw a commensurate decline in the weakfish population. Recently menhaden have increased

and the weakfish fishing has been good. Besides the menhaden, which is the favorite weakfish prey, butterfish, herring, scup, anchovies, silversides and mummichogs are also consumed by adults as well as crabs, amphipods, shrimp, worms and some mollusks. Younger individuals feed mainly on shrimps and other crustaceans but will consume anchovies, young menhaden and other fry smaller than themselves. While preying upon fish, the weakfish schools will usually be nearer the surface, and while preying upon these other organisms, they will be foraging near the bottom. Fishermen are wise then to try fishing at both levels when attempting to locate a school and adjust their rigs and tactics accordingly.

As the catch of weakfish has been generally declining along the Atlantic Coast since 1945, it is becoming increasingly critical to strive for a better understanding of the biology of the weakfish, its spawning behavior, migratory habits and environmental requirements. The relationship between menhaden and weakfish is not completely understood for instance. Only in this way can continued success be assured for both commercial and sport fishermen as they pursue the "Queen of the Delaware Bay", the weakfish.

References

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Mexico. T.F.H. Publ., Inc., Neptune, N.J. 388 pp.

Breder, C. M., Jr. 1948. Field book of marine fishes of the Atlantic coast. G. P. Putnams Sons, N.Y.

Harmic, J. L. 1958. Some aspects of the development of the ecology of the pelagic phase of the grey squeteague, Cynoscion regalis (Bloch and Schneider) in the Delaware estuary. Ph.D. dissertation. University of Delaware. 164 pp.

Seymour, H. 1975. Weakfish--Catch a queen for dinner. Marine Advisory Bulletin #3, CMS. University of Delaware.

THE NORTHERN PUFFER

Sphoeroides maculatus

The northern puffer, Sphoeroides maculatus (Bloch and Schneider), is a member of the class Pisces, family Tetraodontidae (the puffers). This peculiar little fish gets its name from its ability to inflate itself with air or water to an almost spherical shape when disturbed. When not inflated, it is about three times as long as it is deep. It has a conical snout, with a small, terminal mouth. The puffer has no true teeth, but rather the jaw-bones protrude to form cutting edges which serve as teeth. The gill openings are small and oblique. It has small high-set eyes. Scales in the usual sense are absent, being modified into small stiff prickels almost completely covering the skin. The lateral line is feeble, and ventral fins are absent. The dorsal fin is short and soft (adipose) and set far back towards the caudal peduncle. The anal fin is similar to the dorsal fin in size and shape and is transluscent, as are the other fins (Bigelow and Schroeder, 1953; Hildebrand and Schroeder, 1928). Puffers rarely exceed 10 inches although specimens of up to 14 inches have been reported (Hildebrand and Schroeder, 1928).

The coloration is dark olive green above, sometimes ashy or dusky. Laterally, it is greenish yellow to orange, with six to eight dark crossbars. The belly is white (Bigelow and Schroeder, 1953).

While little life history information is available, the northern puffer is known to be extensively distributed from Florida to Cape Cod and occasionally into the Bay of Fundy. It is considered an inshore fish, seldom found in water over a few fathoms deep or more than a mile from land. Sometimes it enters brackish waters. The winter habitat of the puffer is

unknown, but it is believed that they move to deeper water and decrease their activity during the colder months.

S. maculatus is a prolific species, spawning in late spring and early summer usually in shoal water and close to shore. The ovaries of one 10½ inch female held an estimated 176,000 ova (Hildebrand and Schroeder, 1928). In a study at Atlantic City, New Jersey, Welsh and Breder (1922) found ripe females all during the survey, which lasted from July 30 to August 27. Males and females were found in equal numbers.

Eggs of the northern puffer are transparent, demersal, adhesive, and about 0.9 millimeter in diameter. At 67°F, an incubation period of about 112 hours is required (Welsh and Breder, 1922). Newly hatched larvae average about 2.41 millimeters in length and are brilliantly colored. Their hardiness makes them good for embryological studies. Adult puffers exhibit no apparent parental care over their young (Breder and Rosen, 1966). Two days after the eggs hatch, the mouth and vent of the larvae becomes functional. When they reach 7 millimeters, they strongly resemble the appearance of the adult fish. The females generally grow larger and weigh more per unit of length than the males. Mature specimens over 22 centimeters (9 inches) long are almost always females, and those under 17 centimeters (7 inches) are almost always males (Welsh and Breder, 1922).

The breeding habits of S. maculatus vary little with sex or size. Food consists of crabs, shrimp, isopods, amphipods, mollusks, worms, barnacles, and sea urchins (Bigelow and Schroeder, 1953). Crabs seem to be the most popular food item, but the species consumed are of little commercial importance.

The distribution of the northern puffer in the Delaware area is determined largely by temperature and salinity (Abbe, 1967). They are seldom found in waters below 18°C or less than 20‰ salinity. Almost all specimens

FIGURE 106
NOTHERN PUFFER

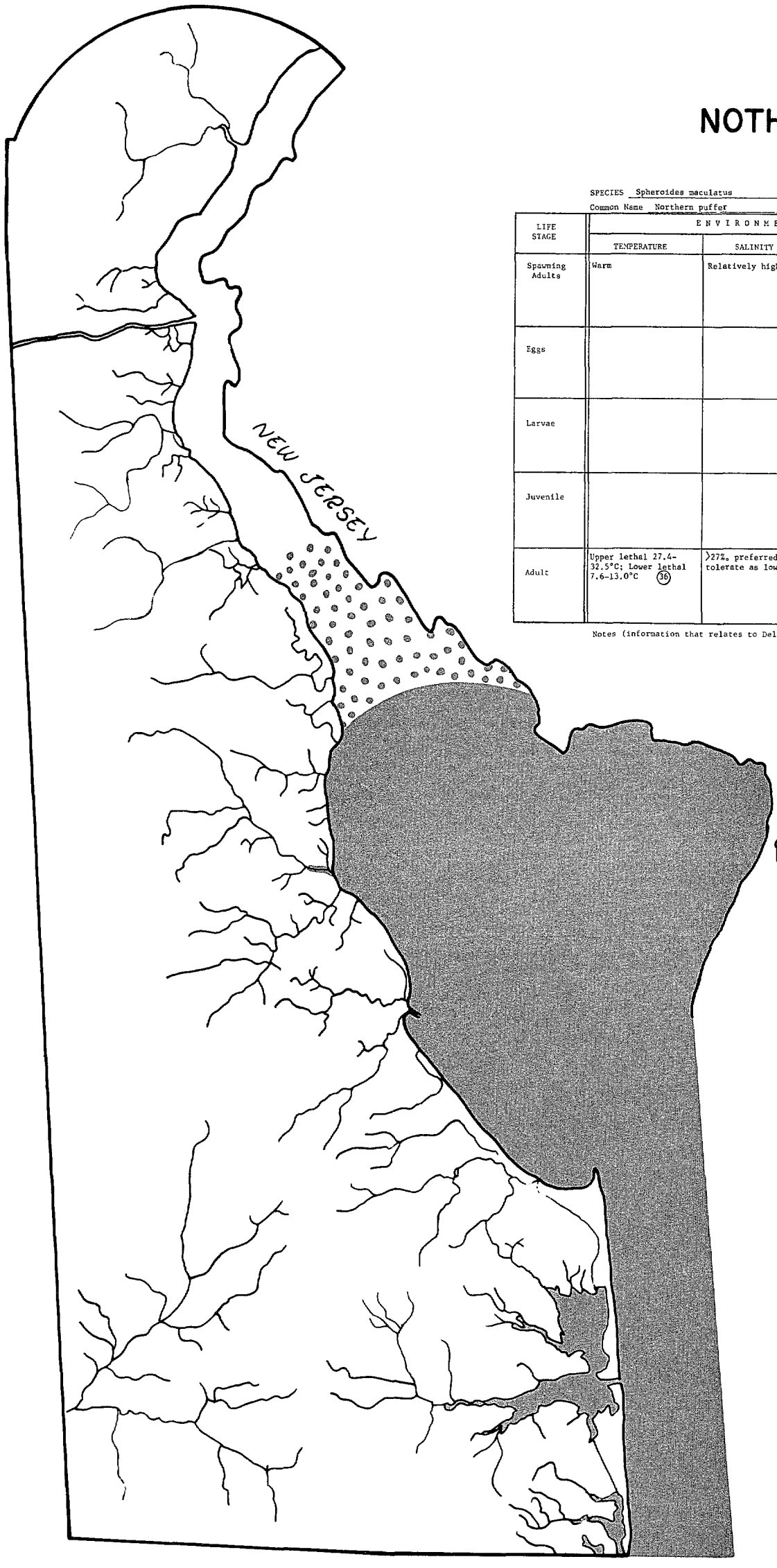
SPECIES Spheroides maculatus

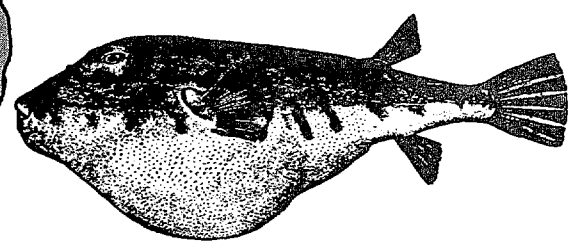
Common Name Northern puffer

Spawning Period Spring-Summer

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Warm	Relatively high			
Eggs					
Larvae					
Juvenile					
Adult	Upper lethal 27.4-32.5°C; Lower lethal 7.6-13.0°C (36)	>27‰ preferred: can tolerate as low as 9‰	Moderately tolerant to low dissolved oxygen		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

GENERAL ADULT DISTRIBUTION

taken in waters of less than 23‰ were juveniles. Northern puffers are quite common in Delaware Bay. In four trawl studies in the Bay, S. maculatus has ranked between seventh and tenth in terms of frequency of catch (Abbe, 1967; Daiber and Wockley, 1969; Daiber and Smith, 1970; Daiber and Smith, 1971).

Because of the occurrence of poisoning by the family Tetraodontidae in other areas of the world, several studies have been initiated with the northern puffer to determine if it might pose any threat to potential consumers in this country. The results are inconclusive. It appears that different organs may become toxic at different stages in the life history of the puffer. The ovaries are the most deadly and their toxicity increases with their state of development, however, the liver is also periodically toxic (Robinson and Schwartz, 1968). The toxin released by the ovaries and occasionally the liver is a cardio-inhibitor which causes cessation of the heartbeat. The toxin appears to be nontransferable. When the toxic ovaries were pressed against the small edible portion of puffer flesh for 48 hours, there was no appreciable transfer of toxin. It has been hypothesized that the toxin may act as a protective mechanism for the eggs (Yudkin, 1945).

The puffer is an edible fish, although the small amount of flesh requires some effort to obtain. Thus, the northern puffer appears, at this time at lease, to have no commercial significance. It seems to feed on no commercially important organisms, although it probably competes with commercially valuable fish species. The details of the ecological significance of this strange little fish are presently unknown.

References

Abbe, G. B. 1967. An evaluation of the distribution of fish population of the Delaware River estuary. Master's thesis. University of Delaware.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. U. S. Government Printing Office, Washington, D. C.

Breder, C. S. and D. E. Rosen. 1966. Modes of reproduction in fishes. Natural History Press, N. Y.

Diaber, F. C. and R. W. Smith. 1970. An analysis of fish populations in the Delaware Bay area. Annual D-J Report, Project Number F-13-R-12. 52 pp.

Daiber, F. C. and R. W. Smith. 1971. An analysis of fish populations in the Delaware Bay area. Annual D-J Report, Project Number F-13-R-14. 94 pp.

Daiber, F. C. and R. Wockley. 1969. An analysis of the fish populations of Delaware Bay area. Annual D-J Report, Project Number F-12-R-10. 35 pp.

Hildebrand, S. F. and W. C. Schroeder. 1972. Fishes of Chesapeake Bay. Smithsonian Institute Press, Washington, D. C.

Robinson, P. F. and F. J. Schwartz. 1968. Toxicity of the northern puffer (Sphoeroides maculatus) in the Chesapeake Bay and its environs. Ches. Sci. 9(2): 136-137.

Welsh, W. W. and C. M. Breder. 1922. A contribution of the life history of the puffer (Sphoeroides maculatus). Zoologica (2) 12.

Yudkin, W. H. 1945. The occurrence of a cardio-inhibitor in the ovaries of the puffer (Sphoeroides maculatus). J. Cell. Comp. Physiol. 25: 85-95.

SUMMER FLOUNDER

Paralicthys dentatus

The summer flounder, Paralicthys dentatus, is one of the most prized recreational fishes caught in the Delaware Bay and Small Bays region. It can reach a length of .9 millimeter and weight of 8 kilograms although larger specimens have been caught, one individual commanding 11 kilograms. The summer flounder is a left-handed oblong flatfish, as it lies on the bottom on its right side with its eyes on the left. Compare the picture of the left-handed summer flounder with the right-handed winter flounder. The summer flounder or fluke has a brownish color pattern with eye-like spots on its left side but it can adopt its color to mimic that of its surroundings. The blind side is white. The dorsal fin of the summer flounder originates over the eye and extends posteriorly to the caudal peduncle. The lateral line arches around the pectoral fin.

The summer founder can be found from Maine to Texas but are most abundant in the middle Atlantic area. During the summer months, they move inshore to estuarine and coastal waters concentrating principally from near the shoreline to a depth of 30 millimeters. During the winter they move out onto the continental shelf from the 50 to 150 meter bottom contour.

Summer flounder spend most of their lives on the bottom, preferring a sandy substrate. There, they lie buried up to their eyes waiting for prey. They hide near pilings or in algae. The summer flounder's diet consist of crabs, squid, shrimp, and worms as well as various types of small fish such as silversides and killifish (in Delaware Bay the diet of small summer flounders consist mainly of sand shrimp, the larger individuals eating mostly small weakfish). The summer flounder, then, is an opportunist, eating whatever is

available. Its large mouth lined with sharp teeth makes it an excellent predator. Summer flounders are also good swimmers and actively stalk small schools of fishes.

Summer flounder spawn during the fall and winter months as they move offshore. Sexual maturity is reached at age three when the fish are a little over 300 millimeters long. The eggs are buoyant and hatch in three to four days. By the time the larvae are 16 millimeters long the right eye has migrated completely to the left side. At 26 millimeters the young fry resemble the adult completely. The eggs and young larvae are carried inshore to the estuaries and sounds where the young fish spend their first year. Although the back bays and estuaries of Delaware, New Jersey and Maryland are used as nursery grounds, the young fish are primarily found in North Carolina and Virginia in near shore waters and sounds. Yearlings tend to move northward thus maintaining populations in the northern part of their range.

Growth of the summer flounder is rapid as Table 9 illustrates. The female grows much faster than the male, a usual occurrence for fish.

TABLE 9

Cumulative Annual Growth of Summer Flounder by Sex

	Male		Female	
	Length (inches)	Weight (pounds)	Length (inches)	Weight (pounds)
1	6.5	0.1	7	0.1
2	10	0.4	11	0.4
3	13.5	0.9	15	1.2
4	15.5	1.4	18	2.2
5	17.5	2.0	20	3.0
6	19.5	2.8	22	4.2
7	20.5	3.3	24	5.5
8	21	3.7	26	7.0
9	22	4.1	27.5	8.6
10	22.4	4.4	28.5	9.7
11	22.7	4.6	29.5	10.9
12	23	4.8	30	11.9
13	23.2	5.0	31	12.8
14	23.4	5.1	31.5	13.4
15	23.5	5.3	32	14.3

FIGURE 107
SUMMER FLOUNDER

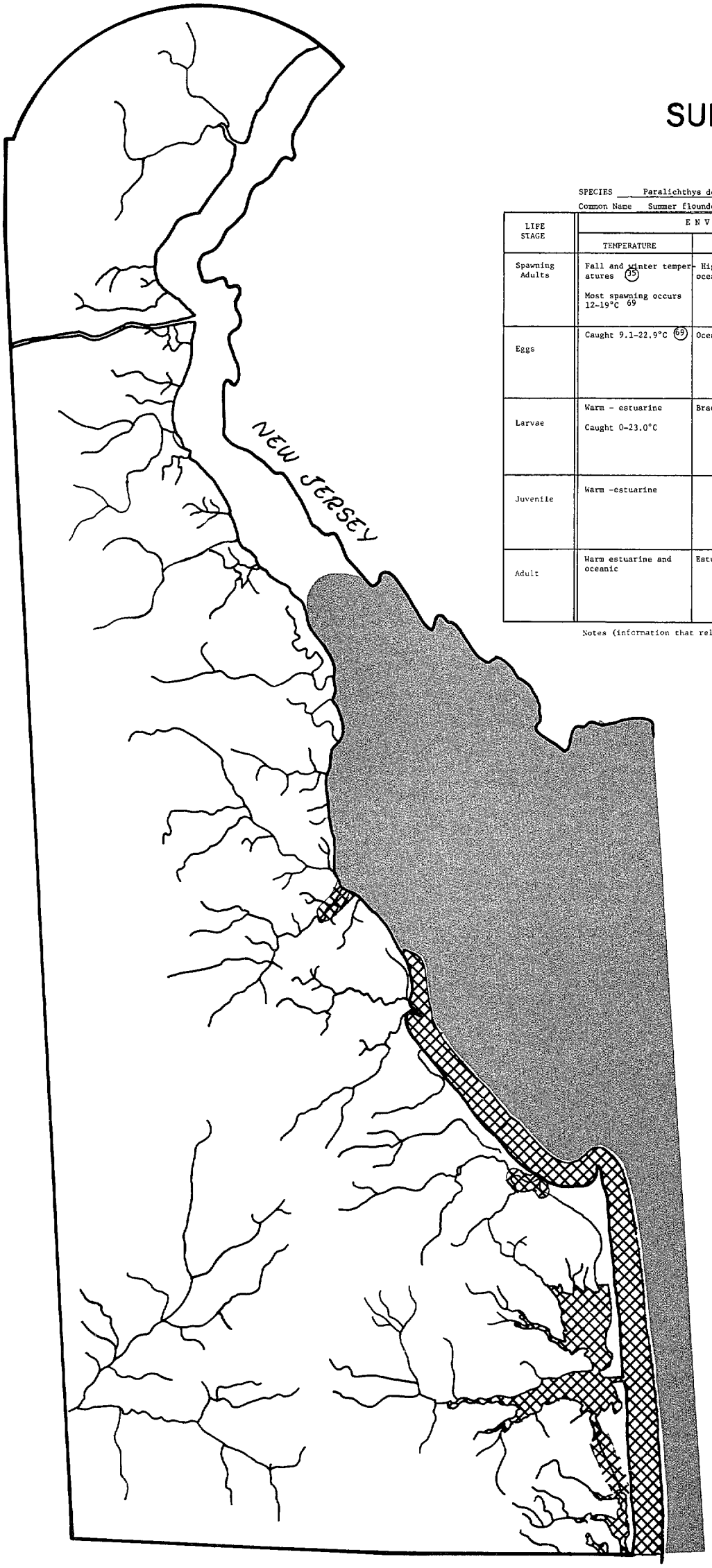
SPECIES Paralichthys dentatus

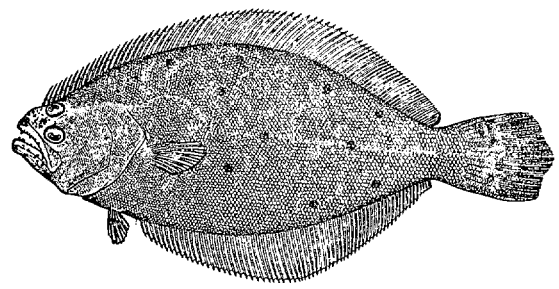
Common Name Summer flounder

Spawning Period Winter

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Fall and winter temperatures (35) Most spawning occurs 12-19°C (69)	High brackish to oceanic			
Eggs	Caught 9.1-22.9°C (69)	Oceanic			
Larvae	Warm - estuarine Caught 0-23.0°C	Brackish to saline			
Juvenile	Warm -estuarine				
Adult	Warm estuarine and oceanic	Estuarine to oceanic	High tolerance to low dissolved oxygen (29) (77)		

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

KNOWN NURSERY AREAS

GENERAL ADULT DISTRIBUTION

Although a commercially important fish in the middle Atlantic states, there have been no commercial landings of summer flounder in Delaware since 1970. Earlier, substantial landings were made, primarily in late summer, using travel or fyke nets. However, the species remains a dominant public sport fishing attraction for summer recreational anglers in Delaware. When cooked properly, it has a mild, delicate flavor. Bottom rigs baited with minnows, shrimp or squid, or bucktails provide the best results. It is advisable to release all summer flounder less than 40 centimeters to give them a chance to reproduce at least once.

References

Bigelow, H. B. and Schroeder, W. C. 1953. "Fishes of the Gulf of Maine", Bull. of the U. S. Bur. of Fish., No. 74.

Hildebrand, S. F. and Schroeder, W. C. 1928. Fishes of the Chesapeake Bay. Bull. of the U. S. Bur. of Fish., No. 43.

Smith, R. W. 1969. An analysis of the summer flounder, Paralicthys dentatus population in the Delaware Bay. Master's Thesis. University of Delaware. 72 pp.

Smith, R. W. 1975. Try flounder -- the oceans platter. CMS, University of Delaware. Sea Grant Pub. #7.

U. S. Fisheries Statistics, Department of Commerce. 1970.

THE HOGCHOKER

Trinectes maculatus

The hogchoker, Trinectes maculatus, Family Soleidae, is probably the most common flatfish in the Delaware Bay estuary and easily distinguishable from other flatfishes. It is a small right-handed flatfish, rarely growing over eight inches in length. The mouth is small and the upper jaw protrudes noticeably beyond the lower jaw. The general oval body shape is accentuated by the very blunt snout, the lack of a distinct caudal peduncle, and by the arrangement of the fins. The dorsal fin starts directly above the mouth and runs continuously along the body fringe to the caudal fin. The ventral and anal fins are continuous and also extend to the caudal from below the mouth. The most striking characteristic of the hogchoker, however, is the complete lack of pectoral fins.

The eyes of the hogchoker are relatively small and set flat into the head. Very rough scales cover both sides of the body with some of the scales being noticeably larger on certain areas of the head. All body surfaces are covered with a rather slimy secretion.

Hogchokers are dark olive to brown in color on the eyed side and usually white to light gray with isolated dark spots or narrow stripes on the blind side. In addition, several very distinct dark bars are usually present on the eyed side as well as a dark longitudinal stripe running along the lateral line.

The hogchoker is common in estuarine areas all along the Atlantic coast where the water is somewhat brackish. Individuals have been found in the open ocean as well as in essentially freshwater sections of the upper estuary. Most of those found in upstream areas are juveniles who apparently move into

fresher water from the higher salinity breeding grounds to spend their first year or two. While the fish are present in all parts of the Delaware estuary, they seem to be more prevalent in the Bay proper over muddy substrates rather than in the shallower shore zone areas.

Relatively little is known of the life history of the hogchoker in this particular area, again most probably because the species has little commercial value. They are considered a good tasting fish, but they are typically very small, averaging only 125-150 millimeters in length as adults. Therefore, no commercial or sport industry has developed around them.

Delaware populations of hogchoker appear to spawn primarily during July into early August. Scientists working in the Chesapeake Bay area have postulated a temperature and day length control mechanism directing the spawning activity. Major spawning does not occur until after the maximum day length period has been reached which is usually just prior to the period of peak water temperature. Both factors seem to be necessary in initiating spawning activity. Although no detailed study exists in the Delaware area, it would be expected that similar controlling mechanisms would be responsible here.

Specific spawning areas have not been noted in Delaware Bay although if the hogchokers follow the pattern as described for parts of the Chesapeake, spawning most probably takes place in the vicinity of the mouth of the Bay in the higher salinity waters. The eggs produced are very small, measuring less than .5 millimeter in diameter. It has not been determined if the eggs are buoyant or demersal, for they have been found both at the surface and on the bottom. Most probably, the position of the egg depends largely on the salinity of the water, and consequently, the density of the surrounding

FIGURE 108
HOGCHOKER

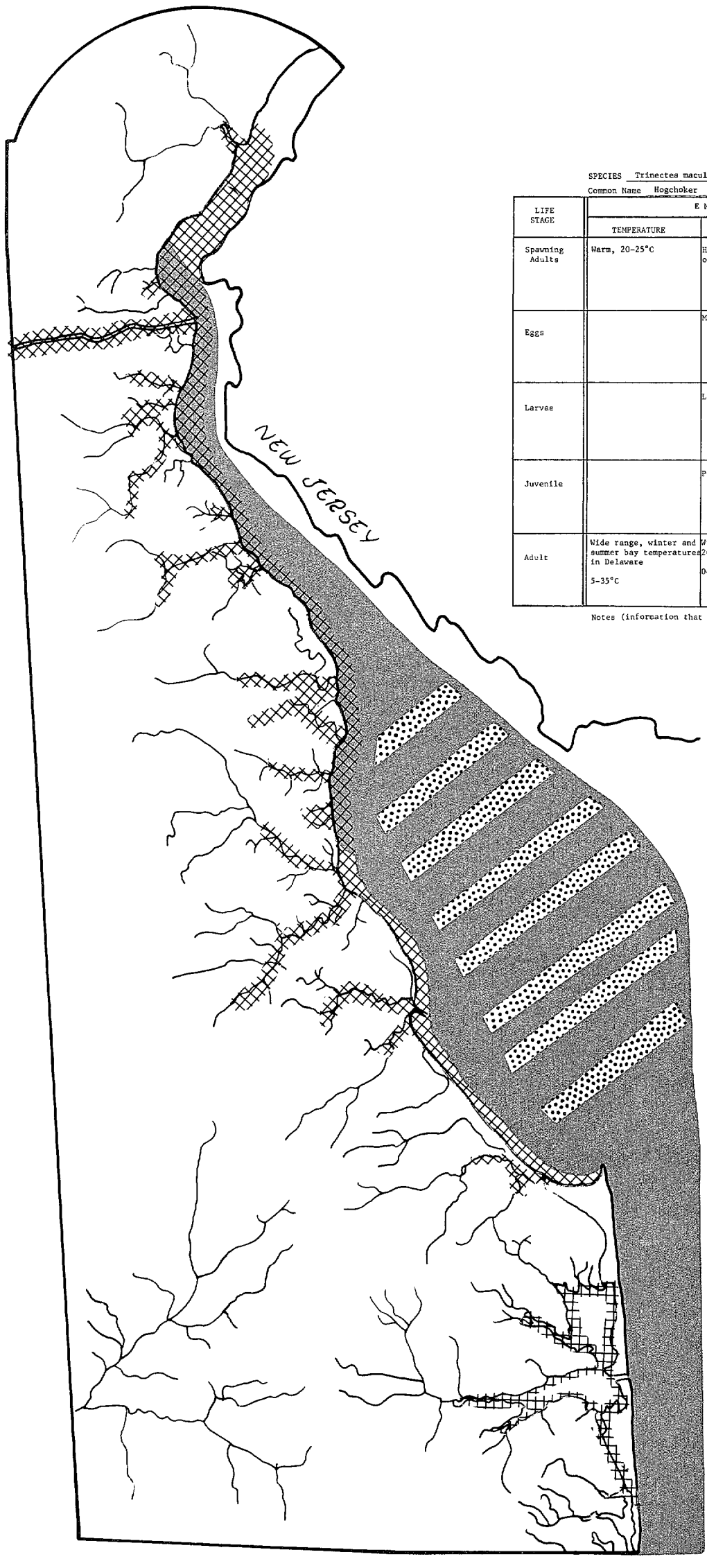
SPECIES Trinectes maculatus

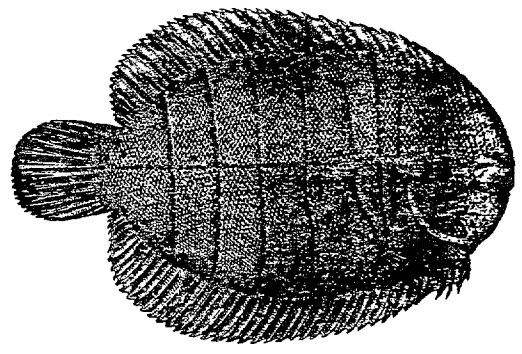
Common Name Hogchoker

Spawning Period July - August (in Delaware)

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	Warm, 20-25°C	High - probably 30‰ or better			
Eggs		Mid-range 10-16+‰			
Larvae		Low 0-8‰			
Juvenile		Prefer fresh to brackish			
Adult	Wide range, winter and summer bay temperatures in Delaware 5-35°C	Wide range - prefer 20-30‰ 0-43‰	High tolerance to low dissolved oxygen	Relative high tolerance to suspended sediments (66)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

PROBABLE SPAWNING AREAS

NURSERY AREAS

ADULT DISTRIBUTION

water. The eggs contain large numbers of oil globules, and hatch in approximately twenty-four to thirty-six hours.

Larvae seem to move upstream immediately after hatching and were found concentrated in the Chesapeake studies in waters of salinity 0-8‰, while eggs were found in areas of 10-16(+)‰ salinity. The juveniles apparently spend their first year or two in these low salinity areas but are continually moving towards the spawning areas of the lower estuary.

Hogchokers appear to mature between their second and fourth years. Three year-old female hogchokers have been found in Delaware Bay carrying ripe eggs. Studies done in the Chesapeake Bay found individuals to be sexually mature at four years of age. Individuals of this age group are capable of completing the migration from the upper estuary to the spawning grounds. After spawning it appears that a large number of the sexually mature fish remain in the general area of the breeding grounds although some do migrate up the estuary with the juveniles. Individuals can apparently spawn at least through their twelfth year.

The growth rate of the hogchoker is apparently rapid the first year or two yet different for males and females. Females are generally longer and heavier than males of the same age, though the length-weight relationships for each sex are very similar. Studies also found populations to contain very many more females than males. The significance of this is unknown.

As a bottom dwelling flatfish, the hogchoker seems to feed predominantly on benthic crustaceans and annelid worms. They have also been found to feed on mollusks, organic detrital material, algae and almost anything else that can be scraped off the bottom. It does appear that the crustaceans and worms are the chief prey and that the other materials are simply ingested in concert

with the prey. It is not known if there are any specific predators of the hogchoker, yet it can be assumed that because of their small size and relative abundance in the Bay, the predatory species do ingest them.

Investigators in the Chesapeake Bay have discovered that the hogchokers are year-round, lifelong residents of the mid-Atlantic bays. Each population, and there may be several fairly distinct ones in a large estuarine area, makes use of a large part of the estuary. They breed in the lower estuary, mature in the upper and mid-estuary and migrate back and forth between the nursery and breeding grounds every year. The most probable factors controlling the various stages and movements of the fish are salinity and temperature, although, again much of this is speculation. Since the hogchoker is a fish that spends its entire life in the Delaware estuary, additional studies are needed to determine its importance in the estuarine community and to determine the environmental requirements for this curious little flatfish.

References

Bigelow and Schroeder. 1953. Fishes of the Gulf of Maine. T.F.H. Publications, Inc., Neptune, N.J. 388 pp.

Hildebrand and Schroeder. 1929. Fishes of Chesapeake Bay. U. S. Government Printing Office, Washington, D. C. 577 pp.

Wockley, R. C. 1968. A partial life history of Trinectes maculatus (Bloch and Schneider), the hogchoker. M.S. thesis. University of Delaware.

Manseuti, R. and R. Pauly. 1956. Age and growth of the northern hogchoker, Trinectes maculatus, in the Patuxent River, Maryland. Copeia 1956(1): 60-62.

Dovel, W. L., J. A. Mihursky and A. J. McErlean. 1969. Life history aspects of the hogchoker, Trinectes maculatus, in the Patuxent River estuary, Maryland. Ches. Sci. 10(2): 104-119.

deSylva, D. P., F. A. Kalber and C. N. Shuster. 1962. Fishes and ecological conditions in the shore zone of the Delaware River estuary. University of Delaware Mar. Lab., De.

JELLYFISH

Although jellyfish are common inhabitants of the coastal waters of Delaware, relatively little is known about them. Even in areas where the jellyfish has been studied, as in the Chesapeake Bay, for instance, the scope of the work has been limited and much remains to be learned about the several species of jellyfish found in the mid-Atlantic region.

The term jellyfish is somewhat misleading for these animals are not fish at all but members of a rather primative group of marine organisms known as the Coelenterates (cell-en-ter-ates). A variety of organisms are included in this group, but they all possess a characteristic hollow body cavity around which the rest of the organism is structured.

The four species of jellyfish found in Delaware waters, the Sea Nettle, the Moon Disc jellyfish, the Lion's Mane jellyfish and the Red Winter jellyfish, all have the same basic appearance--an umbrella or bell-shaped body called a medusae from which extend tentacles. Body size, color and the length and number of tentacles vary depending upon the particular species. Actually, the gelatinous medusae is only one of three life forms that jellyfish pass through in their life cycle. The medusae is the sexually mature adult form of the jellyfish.

Most species of jellyfish have distinct male and female medusae which produce sperm and egg respectively at maturity. Males deposit the sperm into the water and the eggs are fertilized while still in the ovaries of the female medusae. Embryos are shed as free-swimming microscopic larvae called planulae, which are mobile for one or two days before settling to the bottom. The planulae will attach themselves to any hard substance--preferably oyster

or clam shells, but rocks or cans will suffice.

As an attached form, the planulae proceed into a second developmental stage called the polyp stage. The polyps remain small and grow tentacles. When favorable conditions exist, the polyps can begin to reproduce asexually. Unlike the medusae, then, polyps do not produce male and female gametes. Polyps can bud, a process through which parts of the parent polyp are physically pinched off producing new polyps or strobilate. Strobilation is a complex process which results in the formation of ephyra which is actually a juvenile medusae that in two months time eventually develops into the adult mendusae with distinct sexes that we recognize as a jellyfish.

The cycle is then repeated as the medusae produce polyps or planulae which go on to form the ephyra which eventually grow into the adult jellyfish or medusae. The medusae are very short lived and seasonal, dying after they produce a new larval generation. Polyps on the other hand, can be found all year-round.

Three of the species found in Delaware waters--the sea nettle, the moon disc, and the lion's mane jellyfish--exhibit life cycles in which the medusae appear in the late spring and become prominent in the summer. The medusae of the fourth common species, the Red Winter jellyfish, begin to appear in mid-summer and remain in these waters throughout most of the fall.

All medusae have some form of restricted locomotion through the rhythmic contractions of the bell. Most of this movement can carry the jellyfish in a vertical direction only and it is felt that they feed by swimming up through the water and then floating down again. While floating they collect food from the water with their outstretched tentacles which is then passed along special grooves to the mouth and digestive system. Where any lateral movements are

concerned, these organisms are at the mercy of the water currents, winds and tide, leading to erratic unpredictable distribution patterns. On some days, the medusae are very plentiful and on others rather scarce.

The origins of the medusae for the species found in the Delaware Bay remain a mystery to estuarine biologists. General studies undertaken to collect information on other organisms, notably oysters, produced no incidence of attached polyps. There are areas in the Delaware Bay and in the near coastal areas of the Atlantic ocean which possess both suitable substrate and suitable water conditions for polyps and it is felt that more detailed studies will locate some areas in which polyps set. It is possible also that many medusae and ephyra are brought into this general region from surrounding areas because of the current patterns found in Delaware's near coastal waters. Of the four species noted, only one is thought to be exclusively brought into the Delaware area from other distant areas. The production of the other three species is felt to be local but the origins are unknown.

Jellyfish feed on, and in turn, are fed upon by a variety of organisms. The tentacles which are used to trap prey have specialized cells called nematocysts which contain toxins that are fatal to the prey organisms. Some of the toxins--notably those in the sea nettles--can also cause some discomfort in man, producing a stinging sensation. Larvae of several other marine organisms--gastropods, oysters, copepods, epicardeans, barnacles, and eggs of some polychaete worms and rotifers all have been found in the digestive systems of medusae. Some medusae also seem to feed on ctenophores, organisms very similar to the jellyfish themselves.

In turn, the medusae appear to be fed upon by several species of crabs, some types of fish and some sea anemones. Adult barnacles, sponges, tunicotes,

limpets and nudibranchs are known to feed actively upon the jellyfish polyps. Where the jellyfish become a nuisance, it was hoped that introduction of some of these natural predators, especially the nudibranch or sea slug, would help control the jellyfish population. However, little is known about the roles of either the jellyfish or the predators in the total ecosystem, and much more information will have to be gathered before such a project is undertaken.

Comments on individual species:

THE SEA NETTLE--Chrysaora quinquecirrha

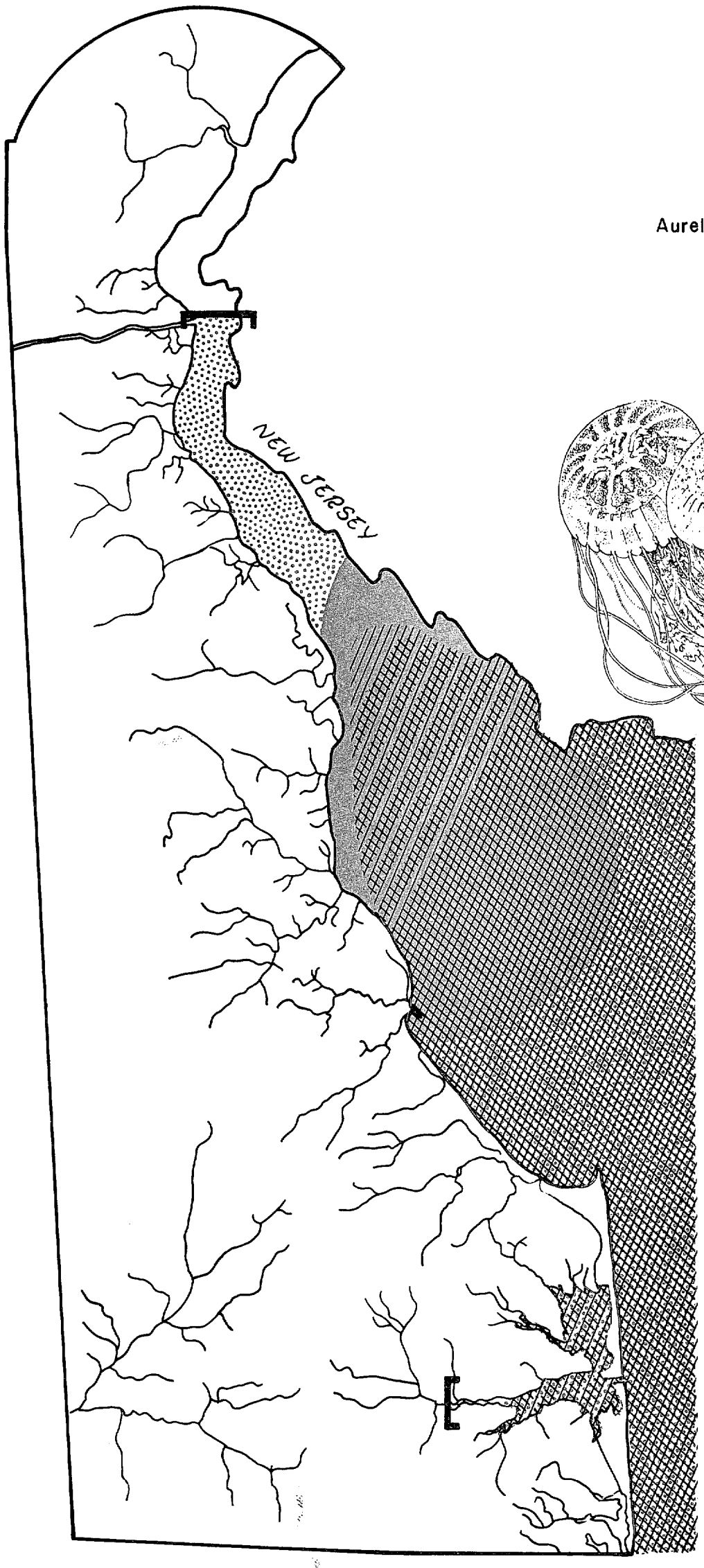
One of the smaller jellyfishes in the area is the sea nettle. It is only about 10 centimeters (4 inches) in diameter. The sea nettle is also one of the most well known. Its twenty-four tentacles contain certain toxins which can irritate man. The medusae become prominant during the summer months often causing problems in resort areas where they bring discomfort to swimmers. The medusae can exist in waters of salinity in the range of 7-30‰ with the polyps being limited to water of 7-25‰ salinity. Nettles are usually milky whitish in color with red bars often appearing on the bell.

THE MOON DISC JELLYFISH--Aurelia aurita

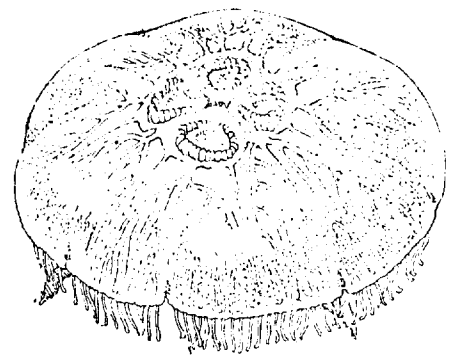
This species seems to be the most common in the Delaware area and one of the largest, since the medusae often reach 45 centimeters (17 inches) in diameter. Unlike the tentacles of the nettles, the tentacles of the moon disc jellyfish are relatively short and much more numerous. The bell is divided into eight equal parts while the gonads number four. These are very large, horseshoe-shaped organs somewhat purple in color and highly visible, and so, a good aid in recognizing the species.

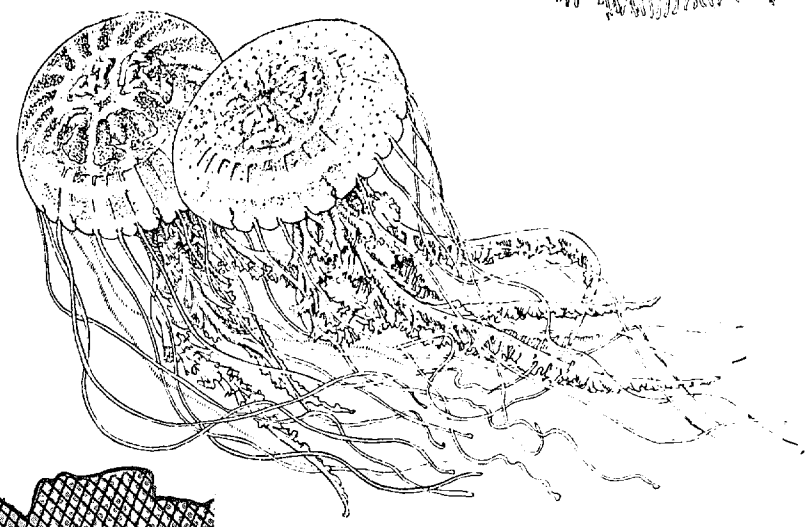
FIGURE 109

JELLYFISH



Aurelia aurita





Chrysaura quinquecirra

AURELLA AURITA
CHRYSAURA QUINQUEARRHA
Spring to Summer

RHOPILEMA VERRILLI
Spring to Summer

CYANEA CAPILLATA
Late Summer Fall

MNEMIOPSIS (Up to 4‰)
Year Round (Limits)

THE LION'S MANE JELLYFISH--Rhopilema verrilli

Like the moon disc jellyfish, the Lion's Mane jellyfish is also rather large, but somewhat distinct in that it has no marginal tantacles. Other organs, the oral arms, which are tentacle-like in appearance, extend out from the mouth of these animals becoming subdivided into many sections during their development. These are then used to collect food organisms from the water and carry them to the mouth. While rarer than some of the other species found here, the Lion's Mane jellyfish does seem to be more common in the waters of the Delaware Bay area than those of the Chesapeake Bay.

THE RED WINTER JELLYFISH--Cyanea capillata

The medusae of this species are not prominent in this region during the late summer and fall as strobilation occurs only when water temperatures begin to fall. Reddish or reddish brown in color, it is somewhat larger than the sea nettle and its tentacles are arranged in eight clusters which originate from the underside of the bell as opposed to the evenly distributed long marginal tentacles of the sea nettles.

References

Cargo, D. G. and L. P. Schultz. 1966. Notes on the biology of the sea nettle (Chrysaora quinquecirrha), in Chesapeake Bay. Ches. Sci. 7(2): 95-100.

_____. 1967. Further observations on the biology of the sea nettle and jellyfishes in Chesapeake Bay. Ches. Sci. 8(4): 209-220.

Cronin, L. E., J. C. Daiber and E. M. Hulburt. 1962. Quantitative seasonal aspects of zooplankton in the Delaware River estuary. Ches. Sci. 3(2): 63-93.

Hughes, D. J. 1973. Factors affecting the distributions of jellyfishes in Delaware Bay. Aspects of biological oceanography 1973. College of Marine Studies, University of Delaware. 75-93.

Watling, L. 1968. Jellyfish-regular summer visitors to Delaware shores. College of Marine Studies, University of Delaware Marine Advisory Service Publication Number 7-B1068.

COMB JELLIES

Ctenophora

Closely related to the jellyfish (Coelenterates) is a phylum of gelatinous organisms called Ctenophora and known popularly as sea walnuts or comb jellies. Comb jellies are distinguished from jellyfish by their small size and by the absence of any obvious tentacles which are characteristic of the larger jellyfish medusae (see Jellyfish). Twenty-one species of ctenophores have been identified from the Atlantic coast of North America, six of which are distinctly cold water species ranging south to New Jersey, the rest being warmer water, predominantly tropical species. The most common species in the Delaware nearshore and Back Bay waters is the sea walnut, Mnemiopsis laidyi.

Adults of this species are spherical or ovoid in shape, radially symmetrical, 10 centimeters long and transparent. They are most prominent during the fall, winter and spring. Little is known of their distribution but they appear to be restricted to salinities above 4-5‰, with no upper limit yet determined. Their salinity preference is somewhat regulated by their temperature preferences in that as the water becomes colder they are found in areas of higher salinity.

The ctenophores or comb jellies are very active plankton feeders and they appear to exert some control on the total population of various species. Planktonic larvae of bivalves, annelid worms and barnacles are all found in the digestive systems of ctenophores. The most common prey, however, seems to be copepods, minute crustaceans which are very numerous in marine waters and very important in all marine food webs.

As far as predators of the ctenophores are concerned, little information is available. Some larger ctenophores will prey on smaller ctenophores when the populations intermingle. Jellyfish are known to be predators of the ctenophores and probably all the animals which prey on the jellyfish would also find the ctenophores suitable prey.

All ctenophores are known to be hermaphrodites meaning that both eggs and sperm are produced by the same adult individual. In most species, fertilization is external as the adults shed the sperm and the eggs into the water.

To the night beach comber, ctenophores like the sea walnut are most recognizable by their luminescence. When the animals are disturbed, they give off a green light in special, canal-like organs along their bodies producing a reticulate, branching pattern of light. At certain times the ctenophores are so numerous in the surf and shallow water areas that the water is constantly flashing from the luminescent displays.

References

Barnes, R. D. 1968. Invertebrate zoology. W. D. Saunders Co., Philadelphia.

Bendall, J. A. 1973. The Ctenophora of the North American Atlantic Coast. Aspects of Biological Oceanography 1973. College of Marine Studies, University of Delaware. pp. 1-12.

Burrell, V. G. 1968. The ecological significance of a Ctenophore (Mnemiopsis leidyi). Master's thesis. College of William and Mary. 62 pp.

Cronin, L. E., J. C. Daiber and E. M. Hulburt. 1962. Quantitative seasonal aspects of zooplankton in the Delaware River estuary. Ches. Sci. 3: 63-93.

Mayer, A. G. 1912. Ctenophores of the Atlantic coast of North America. Carnegie Institution, Washington. Publication Number 162. J. B. Lippincott, Philadelphia. 58 pp.

THE HARD CLAM

Mercenaria mercenaria

The hard clam or quahog was formerly an important commercial species in Delaware. Although hard clams are still available commercially, their importance as a commodity has drastically decreased in the last ten years. Generally, hard clams can be found in subtidal or intertidal waters along the coast of Eastern North America from Nova Scotia to the Yucatan. In Delaware, hard clams are scattered over the Delaware Bay and throughout the small bays. Quahogs are bivalves having two similar, hinged shells and can grow to 12-13 centimeters (4.7-5.1 inches) in length.

Spawning of the hard clam under natural conditions is probably both thermally and chemically stimulated, although a variety of factors seem to directly or indirectly determine the spawning time. In the laboratory, spawning is most active in water which is warmed from below 25°C, or cooled from above 28°C, in combination with the addition of small amounts of sperm. In nature, factors other than temperature may be involved in the stimulation of spawning. It has been reported that in a natural homogenously mixed estuary, most clams spawn during neap tides, possibly because of the higher temperatures and increased food concentrations associated with the lower tidal amplitudes and reduced circulation. Studies conducted in Long Island Sound found higher reproductive activity usually coinciding with the highest seasonal temperatures, ranging from 23.0-30.2°C. Most males in the laboratory spawn at 25-26°C, while most females spawn at 29°C.

In Little Egg Harbor, New Jersey, adult clams tended to spawn during neap tides near the time of low slack water. Since ocean waters are usually cooler than bay waters, neap tide would be the period of least cooling from

oceanic dilution of the Bay. Spawning close to low slack water results in the eggs and larvae being carried into the more favorable environment of the Bay by water movements rather than out into the deeper waters of the ocean. Gametes are voided through the excurrent siphon into the surrounding water where fertilization takes place. This is the beginning of a sequence of larval stages, the most vulnerable period in development. Larval growth and survival are inextricably linked to the condition of the environment. The optimum temperature range for normal egg and larval development is 18-30^{o}C.

The eggs are extremely small and are surrounded by a gelatinous envelope. About twelve hours after fertilization, a free swimming larvae emerges to become a part of the plankton community. Toward the end of its free swimming stage, the larvae develops a muscular, ciliated foot and enters the pediveliger (crawling-swimming) stage. It is during this period that the larvae alternates between a planktonic and benthic existence in its search for a suitable substrate for setting.

Setting periods at a constant temperature of 18^{o}C, range from sixteen to twenty-four days after fertilization. The first completely benthic stage of development is called the plantigrade stage in which the foot becomes the organ of locomotion. During this stage when the clam shell attains a length of 210-300 microns, the siphons begin to develop. Tentacles form around the inhalant and exhalant openings which prevent large sediment particles from entering. By extending its siphon up to the sediment-water surface, the clam is able to circulate water past its gills while being burrowed in the bottom.

The development into the juvenile clam is regulated by many environmental factors. Salinity is of primary importance, particularly in early larval stages. Eggs of the quahog develop into normal, straight-hinged larvae only in

salinities from 20.0-32.5‰, with salinity tolerance varying with the age of the clam. Under laboratory conditions, the optimum salinity for growth is from 24.0-28.0‰ (Chanley, 1958).

Growth rates vary with the type of substrate involved. Clams in coarser sediments show greater growth rates while an increase in silt or clay content retards growth. Clams in sand may grow 24 per cent faster than those in muddy organic sediments. Substrates and sediments are also instrumental in determining the setting locality of the clam larvae which prefer substrates having some solid substance for attachment such as detritus-covered shell or rock.

The sexual development of the quahog follows an interesting pattern. Young clams, 0.6-0.7 centimeter (.23-.27 inch) in length, have bisexual gonads, usually dominated by male characteristics. After the first spawning season, about one half of the juveniles become females.

The feeding habits of the hard clam have been examined both to determine its role in aquatic food web and to develop suitable feeding methods for artificial cultivation. Twelve species of algae from ten genera were tested for food value for clam and oyster larvae. Of those tested, Isochrysis galbana, and Chlorococcum spp., produced the fastest growth in pure cultures.

Certain substances in the environment may be toxic to the hard clam. The effects of vitamins, fungicides, antibiotics, sulfa drugs, and dinoflagellates (marine plantonic organisms) on oyster and hard clam larvae have been examined. The results showed that Vitamin A, Vitamin B, biotin, calcium pantothenate, nicotinic acid, pyridoxine hydrochloride, riboflavin, and thiamine hydrochloride, singly or in combination, had no adverse effects on larval development. Terramycin was extremely toxic. Dinoflagellates induced abnormalities in spawning and larval development.

While in the larval stages, hard clams may be consumed by any number of filter feeders. Small clams may be attacked by oyster drills, such as Urosalpinx, blue crabs, moon snails, conchs (Busycon), horseshoe crabs (Limulus), sea stars, puffers, or waterfowl. All of these predators are found in Delaware and Chesapeake Bays and they undoubtedly play a part in the regulation of hard clam populations.

A survey in 1971 demonstrated the Delaware Bay clam population to be seriously depleted. This may be due in part to the increasing number of clammers since the oyster fishery has declined. However, Indian River and Rehoboth Bays have an abundance of hard clams. The estimated standing crop of hard clams in Indian River Bay is approximately 116,894 bushels, 3 per cent of which is in areas where shellfishing is prohibited. In Rehoboth Bay, the estimated standing crop is about 103,827 bushels, 19 per cent of which is in prohibited areas.

Hard clams constitute a valuable resource for Delaware and other coastal states. The maintenance of this resource depends on a continuation of favorable environmental conditions necessary for the healthy development of the clams. Many areas of Delaware Bay have become contaminated, rendering hard clams unsuitable for human consumption. Other modifications in the environment through human activities which change temperature, salinity, turbidity, or circulation patterns may have deleterious effects on the harvestable population by damaging the extremely vulnerable larval stages of the clam.

Artificial culturing may be one method of insuring a safe transition through the larval stages into the hardier adult clam. Further investigations into the environmental requirements of the various larval stages would aid

FIGURE 110
QUOHOG, HARD CLAM

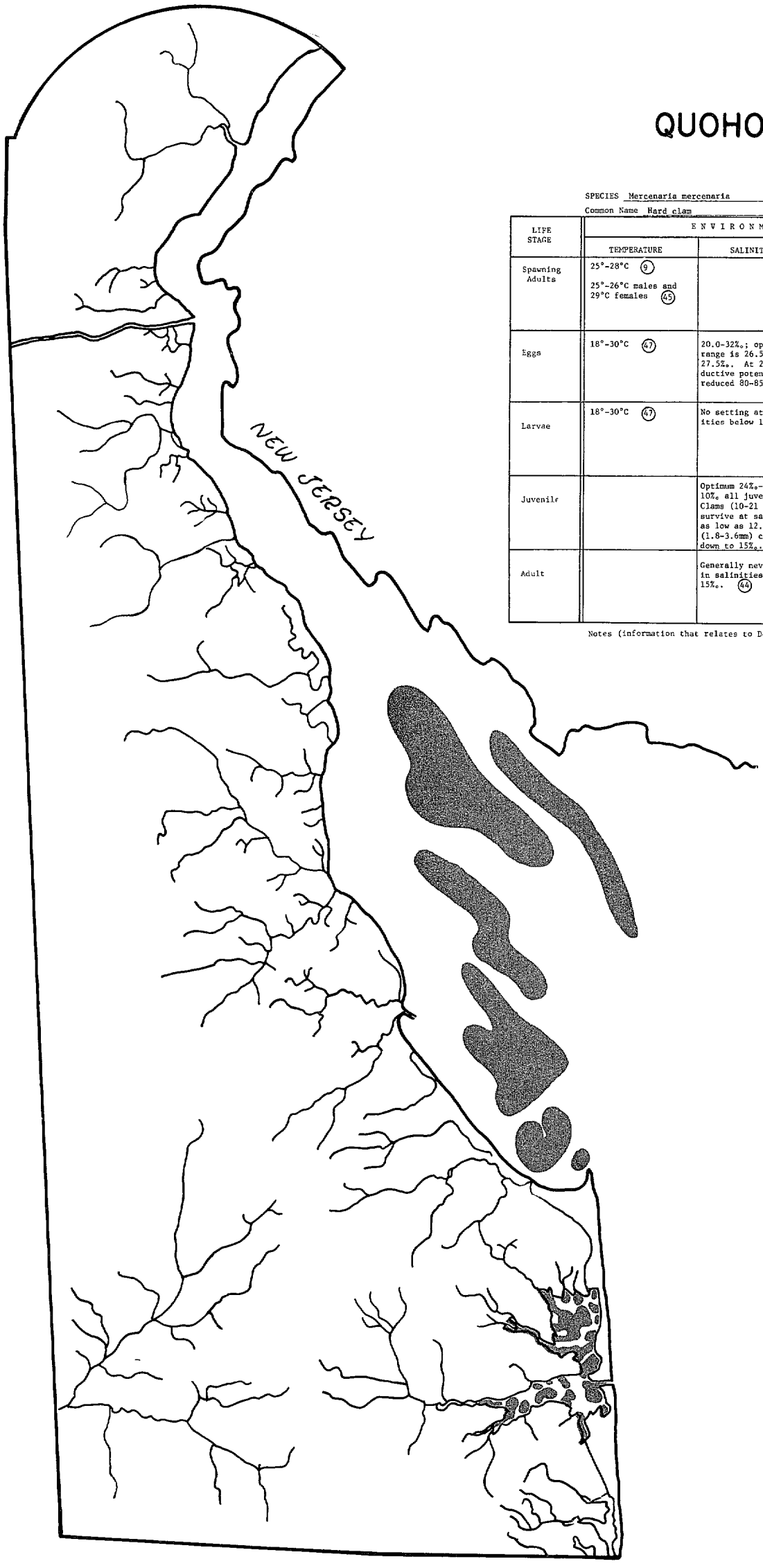
SPECIES Mercenaria mercenaria

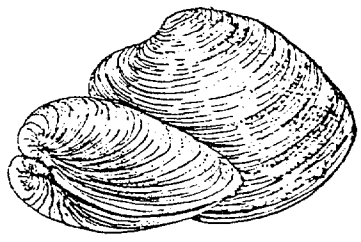
Common Name Hard clam

Spawning Period During highest seasonal water temperatures (23.0-32.0°C); often coincides with neap tides

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults	25°-28°C (9) 25°-26°C males and 29°C females (45)				
Eggs	18°-30°C (47)	20.0-32‰; optimum range is 26.5‰ to 27.5‰. At 20‰ reproductive potential reduced 80-85%. (20)	Normal development at 0.5 mg/l; 100% mortality at 0.2 mg/l (56)		
Larvae	18°-30°C (47)	No setting at salinities below 17.5‰ (20)	Growth stops below 2.4 mg/l (56)		
Juvenile		Optimum 24‰-28‰. At 10‰ all juveniles die. Clams (10-21 mm) can survive at salinities as low as 12.5‰. Clams (1.8-3.6mm) can survive down to 15‰. (10)			
Adult		Generally never found in salinities below 15‰. (44)			

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

GENERAL DISTRIBUTION

in this culturing. Whether artifically or naturally propagated, the hard clam will remain a valuable resource, which will require further study in order to insure its continued survival.

References

Carriker, M. R. 1951. Observations on the penetration of tightly closing bivalves by Busycon and other predators. Ecol. 32: 73-84.

Carriker, M. R. 1961. Interrelationship of functional morphology, behavior, and autecology in the early stages of the bivalve Mercenaria mercenaria. J. Elisha Mitchell Sci. Soc. 77: 168-281.

Carriker, M. R. 1967. Ecology of estuarine benthic invertebrates: A perspective in estuaries. In: Estuaries. G. H. Lauff, ed. Amer. Assoc. Adv. Sci. Publ. 83: 442-487.

Chanley, P. 1958. Survival of some juvenile bivalves in waters of low salinity. Proc. Nat. Shellfish. Assoc. 48: 52-65.

Davis, H. C. 1958. Survival and growth of clam and oyster larvae at different salinities. Biol. Bull. 114: 296-307.

Davis. H. C. and P. E. Chanley. 1955. Effects of some dissolved substances on bivalve larvae. Proc. Nat. Shellfish. Assoc. 46: 59-68.

Davis. H. C. and R. R. Guillard. 1958. Relative value of 10 genera of microorganisms as food for oyster and clam larvae. U. S. Fish and Wildl. Serv. Bull. 58: 291-304.

Humphries, E. and F. C. Daiber. 1967. Shellfish survey of Indian River Bay and Rehoboth Bay, Delaware. Rept. to Northeast Marine Health Sciences Lab., U. S. Dept. HEW.

Landers, W. S. 1954. Seasonal abundance of clam larvae in Rhode Island waters 1950-52. U. S. Fish and Wildlife Serv. Spec. Sci. Rept., Fisheries No. 117.

Loosanoff, V. L. 1936. Sexual phases in the quahog. Sci. 83: 287.

Loosanoff, V. L. 1937a. Development of the primary gonad and sexual phases in Venus mercenaria Linnaeus. Biol. Bull. 72(3): 389-405.

Loosanoff, V. L. 1937b. Seasonal gonadal changes of adult clams Venus mercenaria (L.). Biol. Bull. 72(3): 406-416.

Loosanoff, V. L. 1937c. Spawning of Venus mercenaria (L.). Ecol. 18: 506-515.

Loosanoff, V. L., H. C. Davis, and P. E. Chanley. 1954. Food requirements of some bivalve larval. Proc. Nat. Shellf. Assoc. 45: 66-83.

Loosanoff, V. L., W. S. Miller and P. B. Smith. 1951. Growth and setting of larvae of Venus mercenaria in relation to temperature. J. Mar. Res. 10: 59-81.

Marinucci, A. C. 1975. Interrelationships among growth, growth physiology, and external algal metabolites, in the larvae of the quahog clam, Mercenaria mercenaria (L.). Master's thesis. University of Delaware.

Meglitsch, P. A. 1972. Invertebrate zoology. Oxford University Press, N.Y.

Pratt, D. M. 1953. Abundance and growth of Venus mercenaria and Callocardia morrhuana in relation to the character of bottom sediments. J. Mar. Res. 12: 60-74.

Pratt, D. M. and D. A. Campbell. 1956. Environmental factors affecting growth in Venus mercenaria. Limnol. Oceanogr. 1: 2-17.

Shuster, C. M. 1959. A biological evaluation of the Delaware River estuary. University of Delaware Info. Ser. Publ. #3.

Watling, L. and R. T. Keck. 1971. Hard clam survey of Delaware Bay. Yearly Report, U. S. Dept. Inter., Fish and Wildl. Serv., Bur. Comm. Fisheries.

THE AMERICAN OYSTER

Crassostrea virginica

As a food, the oyster has been popular since before Christ and has since become an economically important bivalve mollusk in many countries. Its value has been considered sufficient to warrant extensive studies into its natural life cycle, its environmental requirements, and means for its artificial propagation.

The American oyster is found from the Gulf of the Saint Lawrence to the Gulf of Mexico and in the West Indies. Local distributions of oyster beds are usually determined by local hydrographic conditions. In the Chesapeake Bay, oysters are found from the Maryland-Virginia border to near the head of the Bay, and in tributaries with salinities of 7-8‰ or more. They are usually not found in waters over thirty-five feet deep, because of anoxic (low oxygen) conditions which may occur. In the Delaware Bay, oyster beds extend from Woodland Beach in the north, to Big Stone Beach in the south, and east to Cape May, New Jersey, in salinities from 2-30‰. Almost all of these beds are subtidal. Populations of oysters can also be found in restricted areas of the Broadkill, Mispillion, Murderkill and St. Jones Rivers.

The American oyster is not a symmetrical bivalve, nor does it have one specific form. Its shell shape varies with different locations and conditions. It is usually elongated with the lower shell deeper and cuplike and the upper shell flat. The lower, or left shell is generally cemented to the substrate. On firm bottoms, oysters develop more round shells while on soft bottoms, or in clusters on reefs, the shells are usually longer and more slender. The average market size oyster is 10-15 centimeters (4-6 inches).

The shell of the oyster is secreted by the mantle which covers most of the body. The mantle also aids in water retention should the oyster become exposed on a beach or reef. The two valves (shells) of the oyster are opened and closed by the adductor muscle, which comprises 20-40 per cent of the total tissue weight of the oyster.

Reproductive material is diffused throughout the oyster. Spawning is initiated by a seasonal increase in water temperature. The female oyster actively discharges eggs by contractions of the adductor muscle, which may last from a few minutes to one hour. The male uses respiratory currents, created by cilia, to carry sperm into the water. It is possible for an oyster to change sex from year to year without affecting reproductive success.

The average female oyster lays about 55.8 million eggs. Recently fertilized eggs are very sensitive to changes in their environment. For example, temperature or salinity shocks are often fatal. The more resistant, free swimming larval stage usually lasts from six to fourteen days, and ends when the larval oyster finds a suitable substrate and attaches itself. The most favorable substrate for setting is shell. Other substrates, listed in order of diminishing suitability, include muddy shell, shelly mud, mud, and marsh debris. Attachment to a substrate is permanent by means of a cement secreted by the byssal gland. Metamorphosis takes place as organs rearrange themselves, and the adult oyster is formed.

It can be seen that the locations of the adult oyster populations are determined during the larval stages. Dispersal of the larvae is largely passive. They move with water currents, usually into estuaries, following wind driven currents on the water's surface or density currents in deeper water. Movement into estuaries tends to increase the chance for survival of

FIGURE III

AMERICAN OYSTER

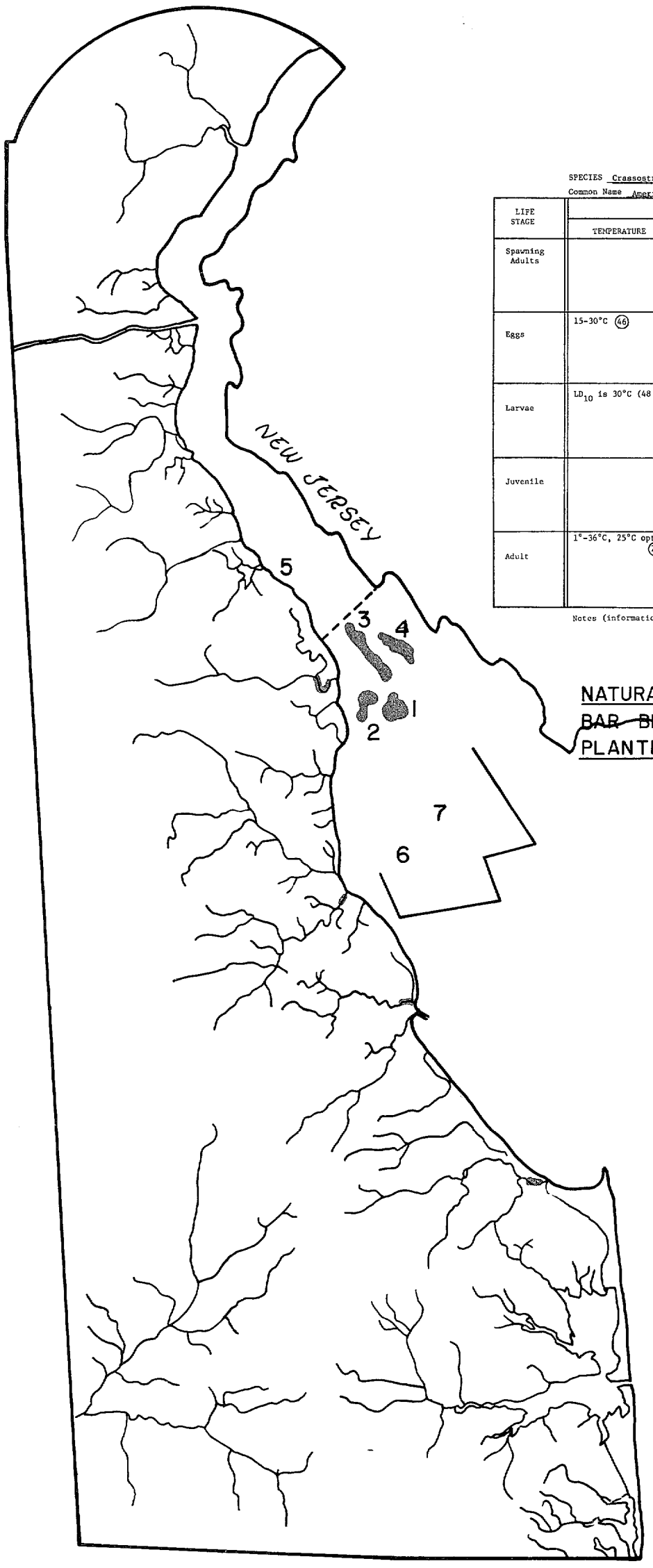
SPECIES Crassostrea virginica

Common Name American oyster

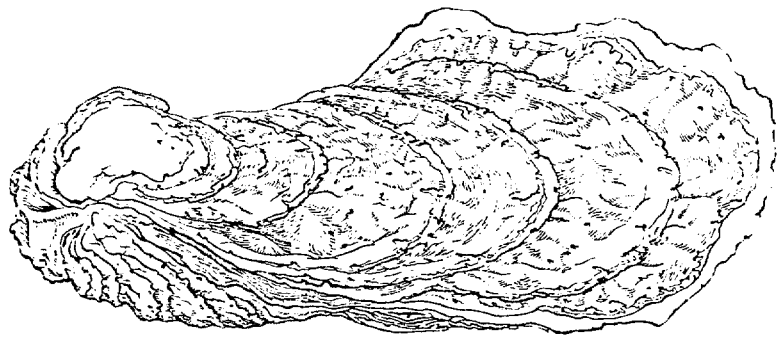
Spawning Period ?

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults					
Eggs	15-30°C (46)	Optimum - 22.5‰ Below 15‰ is poor (46)		Significant effect on survival and growth at 125 mg/l (63)	
Larvae	LD_{10} is 30°C (48 hours) (31)	15‰ or more (46)		Severe mortality at >100 mg/l (65)	
Juvenile					
Adult	1°-36°C, 25°C optimum (74)	7‰ to 27‰ (67)		No effect at 300-700 ppm for mortalities (49) Reduction in pumping rates at 100 mg/l and up (65)	

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)



NATURAL BEDS: 1, RIDGE BED; 2, SILVER BED; 3, OVER THE BAR BED; 4, BLACK BOUY BED; 5, WOODLAND BEACH BED.
PLANTED BEDS: 6, 58; 7, 51; 8, 9.



LEGEND

GENERAL ADULT DISTRIBUTION

APPROXIMATE UPPER BAY LIMIT OF THE OYSTER PARASITES, UROSALPINX CINEREA AND EUPLEURA CAUDATA BASED ON SALINITY TOLERANCES.

BOUNDARY OF THE LEASED OYSTER GROUNDS IN DELAWARE

From: Maurer et al., 1971, Delaware oyster industry: a reality., Trans. Am. Fish. Soc. 100 (1) 100 111; and, Keck, R. et al., 1973, Tidal stream development and its effect on the distribution of the American oyster, CMS, University of Delaware, DEL SG 22 73.

the larvae.

After setting, growth continues until the oyster reaches 2-4 centimeters (.8 to 1.5 inch) in the first year. Sexual maturity is reached after two to three years (4-8 centimeters). Maximum productivity is obtained in four to seven years. Oysters never really stop growing until they die or are harvested.

The American oyster is a filter feeder. It possesses tiny hairs, called cilia, to direct water through a filtering apparatus which removes food particles consisting mainly of diatoms, flagellates and algae.

The American oyster is prey for a large number of animals. In the larval stages, it may fall victim to any number of planktonic grazers. When it comes time to set, it must compete for space with other organiams on the bottom--mussels, sponges, limpets and other fouling organisms. It may be consumed by boring sponges, whelks, oyster drills, starfish, skates, crabs, fish or birds. Man is very destructive to oyster beds through overharvesting and pollution. The Broadkill River was once a very productive oyster area. However, modifications during the construction of the Lewes-Rehoboth Canal and the closing of the old Broadkill Inlet have altered the natural drainage and plushing patterns of the area resulting in little retention of oyster larvae in the river. Water improvement projects, pollution, disease and overfishing have all contributed to the decline in the number of harvestable oysters.

The successful establishment of oyster beds depends upon favorable environmental conditions during each developmental stage. Eggs and sperm cannot tolerate temperatures above $30^{o}C$ or below $15^{o}C$. Salinities below $15‰$ are very poor for egg development, with $22.5‰$ optimum.

Larvae are somewhat more tolerant than eggs to environmental variations. Growth noticeably decreases in salinities of $12.5‰$ or less, but above $15‰$,

most growth is normal. Larvae may also survive for 203 weeks in the absence of food. However, such things as DDT in concentrations of 0.05 ppm produce total larval mortality.

Adult American oysters live in salinities from 7-30‰ and temperatures from 1-36°C. The optimum temperature for adult oysters is about 25°C and rapid changes in either salinity or temperature may be fatal. Suffocation by siltation is a major cause of death among oysters. Petroleum products are also highly damaging to oysters in all stages of development.

The existance of both planktonic and benthic life stages of the American oyster makes it more susceptible to damage from man's activities. The depletion of Delaware's harvestable oyster population should be a clear example of this. The continued alteration of circulation patterns through marine construction, of water temperature through heated effluents, and of turbidity through biological waste and dredging cannot benefit the oyster population.

References

Bolitho, H. 1961. The glorious oyster. Hoizon Press, N. Y.

Galtsoff, P. S. 1964. The American oyster, Crassostrea virginica Gmelin. U. S. Fish and Wildl. Serv., Fish. Bull. #64. 456 pp.

Keck, R. T. 1969. A comparative oyster survey of the Broadkill and Leipsic Rivers. Master's thesis. University of Delaware.

Lippson, A. J. (ed.). 1973. The Chesapeake Bay in Maryland: An atlas of natural resources. Johns Hopkins University Press, Baltimore.

Loosanoff, V. L. and H. C. Davis. 1963. Rearing of bivalve molluscs. In: Advances in marine biology. (F. S. Russell, ed.) Vol. I. Academic Press, London.

Manning, J. H. and H. H. Whaley. 1954. Distribution of oyster larvae and spat in relation to some environmental factors in a tidal estury. Proc. Natl. Shellf. Assoc., Vol. 45: 56-65.

Maurer, D. and L. Watling. 1973. The biology of the oyster community and its associated fauna in Delaware Bay. Del. Bay Rept. Series, Vol. 6.

Tinsman, J. C. 1974. The effects of thermal effluent on the American oyster, Crassostrea virginica Gmelin, in Indian River Bay, Delaware. Master's thesis. University of Delaware.

Rouse, A. M. 1972. Hepatopancreas glycogen concentrations and their relationship to ecdysis in the blue crab, Callinectes sapidus Rathbun. Master's thesis. University of Delaware. 85 pp.

Delaware Statistical Abstract. 1975. Delaware State Planning Office, Thomas Collins Building, Dover, Delaware. 233 pp.

OYSTER DRILLS

Urosalpinx cinerea
Eupleura caudata

Oyster drills constitute a serious menace to the shell fisheries of the world, inflicting heavy damages on young oyster populations. Two such drills, both of which are found in the Delaware area, are the Urosalpinx cinerea (Say) and the Eupleura caudata (Say). Oyster drills are gastropods (snails) of the family Muricidae. More data is available concerning Urosalpinx than Eupleura, however this discussion concerns both genera. Comparisons between the two are made when possible.

The oyster drill is a slow moving, small, predatory snail. Its shell is thick and solid, conically spiralled with longitudinal ribs, in colors ranging from greyish yellow to brown or white. It is usually about 21-25 millimeters long in the Chesapeake Bay (Frederighi, 1931). Its cream colored body fits tightly into the shell. Two tentacles with attached eyes are found on the head. The mouth is at the end of a long proboscis. Locomotion is by use of a foot.

Oyster drills are found along the east coast of North America from Canada to Florida and also in marine and brackish waters of California, Washington and Great Britain. Their extensive distribution is largely due to unknowing transport by man. Local distributions vary from mid-intertidal levels to unknown depths. In the summer, they congregate predominantly on intertidal reefs, pilings, rock surfaces and oyster beds. Delaware Bay supports a sizeable population of oyster drills, much to the detriment of the oyster fishery (Carriker, 1955).

Predation upon shellfish is accomplished by means of a drilling apparatus located in the proboscis. Chemical secretions and a rasping tongue allow

penetration of the shell (Purchon, 1968). Food of the oyster drill may include other drills, limpets, mussels, soft and hard clams, scallops, oysters, small crabs, dead fish and encrusting bryozoans. Preferred foods are barnacles, mussels and oysters.

Feeding begins almost immediately upon hatching. The rate of feeding is determined by the size of the drill and its prey, water temperatures and salinity. Maximum feeding occurs in waters of 25.0-27.5°C (Manzi, 1970b, in Joyce, 1972). T. C. Nelson (in Carriker, 1955) reported a 60 to 80 per cent destruction of oyster spat in the Delaware Bay in 1923. It is probable that Eupleura is more destructive than Urosalpinx (Manzi, 1970a, in Joyce, 1972).

Spawning occurs throughout the summer season, being most intense in June and July. On the average, a female oyster drill will lay 300 eggs in a season (Mackenzie, 1961, in Joyce, 1972). Eggs are deposited in cases which open after twelve to twenty days. Normal development requires salinities of 14‰ or greater. An important aspect of the early development of the oyster drill is that it lacks a free-swimming stage, so that when the egg case opens, a crawling juvenile emerges. This greatly restricts the natural migration possible by these snails.

At the end of the first year, the oyster drill can be 8-20 millimeters long. Growth rates fluctuate with local conditions of temperature, food sources, and population density. Maturity is reached in one to three years, at lengths of 35-40 millimeters.

The oyster drill is remarkably adaptable. Both Urosalpinx and Eupleura are euryhaline, but have a lower salinity limit of 15‰. Temperatures from -3 to 30°C have been known to support the oyster drill in nature. Usually, lower temperatures cause the drill to hibernate by burrowing into

Figure 112

SPECIES Eupleura caudata

Common Name Oyster Drill

Spawning Period Throughout summer; maximum June-July

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults					
Eggs		>14‰			
Larvae					
Juvenile					
Adult	3-30°C (8)	10-30‰ (8)			

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)

For approximate distribution limits of these oyster parasites refer to Figure 111, Page 428.

SPECIES Urosalpinx cinerea

Common Name Oyster drill

Spawning Period Throughout summer; maximum June-July

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults					
Eggs		14‰			
Larvae					
Juvenile					
Adult	3-30°C (8) Maximum feeding 25-27.5°C	15‰ to 27‰ (67) 10‰ to 30‰ (8)			

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)

the substrate (Carriker, 1953).

Overall, the oyster drill is a formidible enemy of shellfish. It has a hard, well sealed shell, few natural enemies, and is quite adaptable to varying environmental conditions. The young are well protected in an egg case. There are, however, a few characteristics which might give man a chance to control the oyster drill. Its limited migratory ability should allow containment of drill populations if enough care were taken to prevent its transfer in oyster planting operations. It is also possible to grow oysters in salinities which are fatal even to the oyster drill. The permeability of the drill egg cases make the young drills susceptible to chemical poisons.

In the future, control of the drill will probably reflect much of its life history characteristics. At the present time, dredging, trapping, and poisoning are all used in drill population control attempts, with questionable success. However, it is now realized that careless planting of oysters which carry oyster drills can result in a tremendous loss of oyster production. Efforts should continue to restrict the spreading and control the existing population of oyster drills in order to insure future oyster harvests.

References

Carriker, M. R. 1953. A review of those aspects of the biology of the oyster drill Urosalpinx cinerea (Say) fundamental to its control. Convention papers, 1953 Nat. Shellfish. Assoc.

Carriker, M. R. 1955. Critical review of biology and control of oyster drills Urosalpinx and Eupleura. U.S. Dept. of Interior, Fish and Wildl. Serv., Spec. Sci. Rept., Fisheries No. 148.

Frederighi, H. 1931. Studies on the oyster drill (Urosalpinx cinerea Say). Bull. U.S. Bur. Fish 47: 83-115.

Joyce, E. A. 1972. A partial bibliography of oysters, with annotations. Mar. Res. Lab., Fla. Dept. Nat. Res., St. Petersburg, Fla. Spec. Sci. Rept. No. 34.

Mackenzie, C. J., Jr. 1961. Growth and reproduction of the oyster drill Eupleura caudata in the York River, Virginia. Ecol. 42(2): 317-337.

Manzi, J. J. 1970a. The combined effects of salinity and temperature on the feeding, reproductive and survival rates of Eupleura caudata (Say) and Urosalpinx cinerea (Say). Proc. Nat. Shellfish. Assoc. (1969) 60.

Manzi, J. J. 1970b. The effect of temperature on the feeding rate of the rough oyster drill Eupleura caudata (Say). Proc. Nat. Shellfish. Assoc. (1969) 60.

Nelson, T. C. 1923. Investigations of the oyster drills Urosalpinx and Eupleura. Rept. N. J. Agr. Exp. Sta. 1922: 334-335.

Purchon, R. D. 1968. The biology of the mollusca. Pergamon Press, N.Y.

THE BLUE CRAB

Callinectes sapidus (Rathbun)

The blue crab, Callinectes sapidus,is a crustacean in the family Portunidae which is characterized by having the last pair of legs flattened into paddles for use in swimming. The name of this valuable shellfish, Callinectes sapidus, can be translated as "savory graceful swimmer". The blue crab is found on a variety of bottom types in estuaries and shallow oceanic water from Connecticut to Texas.

The larger and more powerful male has an abdomen in the form of an inverted "T" or a "pop-top" opener. The legs of the mature male are bright blue. The immature female has a triangular abdomen, while the mature female has a broad, rounded abdomen and legs tinged with red.

The young of the blue crab are hatched from eggs which when first laid are about .25 millimeter (.01 inch) in diameter and are orange or yellow in color. As the eggs develop while being held by the female under her abdomen, they change to a very dark color due to the color of the eyes of the larvae. The crabs hatch into a larval form called the zoea stage which is the first of three stages of development. The second larval stage is the megalops stage, and the final stage has the true crab shape. The blue crab proceeds from stage to stage and attains growth through a process known as molting in which the exoskeleton is shed and the crab grows rapidly in size through water absorption before the next exoskeleton is formed.

The first larval stage, zoea, is microscopic in size (1.0 millimeter) (.04 inch) and is very unlike the adult crab. The zoea has a large rostral spine, a pair of smaller lateral spines, and a pair of large compound eyes on the large

carapace or head. The crab in this stage is free swimming, moving backwards by jerking its abdomen up against the lower side of its body.

The next larval stage, megalops, more closely resemble the adult blue crab, having a rather flattened body with an abdomen shorter and wider than the zoea. However, the eyes of the megalops are still more prominent than in the adult and the last pair of legs have not yet been modified into paddles. The megalops swims freely, but it can also walk along the bottom.

The last metamorphysis transforms the megalops form into the crab stage. Now the animal closely resembles the adult except for its eyes which are on large, protruding stalks. The blue crab is 0.32 centimeter (.12 inch) wide at this point, but it will grow through successive moltings to the adult size of 13-18 centimeters (5-7 inches) in width. Approximately twenty-five moltings transpire from hatching as a zoea to full maturity.

Mating occurs only once in the lifetime of the female blue crab while the male can fertilize several females. Timing of the mating is critical since the female is only capable of mating immediately following her last molt in which the abdomen changes from a triangular to a broad, rounded shape. For a few days prior to the female's molting and copulation the male carries the female around using three pairs of his walking legs. Immediately following shedding of the female's exoskeleton copulation is completed with spermatozoa being transferred to the female's sperm sacs which supply sperm for each of her two or three spawnings. Each spawning produces one-half to two million eggs.

Hatching can occur in about 15 days following spawning depending on water temperature, but often if spawning occurs in the fall, hatching is delayed until the following spring. The blue crab matures in twelve-fourteen months and is therefore able to reproduce during the summer following hatching.

FIGURE 113
BLUE CRAB

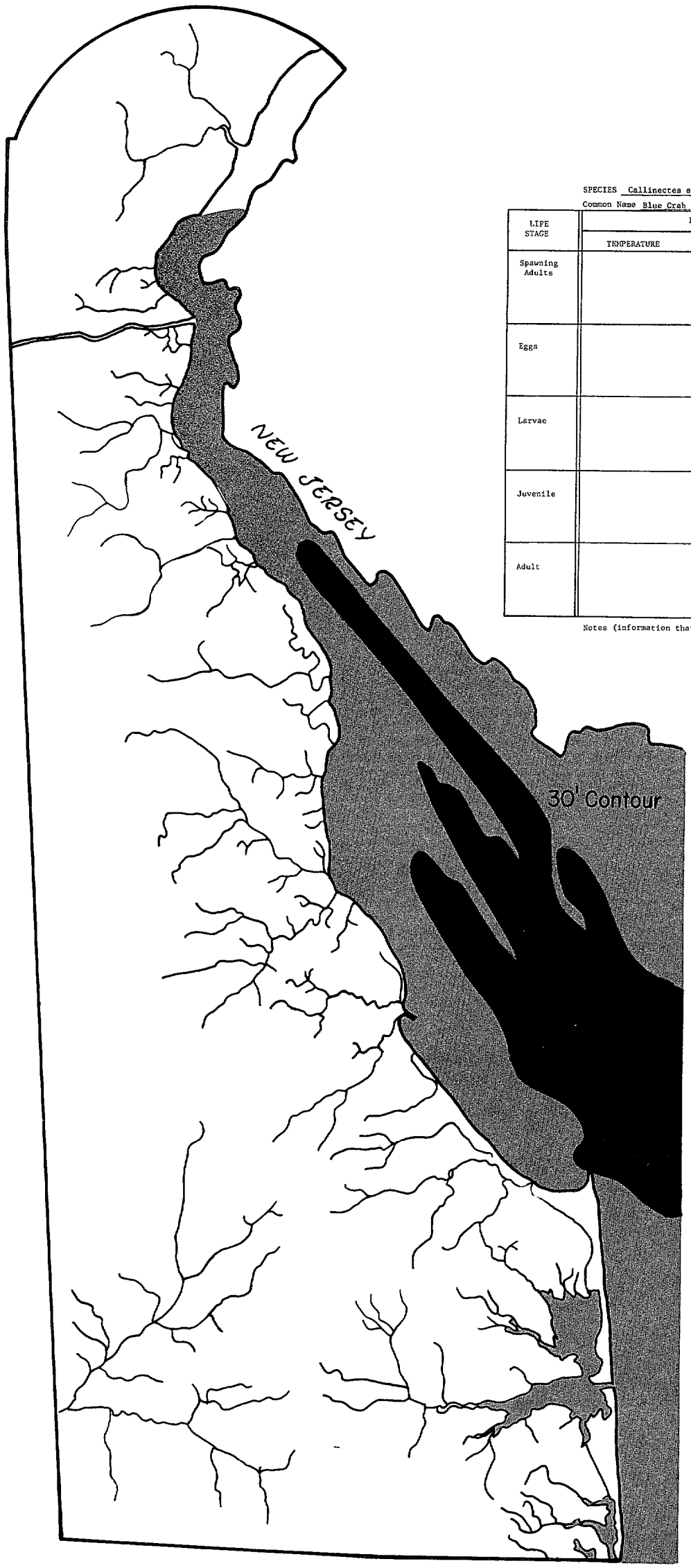
SPECIES Callinectes sapidus

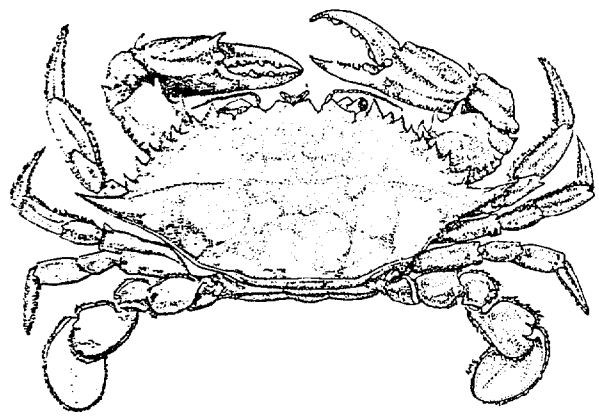
Common Name Blue Crab

Spawning Period

LIFE STAGE	ENVIRONMENTAL REQUIREMENTS				
	TEMPERATURE	SALINITY	DISSOLVED OXYGEN	TURBIDITY	
Spawning Adults					
Eggs					
Larvae					
Juvenile					
Adult		0‰ to 34‰ (67) 0‰ tolerance only at high temperatures (28-30°C) (53)			

Notes (information that relates to Delaware as, spawning places, nursery areas, etc.)





LEGEND

PROBABLE CONCENTRATED WINTER DISTRIBUTION MALES ON DEEPER PORTIONS OF BAY, FEMALES MIGRATE SOUTH.

SUMMER DISTRIBUTION

Blue crabs eat a variety of foods, both zooplankton and pyytoplankton, macroscopic plants, other blue crabs which may be molting, recently dead animals and young shellfish. They are also capable of catching and eating small fish. Immediately following molting the blue crabs are vulnerable to predation by a variety of carnivore predators. To avoid predation at this time the crab burrows into the mud or hides in various cavities.

An intensive study in the 1950's disclosed considerable size variation among mature female blue crabs. Significant variation was noted within the Delaware Bay population which from data on adult size, structure and migration appears to be just one population. Separate populations are found in Chesapeake and Chincoteague Bays; on the average, the Chincoteague Bay crab was found to be smaller than either the Chesapeake or Delaware Bay crab. Differences in size may be the result of environmental causes. Salinity, however, was eliminated as a causitive factor following further laboratory investigations.

The blue crab was found to distribute itself in Delaware Bay according to salinity and water temperature. Generally the crabs are in lower salinity water in the summer and higher salinity water during the winter. Following mating in the summer which normally occurs in lower salinity water, the female returns to higher salinity water to spawn. After hatching the larvae move toward lower salinity water to mature.

Commercial crabbers in Delaware follow the major migrations of the blue crabs and use gear appropriate for the depth of water and behavior of the crab. During the summer only crab pots can be used to catch crabs. They are baited and set out in lines in relatively shallow depths. During the winter only crab dredges can be used to collect the semi-dormant crabs which burrow into the deeper portions of the bay. Sport fishing for crabs is limited to shallow

water during the summer using pots, nets or traps, yet accounts for a large share of the total weight of crabs landed.

The value of the blue crab landings in Delaware are second only to the clam fishery. Commercial landings in 1973, the last year for which figures are available, were 2,373,400 pounds with a value of $653,000, which was more than double the quantity caught in 1971 and five to six times the landings in the late 1960's. There is no doubt that much more crab is taken each year than the statistics relate due to fishing by residents and vacationers.

The fact that crabs are so numerous and ubiquitous portends their great importance in the estuary. They act both as predators and scavengers and therefore help clear the estuary of dead plant and animal material. In this way, crabs act as recyclers of nutrients and energy, by disposing of unwanted food sources (rotting fish, detritus) and relinquishing this energy to higher trophic levels as birds, larger fishes and humans. Those who have not availed themselves of backfin crab meat have certainly missed one of the choice delights of the Delaware estuary.

References

Churchill, E. P., Jr. 1918. Life history of the blue crab. Bull. Bur. Fish. 36: 91-128.

Cronin, L. E. 1954. Blue crab studies. Biennial Report, 1953-54. Mar. Lab. Rept., Dept. Biol. Sci., Univ. of Delaware. No. 2. pp. 65-70.

Haefner, P. A., Jr. 1962. On the growth increment of blue crabs, Callinectes sapidus Rathbun, during ecolysis in different salinity waters. Ph.D. dissertation. University of Delaware. 43 pp.

Porter, H. J. 1955. Variation in morphometry of the adult femal blue crab, Callinectes sapidus Rathbun. Master's thesis. University of Delaware. 69 pp.

Porter, H. J. 1956. Delaware blue crab. Estuarine Bull. 2(2): 1, 3-5.

ZOOPLANKTON

The small microscopic animals known collectively as the zooplankton represent some of the most important organisms in the estuaries. As primary consumers, they are the critical link between the primary producers--the plants--and the higher level consumers--the fish. Zooplankton feed on various types of plant material and, in turn, are fed upon by the fish and other predators. To most people, the fish are the most familiar and important animals in the estuaries, but without these very small inconspicuous animals, a large fish population would not be possible.

Many different kinds of organisms representing many different systematic groups contribute to the zooplankton population. It is impossible at this time to say actually how many different zooplankton organisms there are in this area. Study of these organisms is somewhat difficult for their numbers and distributions change yearly, seasonally, and even daily, and their small sizes create unique sampling and identification problems for the scientist. Sufficient study has been done, however, to at least indicate what seem to be some of the more important zooplankton animals in the Delaware region. Although the populations of these individual species fluctuate greatly, they do seem to contribute the most to the zooplankton productivity.

Ten species, representing eight genera, seem to be the most common: Acartia tonsa, Eurytemora hirundoides, E. affinis, Pseudodiaptomus coronatus, Centropages typicus, C. hammatus, Temora longicornis, Cyclops viridis, Gammarus fasciatus and Neomysis americana. The first eight of these are small crustaceans known as copepods, the most common zooplankton group. Gammarus is a member of the amphipod group and Neomysis of the mysid group.

FIGURE 114

COPEPOD – SUMMER DISTRIBUTION

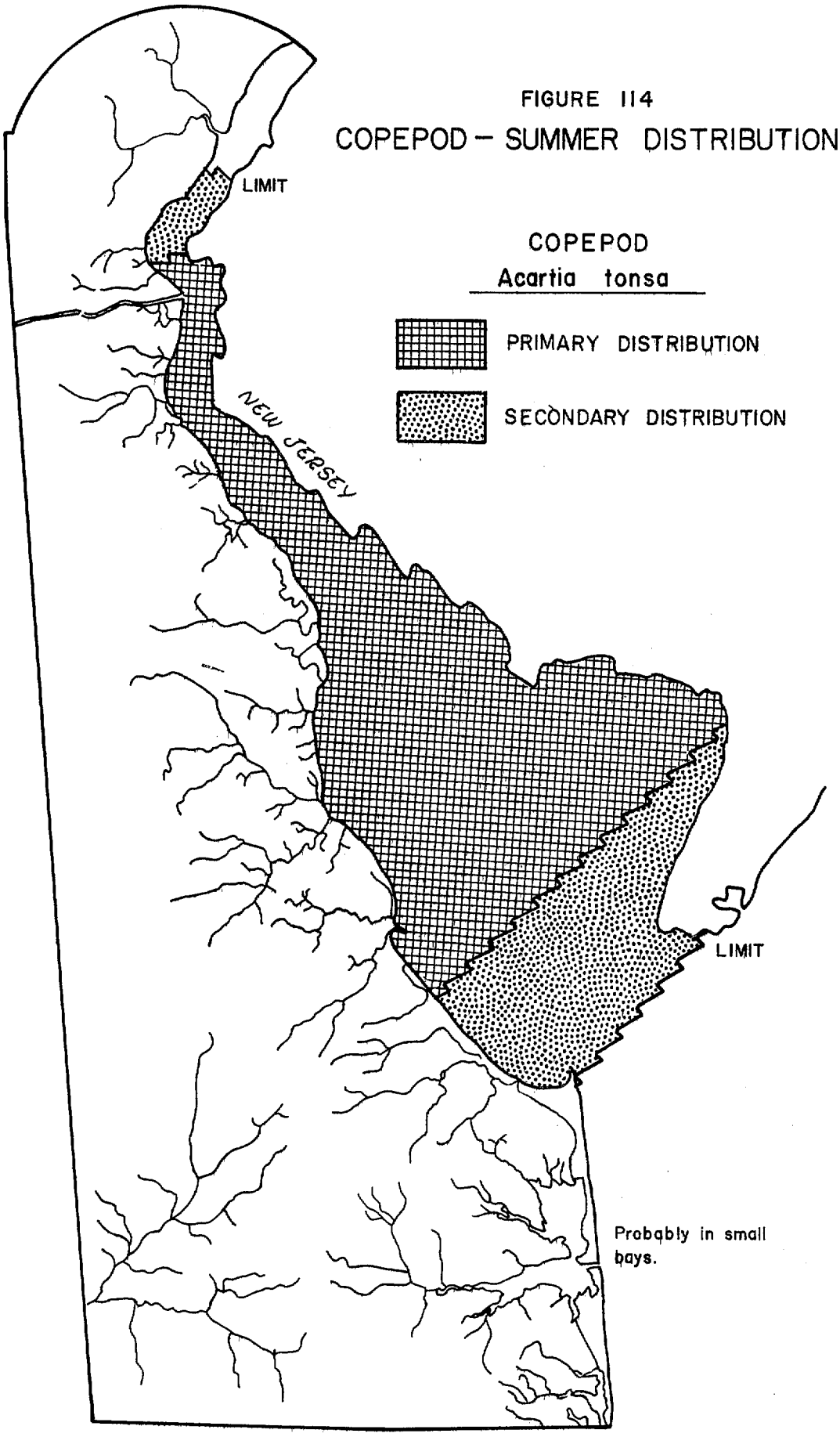
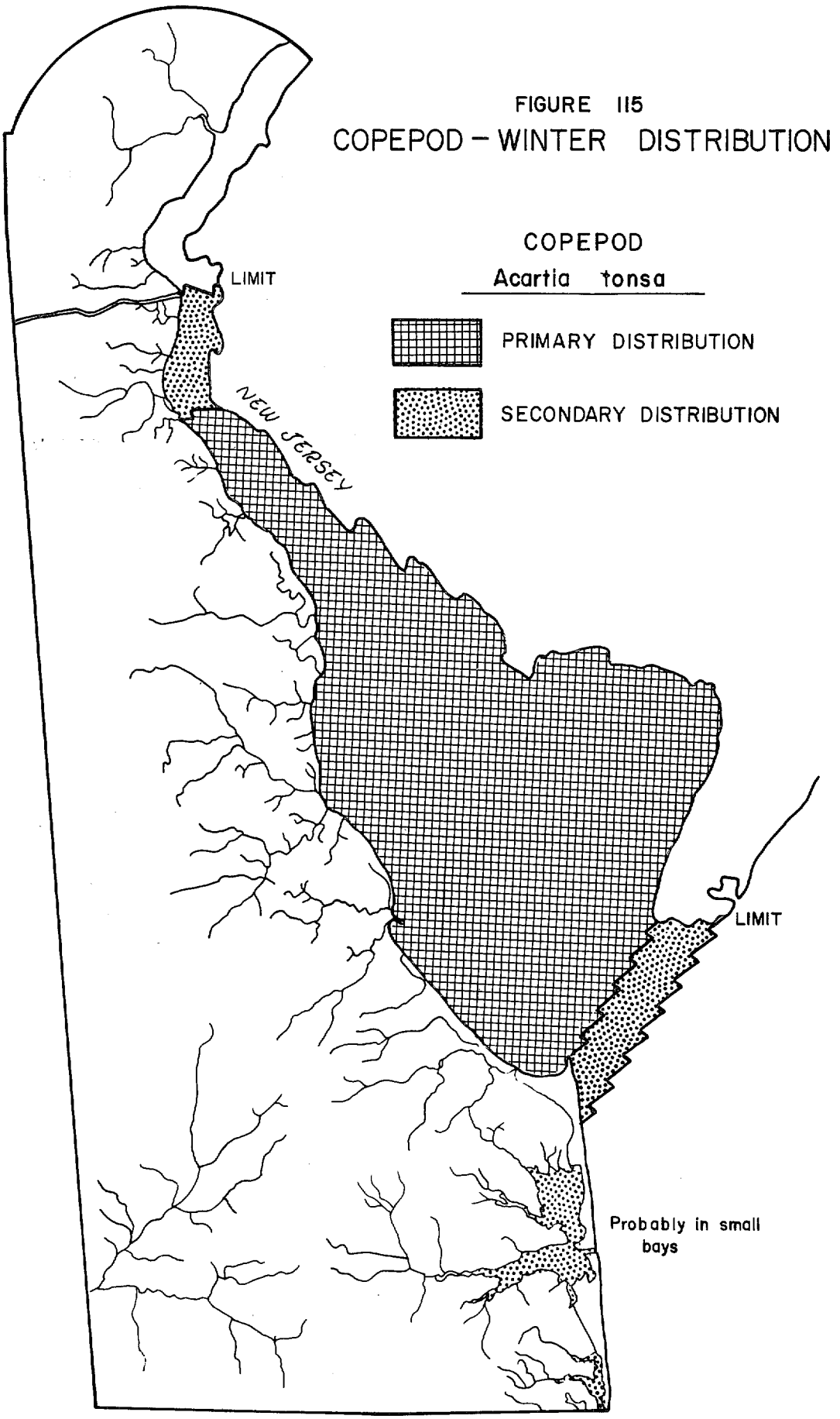


FIGURE 115

COPEPOD – WINTER DISTRIBUTION



FROM: SHUOTER (1958), DEEVEY (1960), BISHOP (1963), CRONIN ET AL (1962), JENSEN (1974)

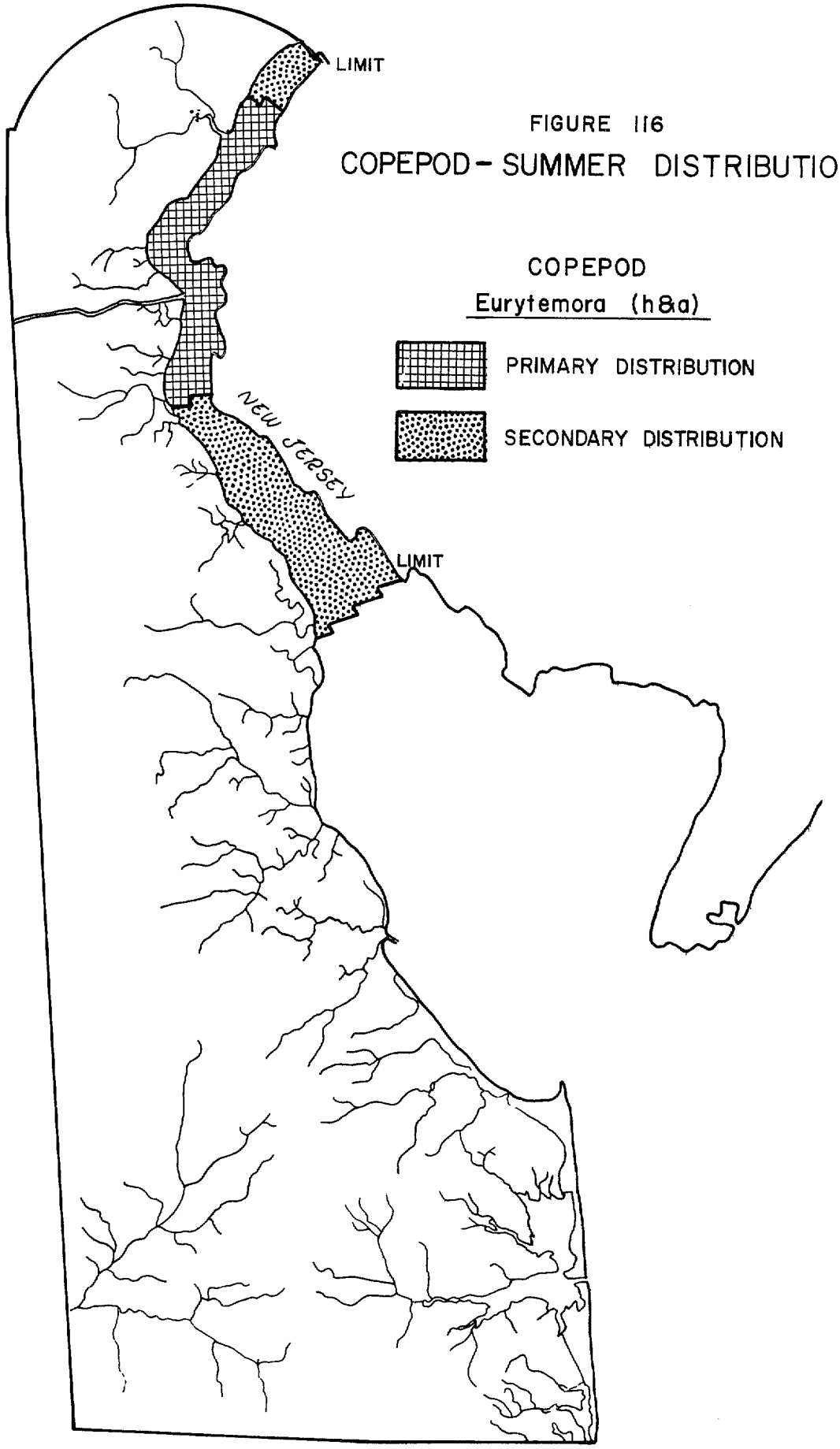


FIGURE 116

COPEPOD - SUMMER DISTRIBUTION

COPEPOD

Eurytemora (h&a)

PRIMARY DISTRIBUTION

SECONDARY DISTRIBUTION

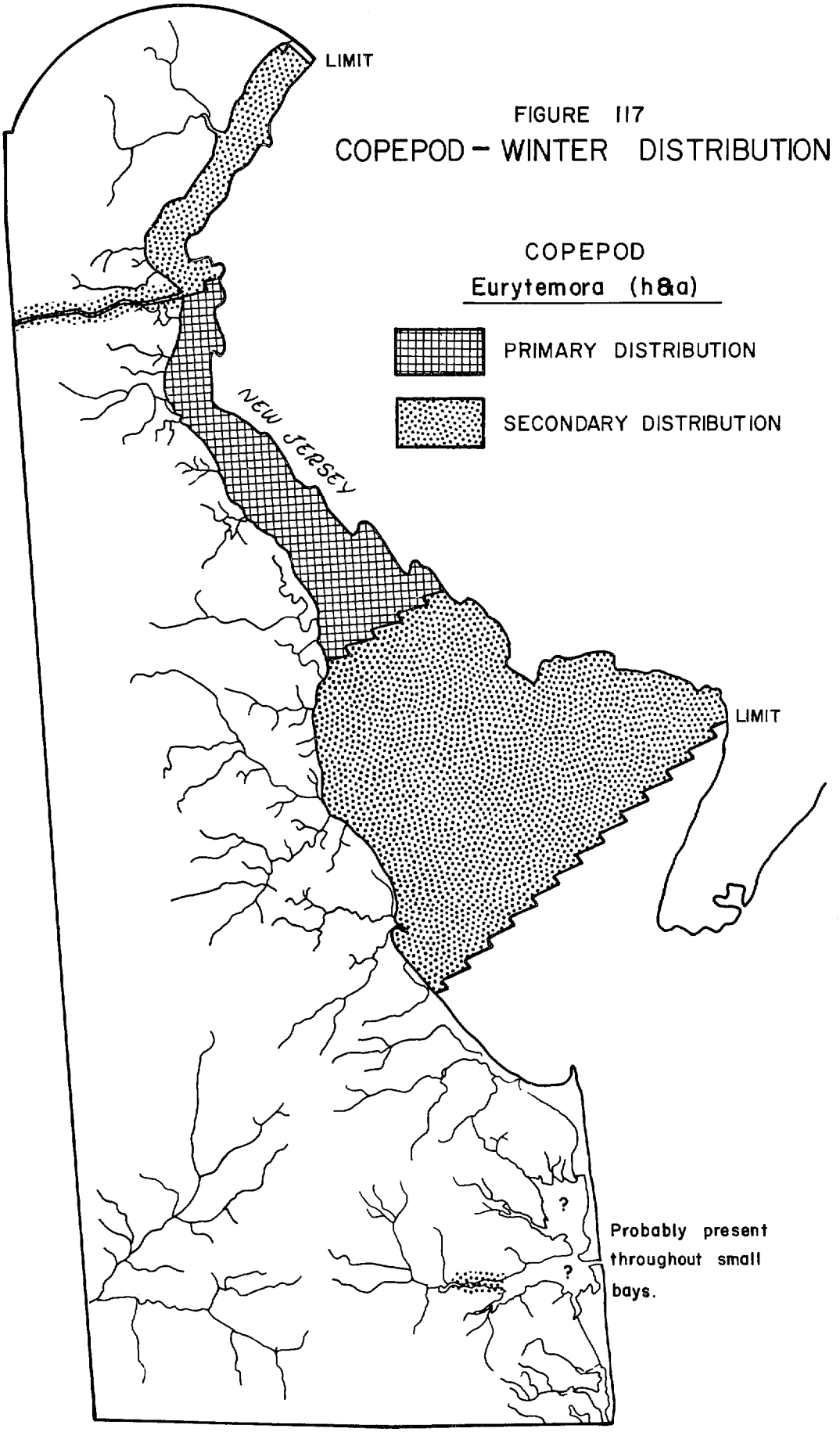


FIGURE 117

COPEPOD – WINTER DISTRIBUTION

COPEPOD

Eurytemora (h&a)

PRIMARY DISTRIBUTION

SECONDARY DISTRIBUTION

FROM: CRONIN ET AL (1962), DEEVEY (1960), SHUOTER (1958), DELAWARE ECOLOGICAL SURVEY (1973), ICTHYOLOGICAL ASSOCIATES (1970-73).

FIGURE 118

COPEPOD - SUMMER DISTRIBUTION

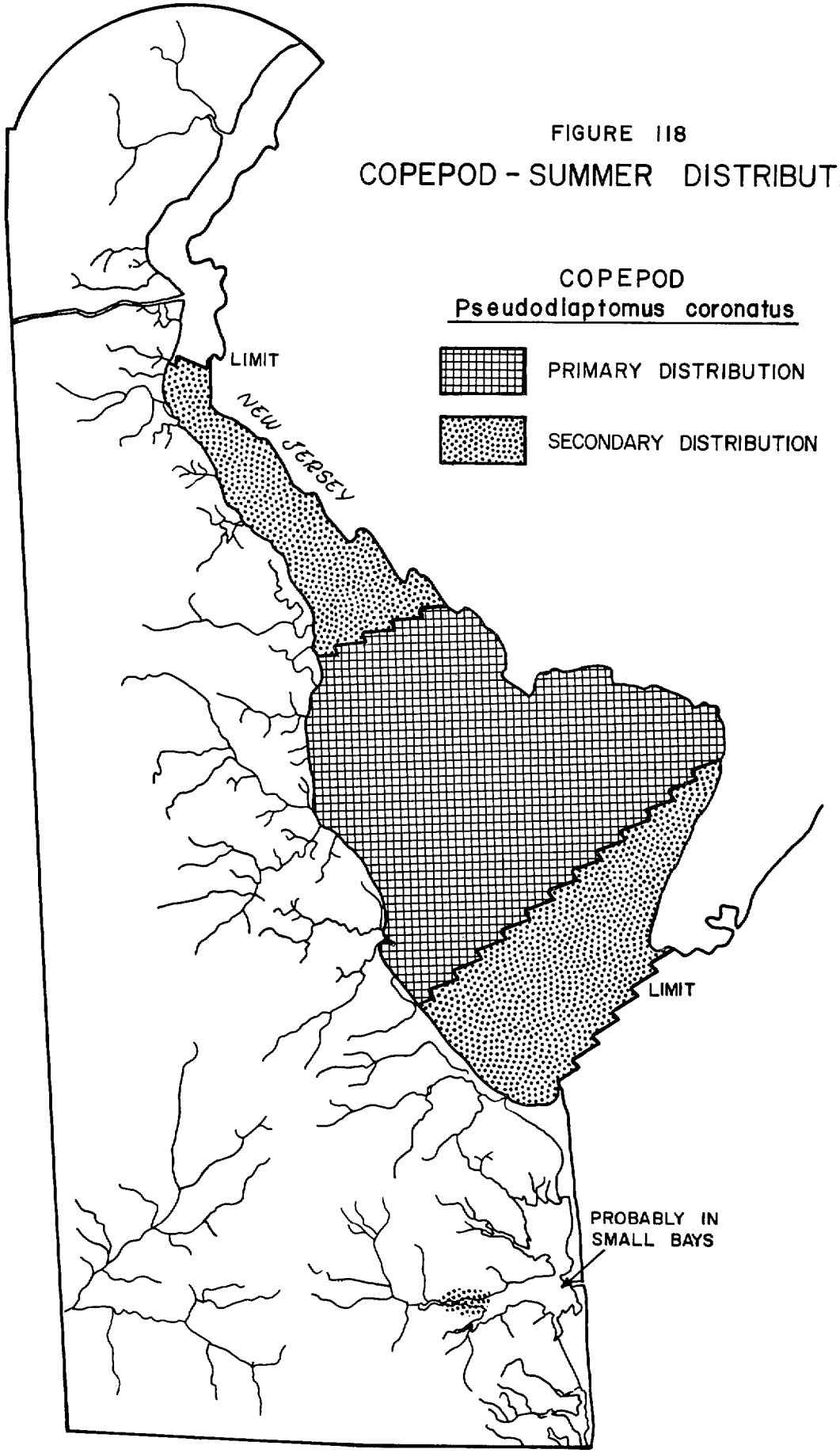
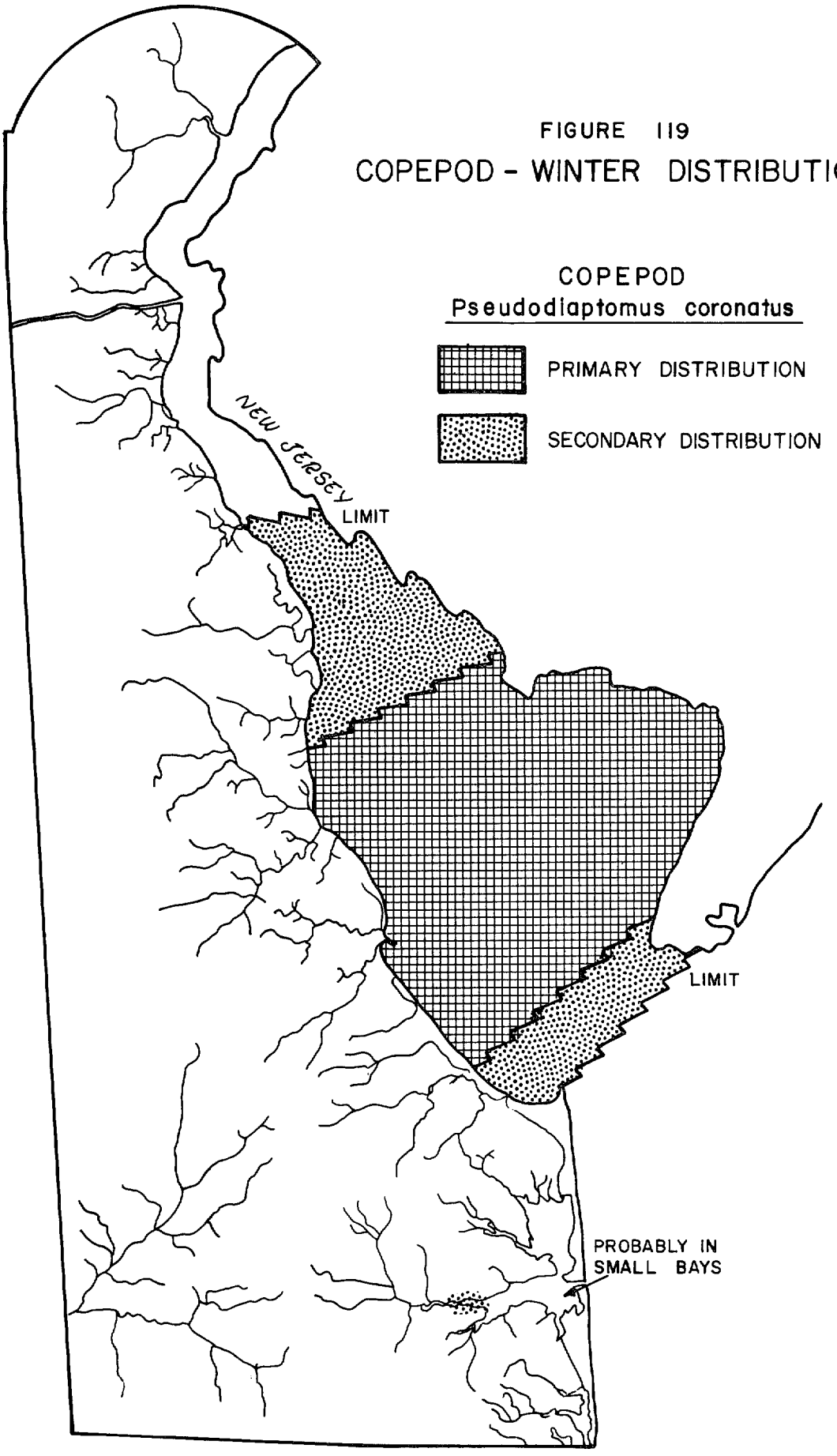


FIGURE 119

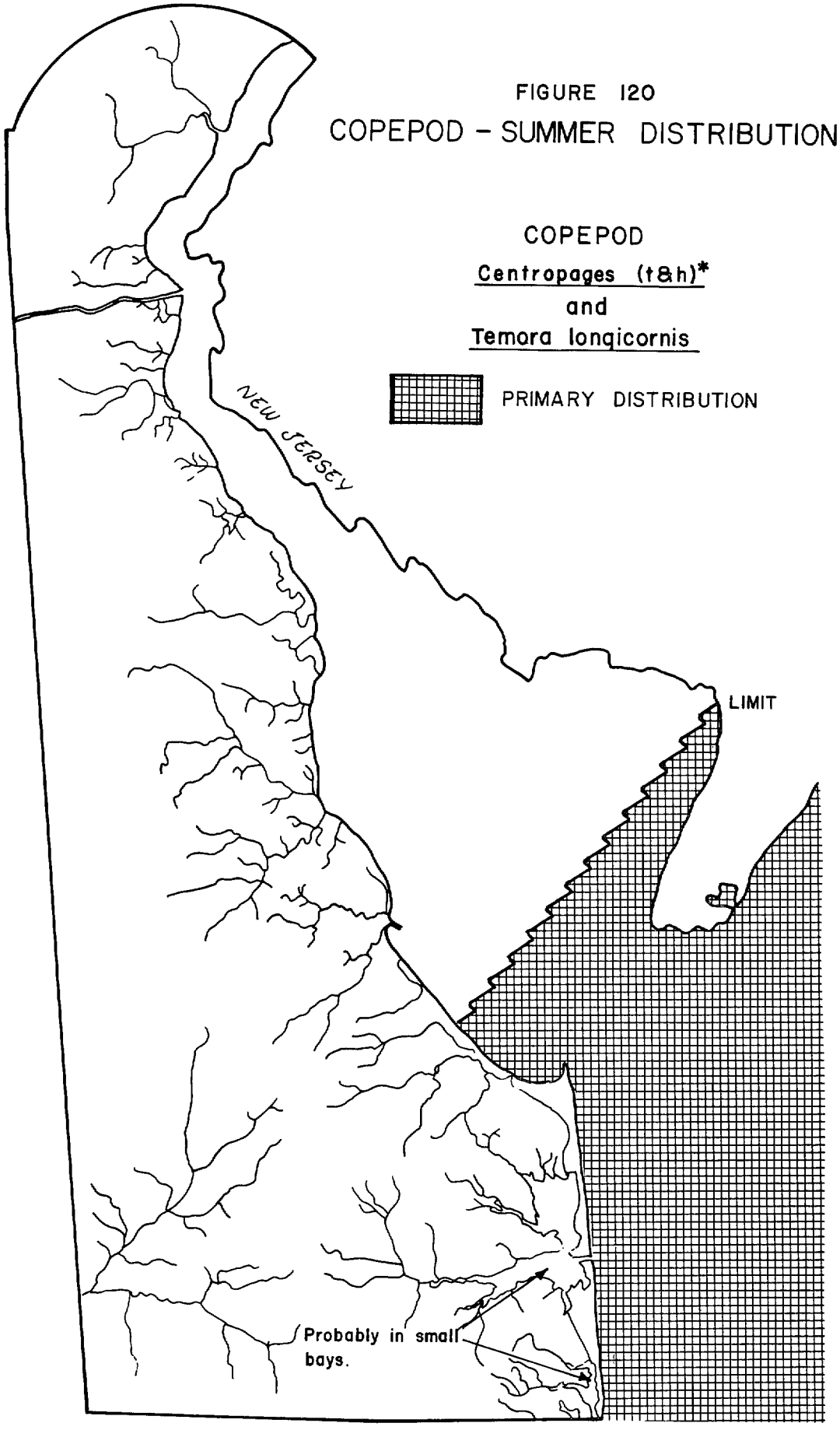
COPEPOD - WINTER DISTRIBUTION



FROM: CRONIN ET AL (1962), ICHTHYOLOGICAL ASSOCIATES (1970-73), ECOLOGICAL ANALYSTS (1974).

FIGURE 120

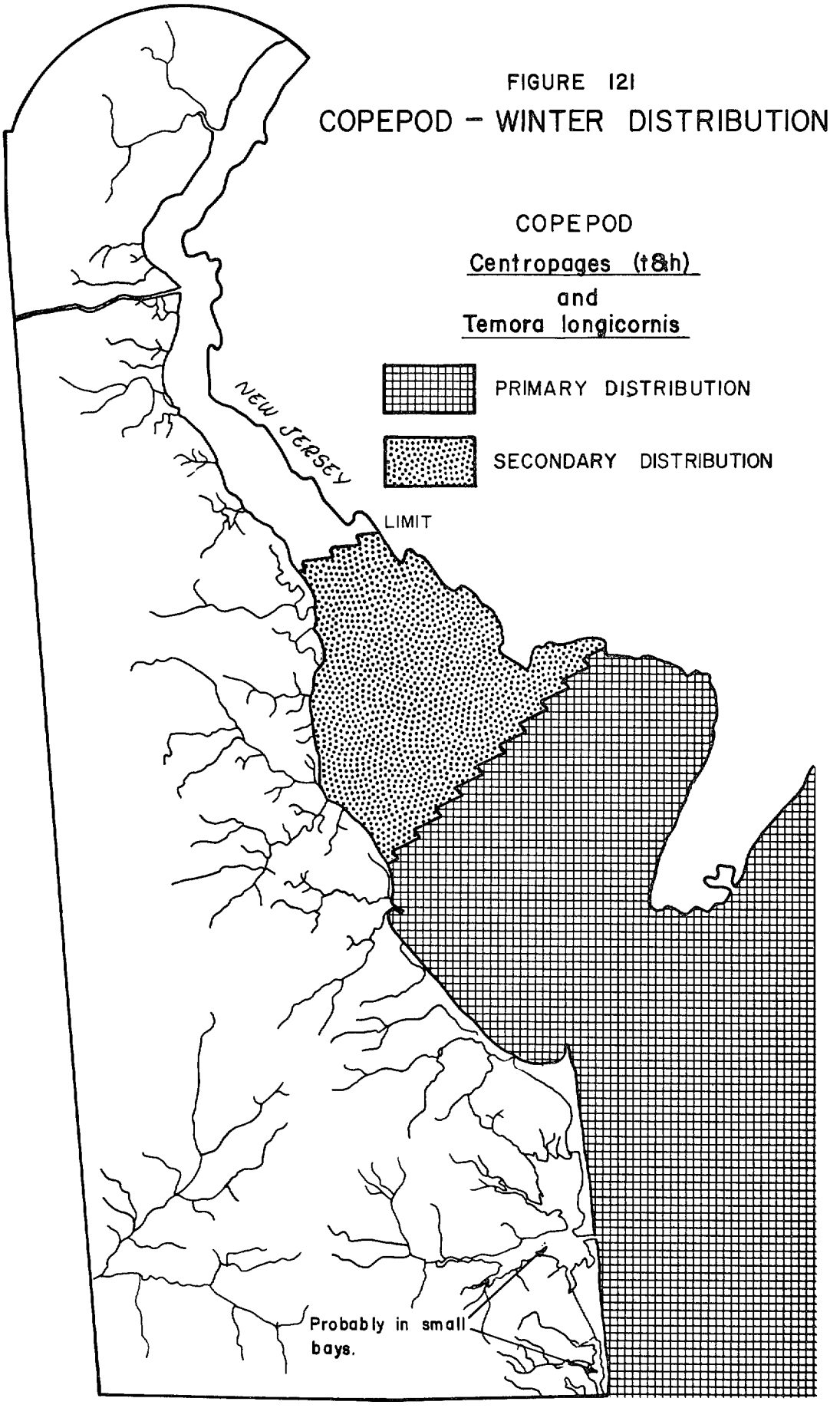
COPEPOD - SUMMER DISTRIBUTION



*CENTROPAGES TYPICUS AND C. HEMATUS COUNTED TOGETHER.

FIGURE 121

COPEPOD – WINTER DISTRIBUTION



FROM: CRONIN ET AL (1962)

FIGURE 122

COPEPOD – SUMMER DISTRIBUTION

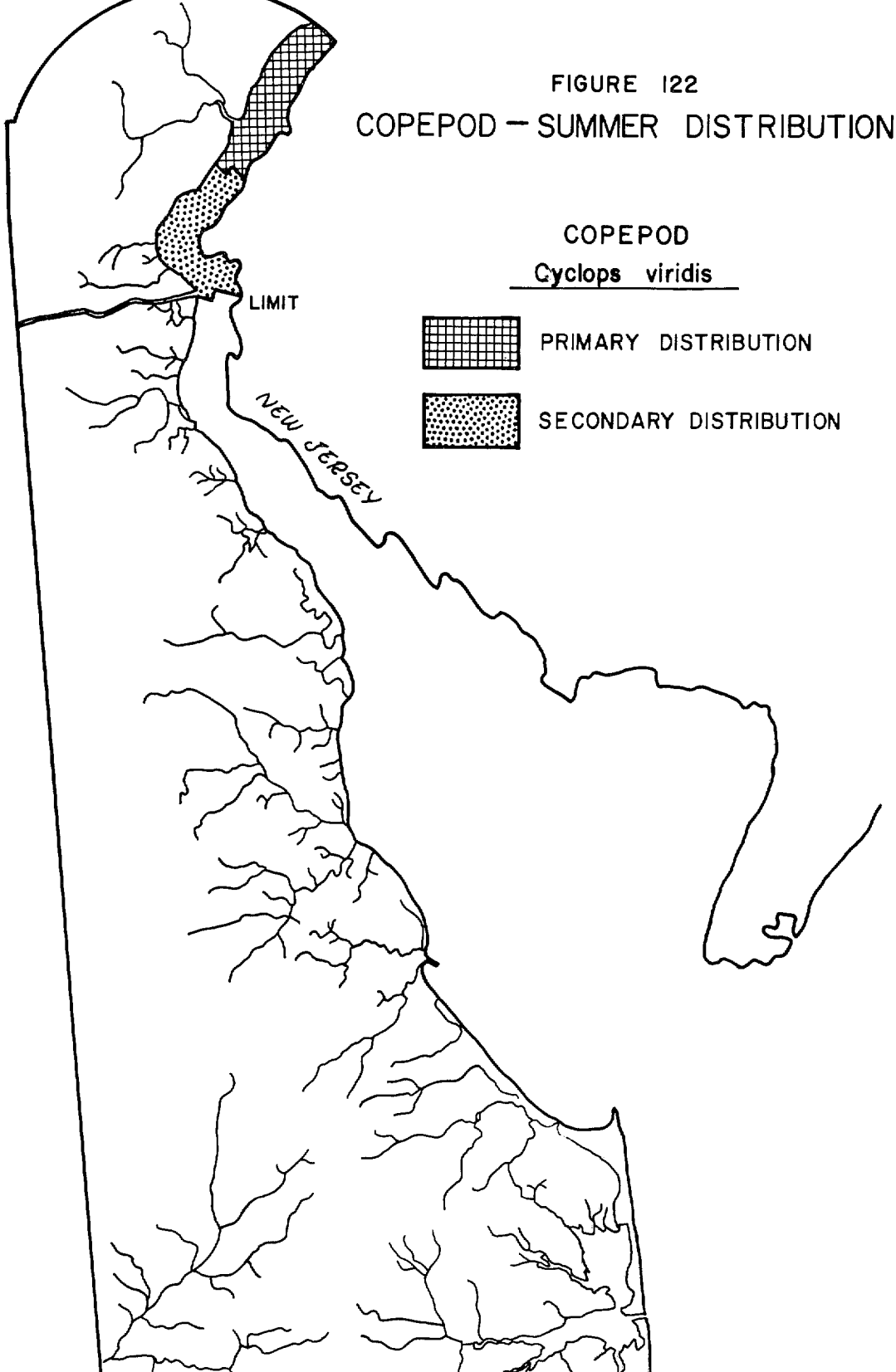
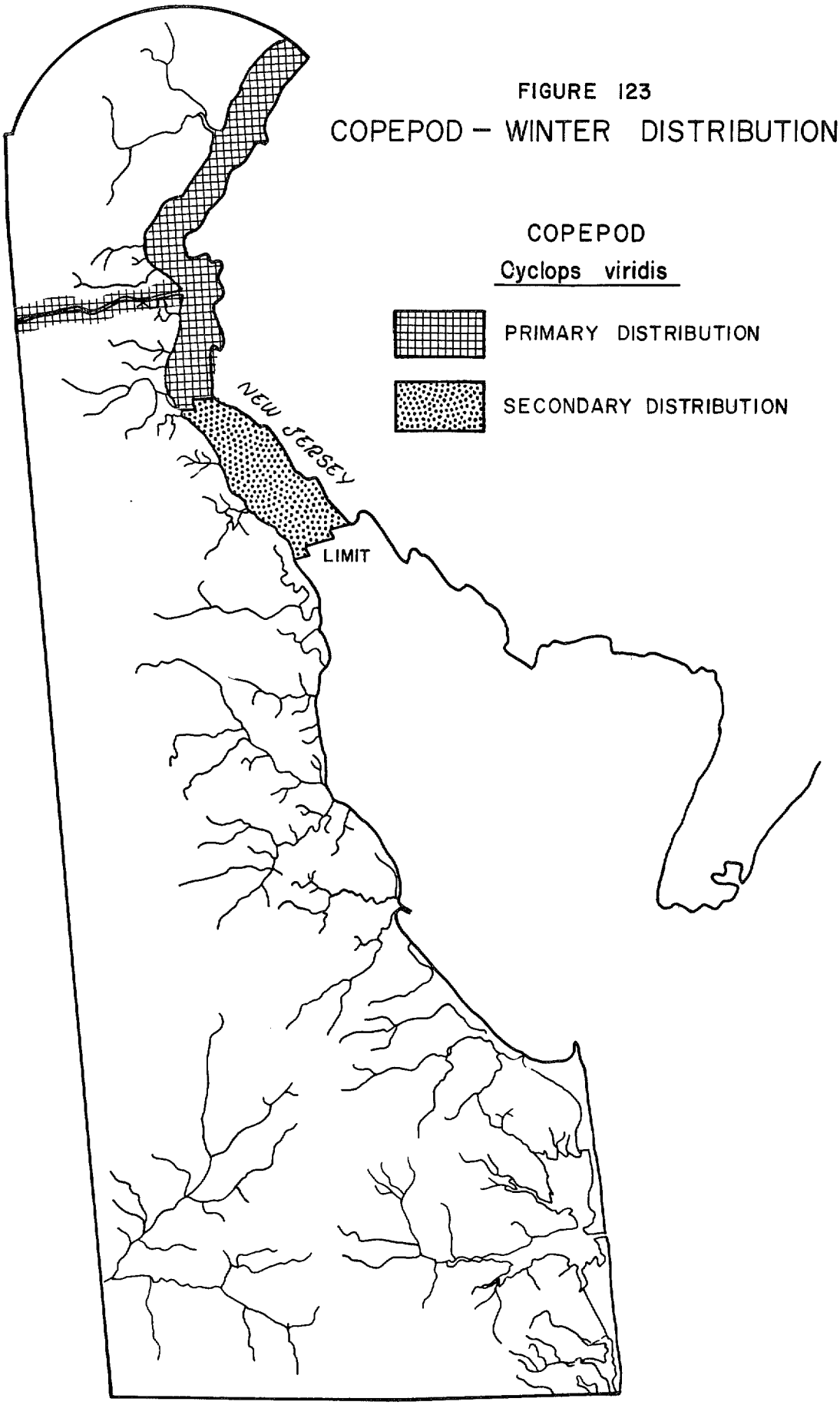


FIGURE 123

COPEPOD – WINTER DISTRIBUTION



FROM: DEEVEY (1960), CRONIN ET AL (1962), DELAWARE ECOLOGICAL SURVEY (1973)

FIGURE 124

AMPHIPOD – SUMMER DISTRIBUTION

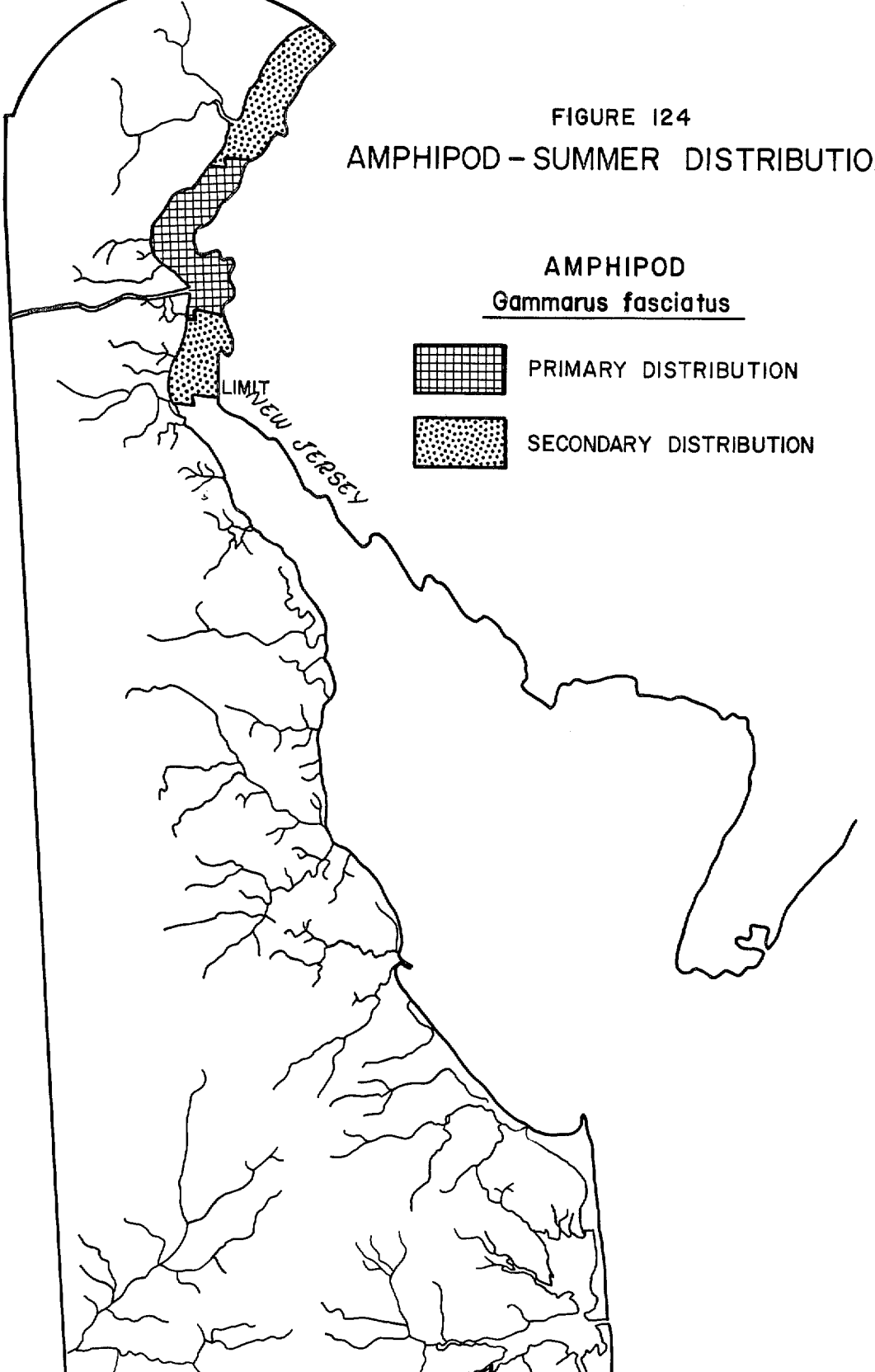
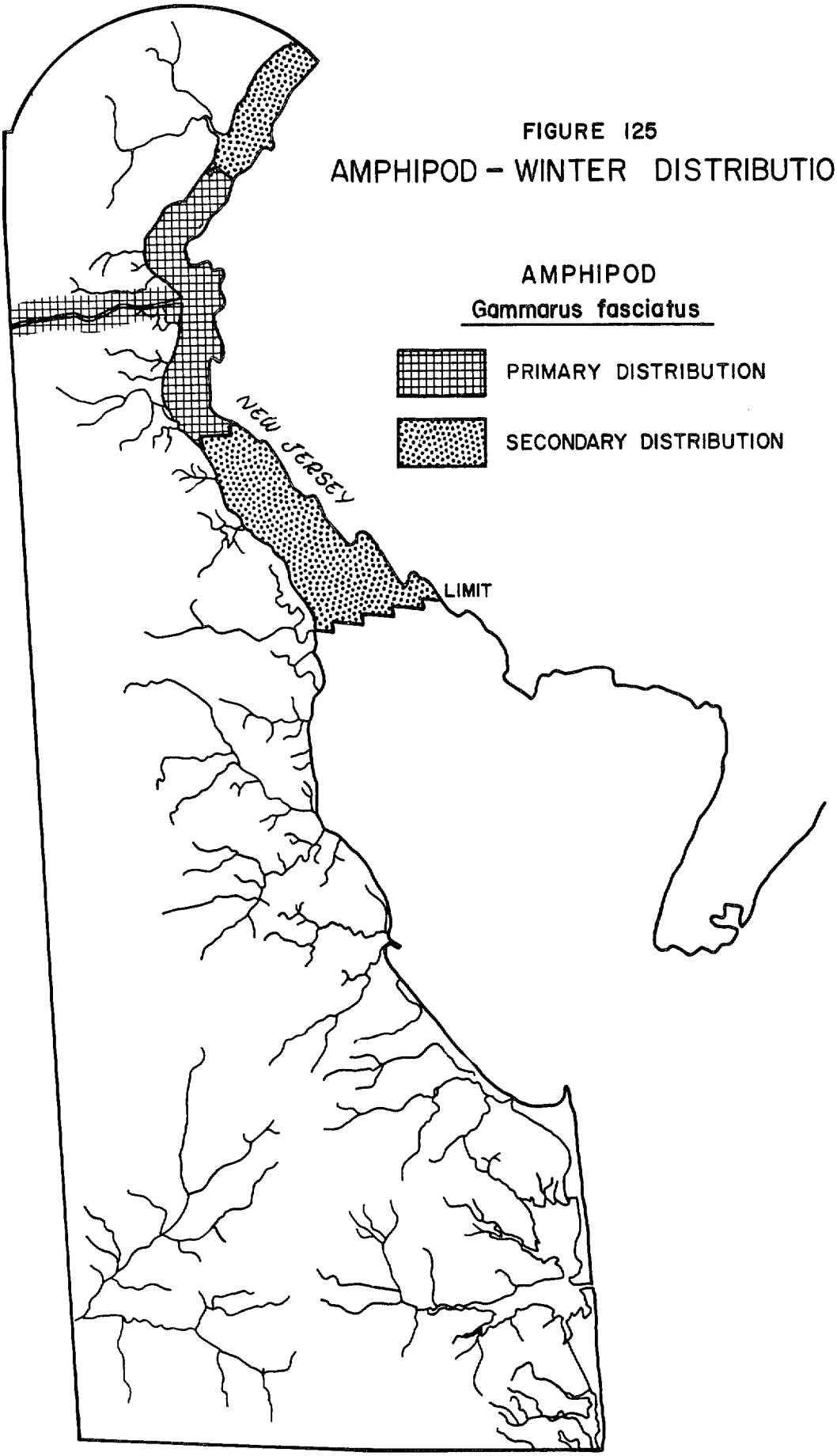


FIGURE 125

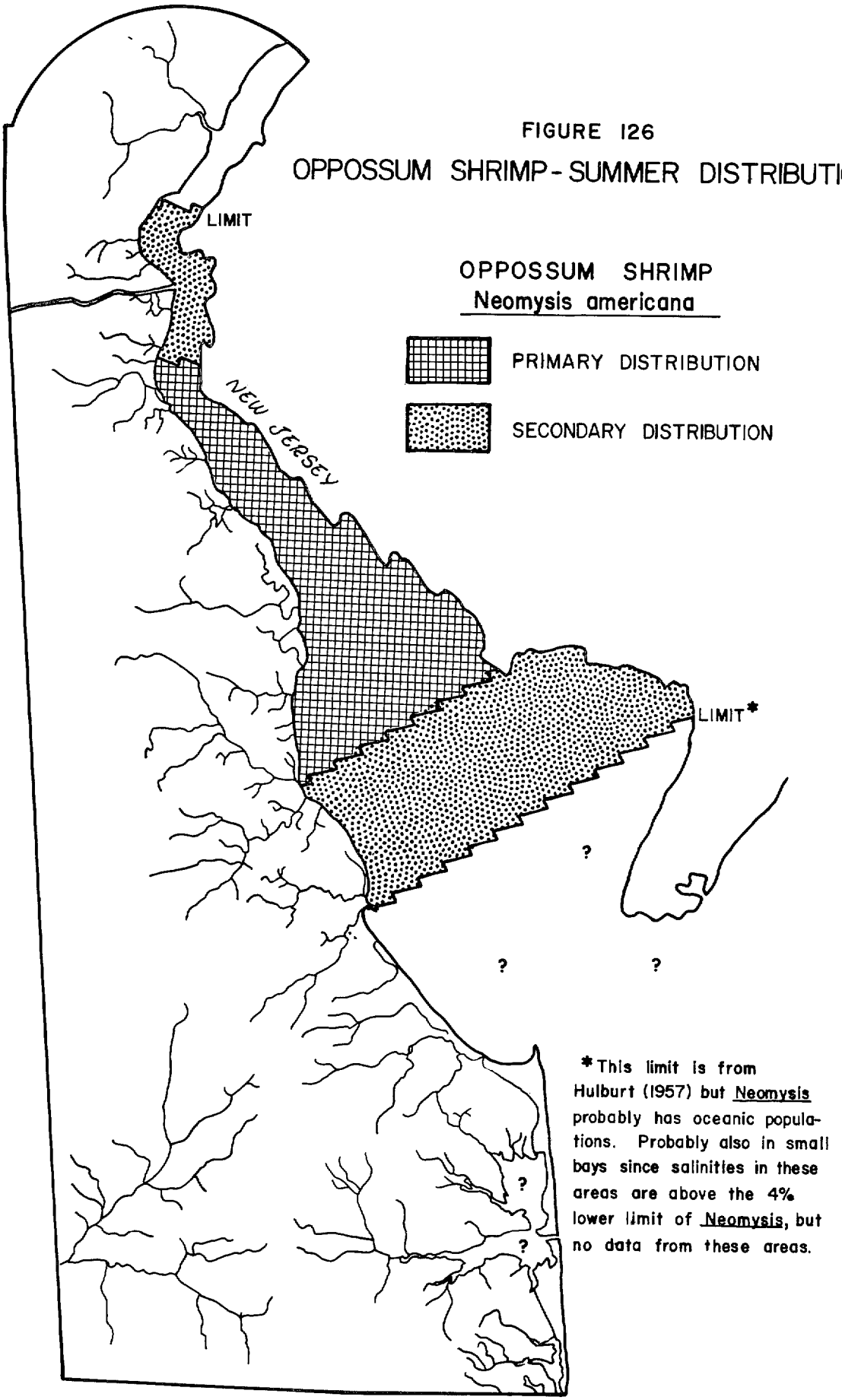
AMPHIPOD – WINTER DISTRIBUTION



FROM: CRONIN ET AL (1962), DEEVEY (1960), SHUOTER (1958), ICTHYOLOGICAL ASSOCIATES (1970 73), DELAWARE ECOLOGICAL SURVEY (1973)

FIGURE 126

OPPOSSUM SHRIMP - SUMMER DISTRIBUTION

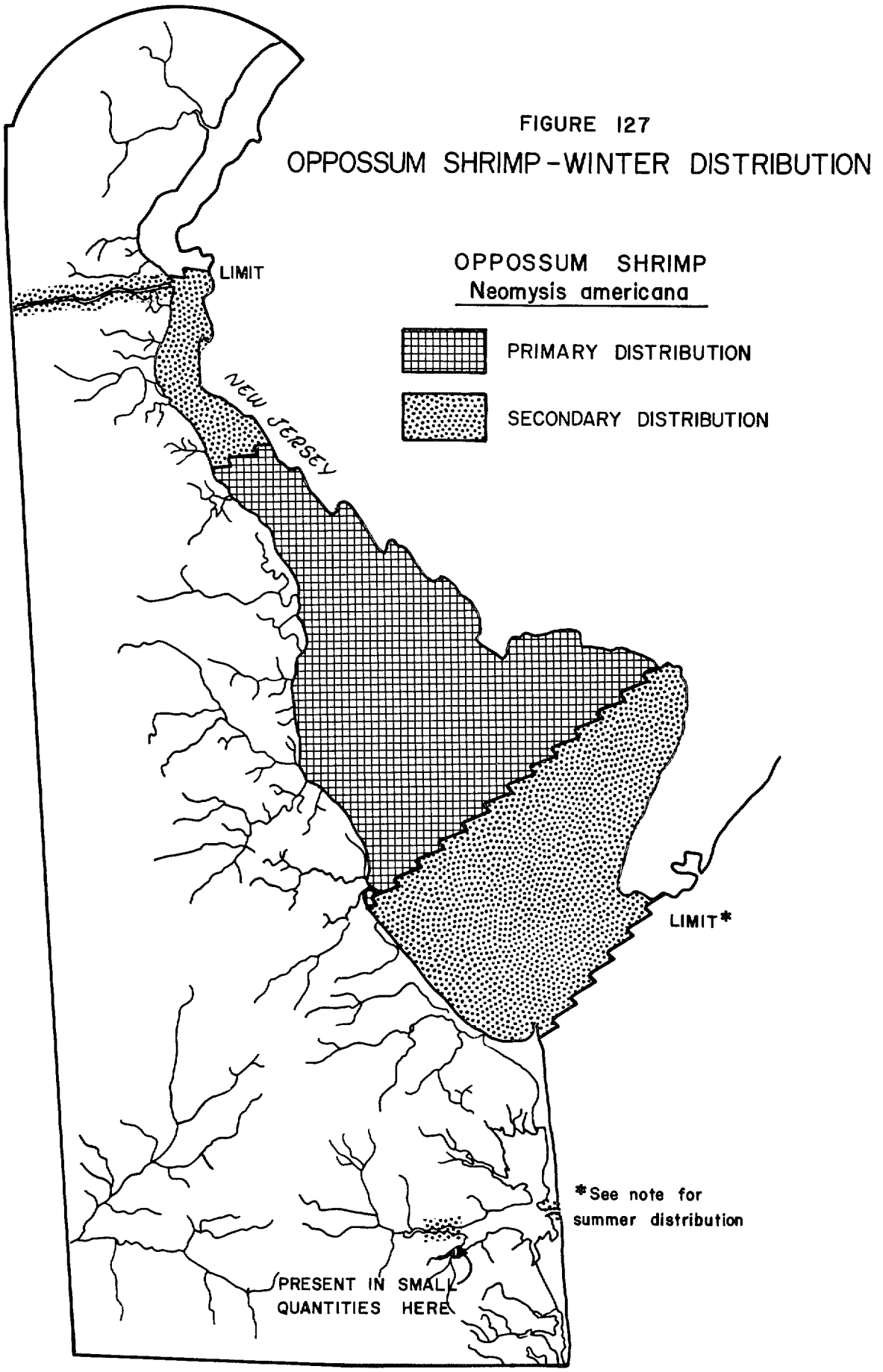


*This limit is from Hulburt (1957) but Neomysis probably has oceanic populations. Probably also in small bays since salinities in these areas are above the 4‰ lower limit of Neomysis, but no data from these areas.

FROM: HULBERT (1957)

FIGURE 127

OPPOSSUM SHRIMP - WINTER DISTRIBUTION



FROM: HULBURT (1957), DELAWARE ECOLOGICAL SURVEY (1973), ICTHYOLOGICAL ASSOCIATES (1970 73),

All are fairly similar in size, appearance, habits and are closely related evolutionarily. Acartia, Gammarus and Neomysis are probably the three most important species year in and year out, but the others also contribute much to estuarine productivity at particular times as well as other species not included in this report.

Each of these animals has particular characteristics that control their numbers and distributions, but some things can be said about them as a group. Most zooplankters are filter feeders, consuming material they extract from water strained through their gills. Their chief food is probably the phytoplankton organisms, but they are also known to consume large amounts of detrital material. Some of the detritus they utilize for their own growth and some of it is eliminated in fecal pellets that are consumed often by benthic organisms such as oysters. This fecal material has high concentrations of nutrients that seem to play an important role in the nutrition of some of these benthic animals.

As planktonic organisms, zooplankton spend a large amount of time in the water column, floating with the currents. Some do spend time on the bottom searching for food, but these, too, will be found floating or swimming in the water during some part of the day. Unfortunately, scientists do not understand all that is involved in the vertical migrations of these animals, some of which cover the whole length of the water column. All zooplankton do have limited powers of locomotion, but their distributions are very much affected by tides and currents. Besides these physical distributional parameters, salinity, temperature, oxygen, turbidity, light and bottom types as well as numerous other parameters affect the distributions of these animals. How all of these fit together to affect the distributions,

fluctuations and interactions of these animals can only be answered through more study.

One of the most important characteristics that all these organisms share is that they have multiple spawning periods throughout the year. There are certain times when spawning activity is greatest, but new individuals are usually being produced constantly. Some of these organisms produce as many as six new generations every year. With the continual production of new individuals, organisms feeding upon the zooplankton are assured of a food source all year long. More zooplankton are, of course, produced during the times when more predators are in the area, which is part of the synchrony of the energy flow system, so most of the new generations are produced in the spring and summer. But these year long egg laying periods are important to the year-round resident predators, and represent important stages in the maintenance of a well-developed zooplankton population itself.

Acartia tonsa

This species is probably the most common and most widespread species in the Delaware estuary. It is a very euryhaline and eurytherimic species being able to withstand salinities of 4-5^{o}/oo to 30^{o}/oo or more and temperatures from -.5^{o}C to 28-30^{o}C. (Acartia has even been found in salt ponds where the salinities reach as high as 75^{o}/oo.) It is most abundant though in water below 30^{o}/oo and reaches maximum density usually in water below 20^{o}/oo. Their relegation to waters well below their salinity tolerance is thought to be a reflection of competition with other groups at higher salinities. In response to general salinity changes in the Bay, they are found up river in the summer and down towards the mouth of the estuary in the winter and spring.

Eggs are laid continuously throughout the year although there are peak brood periods. Four or five generations are produced in the summer with possibly two more being produced in the fall or winter. Summer development is relatively quick with individuals maturing to the egg laying stages in about one month. Development at other times is somewhat slower.

Studies done on this species indicate that it might exert major control in some instances on the size of the phytoplankton crop. In a study done in the Chesapeake Bay area, Acartia was thought to account for about 50 per cent of all the phytoplankton consumed, and similar amounts are probably consumed in the Delaware estuary. While few studies have been done on the species in the small bays and tidal creeks of Delaware where Acartia should be able to exist, one done in the Indian River area indicates that there might be greater concentrations of Acartia in these areas than in the ocean or bay. Since the species is numerous and is involved in complex interactions with both the phytoplankton and fish predators, more study should be done on the distribution and environmental requirements of Acartia tonsa.

Eurytemora affins and Eurytemora hirundoides

These two closely allied species are very prominent in the upper portions of the estuary. They are much less euryhaline than Acartia for they usually disappear in salinities higher than 20°/oo. Individuals have been found in essentially freshwater far up river, but these species are most abundant in water between 1°/oo and 10°/oo salinity. They are found all year long here and move up or down stream as the salinity regime of the Bay changes seasonally. While these species are not nearly as abundant overall as Acartia, they do replace Acartia as the most common copepods in the up-bay

areas where Acartia is at its range limits. Again, few studies have been done on zooplankton distribution in the small bays and tidal creeks, but these species have been found especially prevalent in the Chesapeake and Delaware Canal, indicating the possible importance of smaller systems like the Canal, creeks and small bays in their population maintenance.

Centropages typicus and Centropages hammatus

These forms are principally oceanic in origin and are more abundant outside of Delaware Bay. Usually the two are discussed together for they are thought to have the same basic life cycles and distributional patterns. They may or may not be true for there do appear to be some differences in their habitat preferences. C. hammatus according to some studies appears to prefer more sheltered areas than does C. typicus and so might be the more common of the two within the estuary.

The rest of their environmental preferences seem very similar. Both can withstand temperatures from -.5°C to 25°C and salinities from 3-4°/oo to 30°/oo or greater. They are most abundant, however, in water of 20°/oo salinity or greater. Population size is largest in the winter, fall, and spring and smallest in the summer. C. typicus in some studies was present all year except spring, and C. hammatus abundant only in winter, while in other studies no distribution is made, so the seasonal differences of these two are not yet clear.

Both species spawn continuously throughout the year where present. C. typicus spawns primarily in January, February, April, the summer and October, though, with five or six distinct generations being produced. Adults probably do not live more than a few months. C. hammatus spawns primarily from January to March, May, and late June to July with at least three

generations being produced each year.

Temora longicornis

Like Centropages typicus and C. hammatus, this is typically an oceanic species. It is difficult to determine how common the species is, for individuals are known to prefer water five to ten fathoms deep and deeper, and the lack of proper sampling at these depths might be partially responsible for the numbers reported. Temora is most prevalent in the spring and its up-bay extent is greatest at this time. Its salinity and temperature tolerances appear very similar to those of Centropages and its distribution in the Delaware area, is, thus, found to be very similar. Temora is one of the more common zooplankton organisms when the whole zooplankton community is being considered; however, its abundance is very much less than those of Acartia and the two species of Eurytemora.

Pseudodiaptomus coronatus

Pseudodiaptomus coronatus is primarily an estuarine species for it is not generally found in areas of the Continental Shelf. Usually it is most prevalent in the down estuary portion of Delaware Bay where the salinity ranges from 15-20^{o}/oo, although it is found in water with a salt content as low as 5^{o}/oo. The numbers of Pseudodiaptomus seem to be fairly constant throughout the year, but they are slightly higher in the summer and fall. Reproduction appears to be fairly constant from May to November and in this time possibly five generations are produced. Again, when considering the total zooplankton community, it must be considered a fairly common species, although in relation to Acartia and Eurytemora, it is of relatively minor importance.

Neomysis americana

The oppossum shrimp, Neomysis americana, has been found to be the most common mysid in the Delaware region. Mysids are, generally, very small crustaceans on the order of one to three centimeters in length as adults and resemble the larger true shrimps in general body design. Most mysids are marine but some do inhabit primarily freshwater. Several of the marine species are found in the mid-Atlantic area, although only one, the oppossum shrimp, is present in this area in any great numbers.

Neomysis americana is considered a fairly eurythermic and euryhaline species. There are probably temperature limits to successful reproduction but scientists do not know how narrow these limits are. As a marine species, it is found in the higher salinity areas of the Bay but withstands salinities as low as 4-5^{o}/oo, and their up-bay distribution limit seems to correspond to the 4-5^{o}/oo isohaline. Greatest concentrations of organisms are found between 10 and 25^{o}/oo, and the area of greatest concentration moves up and down the Bay with the changing salinity pattern of the seasons.

The oppossum shrimp is considered to be a fairly shallow water species that spends much time on the bottom. Individuals do rise to the surface at night in response to changes in the light regime. Why these animals respond as they do to light is not really known, but the response is obviously an important one for it completely controls their daily vertical distribution.

Since these organisms do spend much time on the bottom, it might be expected that they have bottom sediment preferences that could affect the distribution. They do seem to be more prevalent in areas having a sandy bottom with low silt content than in areas with other bottom types. How important such possible preferences are in regulating the distribution of

the oppossum shrimp is not known, but since they do spend most daylight hours on the bottom, it could have a fairly large influence.

Similar to many of the smaller crustaceans, mysids have several spawning or brood periods throughout the year. Neomysis spawns all year, but the three major brood periods seem to be April to May, June and late August. Each one of these spawning populations represents a new generation, since mysids, at least the females, die after spawning. There are also very distinct size groups of Neomysis, with the sizes reflecting the time of year in which these individuals were produced. The summer group consists of individuals six to ten months old at maturity that were hatched in the previous winter and spring. The overwintering group is composed of individuals that were hatched in the summer and autumn. They are larger at maturity than are individuals of the summer group for they will not spawn until the next summer or fall, making their growth period ten to fourteen months.

The particular environmental characteristics existing during each one of these brood periods greatly affects the standing crop of Neomysis at some later date. One feature of the Neomysis population is, in fact, that its size is highly variable from year to year. Neomysis has been identified as one of the more important food items in the diets of such fish as the flounder, herring, shad, anchovy, spot, croaker, striped bass and, especially, the weakfish. Fluctuations in the populations of these fish might be partially correlated to fluctuations in the populations of Neomysis. Changes in the mysid populations would also affect the population sizes of the phytoplankton upon which they graze. All of these interactions involving oppossum shrimp, their predators and their prey, are important but very complex, and scientists know little of the details involved. Since the species is one of the more

common and essential components of the zooplankton community, it is important that some of these details be better understood and hopefully, more study will be directed in this area.

Cyclops viridis

Like Gammarus, this is an essentially freshwater form important only in the upper portion of the estuary. Below salinities of 1°/oo, it is often the most important of the copepods. Although it is a major component of the spring zooplankton community, the species is present at all times of the year; however, it is generally of little importance relative to other groups during the summer, autumn and winter.

While salinity seems to be one of the predominant factors controlling its distribution, oxygen levels in the water also appear important. In a two year study done in 1951-53, the least numbers of Cyclops were found in one summer when the oxygen content of the water was very near zero. In the following summer, oxygen levels were very much higher as was the concentration of Cyclops viridis.

References

Barnes, R. D. 1968. Invertebrate zoology. W. B. Saunders Co., Phila.

Bishop, J. W. 1966. The abundance of Acartia tonsa with respect to temperature, salinity and phytoplankton in Indian River, University of Delaware Res. Founda., Inc. Mimeo. 20 pp.

Bowman, T. E. 1961. The copepod genus Acartia in Chesapeake Bay. Ches. Sci. 2: 206-207.

Cronin, L. E., J. C. Daiber and E. M. Hulburt. 1962. Quantitative seasonal aspects of zooplankton in the Delaware River estuary. Ches. Sci. 3: 63-93.

Cuzon du Rest, R. P. 1963. Distribution of the zooplankton in the salt marshes of southeastern Louisiana. Publ. Inst. Mar. Sci. 9: 132-155.

Deevey, G. E. 1960. Zooplankton distribution of the surface waters of the Delaware Bay region. Bull. Bing. Oceanogr. Coll. 17(2): 8-53.

Heinle, D. R. 1966. Production of a calanoid copepod, Acartia tonsa, in the Patuxent River estuary. Ches. Sci. 7(2): 59-74.

Hopkins, T. L. 1956. On the breeding and occurrent of the oppossum shrimp (Order Mysidacea) in Indian River Inlet, Delaware. Master's thesis. University of Delaware.

Hopkins, T. L. 1965. Mysid shrimp abundance in the surface waters of Indian River Inlet, Delaware. Ches. Sci. 6: 86-91.

Hulburt, E. M. 1957. The distribution of Neomysis americana in the estuary of the Delaware River. Limnol. Oceanogr. 2(1): 1-11.

Raytheon Company. 1973. Final site selection report, 30 April, 1972 - 17 April, 1973, for Delmarva Power and Light Co. 174 pp.

Schuler, V. J. (project leader). 1974. An ecological study of the Delaware River in the vicinity of Artificial Island. Progress Rept. Jan.-Dec. 1972.

Shuster, C. N., Jr. 1959. A biological evaluation in the Delaware River estuary. Information Series, Publ. No. 3. University of Delaware Mar. Lab. 77 pp.

Thomas, D. L. 1970. The early life history and ecology of six species of drum (Sciaenidae) found in the lower Delaware River, a brackish tidal estuary. In: An Ecology Study of the Delaware River in the Vicinity of Artificial Island. Progress Report for the period Jan.-Dec. 1970. Ichthyological Assoc. Del. Prog. Rept. #3, Part III. 261 pp.

Ahokas, R. A. and F. G. Duerr. 1975. Salinity tolerance and extracellular osmoregulation in two species of euryhaline teleosts, Culaea inconstans and Fundulus diaphanus. Comp. Biochem. Physiol. A Comp. Physiol. 52(3): 445-448.

Auld, A. H. and J. R. Schubel. 1974. Effects of suspended sediment on fish eggs and larvae. CBI, Johns Hopkins University, Ref. 74-12, Spec. Rept. 40.

Austin, H. M., A. D. Sosnow and C. R. Hickey, Jr. 1975. The effects of temperature on the development and survival of the eggs and larvae of the Atlantic silverside, Menidia menidia. Trans. Am. Fish Soc. 104(4): 762-765.

Bayliff, W. H., Jr. 1950. The life history of the silverside, Menidia menidia, (Linnaeus). Bd. of Nat. Res., Dept. of Res. and Education. CBL, Solomons Island, Maryland.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fishing Bull. 74. U. S. Govt. Printing Ofc., Washington, D. C.

Bigelow, H. B. and W. W. Welsh. 1925. Fishes of the Gulf of Maine. In: Bayliff, W. H., Jr. 1950. The life history of the silverside, Menidia menidia, (Linnaeus).

Breder, C. M. and D. E. Rosen. 1966. Modes of reproduction in fishes. Amer. Museum of Natural History. The Natural History Museum, Garden City, N.Y. 941 pp.

Carriker, M. R. 1955. Critical reviews of the biology and control of oyster drills, Urosalpinx and Eupleura. U. S. Dept. of Interior, Fish and Wildl. Larvae, Spec. Sci. Rept., Fisheries, No. 148.

Carriker, M. R. 1961. Interrelationships of functional morphology, behavior and autecology in the early stages of the bivalve, Mercenaria mercenaria. J. Elisha Mitchell Sci. Soc. 77: 168-281.

Chanley, P. 1958. Survival of some juvenile bivalves in waters of low salinity. Proc. Nat. Shellfish. Assoc. 48: 52-65.

Chidester, F. F. 1916. A biological study of the more important of the fish enemies of the salt marsh mosquitoes. In: Breder, C. M. and D. E. Rosen. 1966. Modes of reproduction in fishes.

Chittenden, M. E., Jr. 1972. Responses of young American shad, Alosa sapidissima, to low temperatures. Trans. Am. Fish Soc. 101(4): 680-685. (Bio. Absts. 55(11): 63916).

Chittenden, M. E., Jr. 1972. Effects of handling and salinity on oxygen requirements of the striped bass, Morone saxatilus. J. Fish. Res. Bd. Canada 28(12): 1823-1830. (Bio. Absts. 54(8): 42647).

Chittenden, M. E., Jr. 1972. Salinity tolerance of young blueback herring, Alosa aestivalis. Trans. Am. Fish Soc. 101(1): 123-125.

Chittenden, M. E., Jr. 1973. Salinity tolerance of young American shad, Alosa sapidissima. Ches. Sci. 14(3): 207-210.

Chittenden, M. E., Jr. 1973. Effects of handling on oxygen requirements of American shad, Alosa sapidissima. J. Fish. Res. Bd. Canada 30(1): 105-110. (Bio. Absts. 56(7): 36452).

Clemens, H. P. and K. E. Sneed. 1957. The spawning behavior of the channel catfish, Ictalurus punctatus. In: Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes in the Chesapeake Bay region.

Crawshaw, L. I. 1975. Attainment of the final thermal preferendum in brown bullheads acclimated to different temperatures. Comp. Biochem, Physiol. A. Comp. Physiol. 52(1): 171-174. (Bio. Absts. 61(3): 17730).

Daiber, F. C. 1957. The sea trout. Est. Bull. 2(5): 2-6.

Davis, H. C. 1958. Survival and growth of clam and oyster larvae at different temperatures. Biol. Bull. 114: 296-307.

Dawson, A. B. 1933. The relative numbers of immature erythocytes in the circulating blood of several marine species. Biol. Bull. 64: 33-43.

Dees, L. T. 1961. Sturgeons. In: Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes in the Chesapeake Bay region.

deSylva, D. P., F. A. Kalber and C. N. Shuster. 1962. Fishes and ecological conditions in the shorezone of the Delaware River estuary. Marine Lab. Info. Sci. Publ. 5, University of Delaware. 164 pp.

Dovel, W. L., J. A. Mihursky and A. J. McErlean. 1969. Life history aspects of the hogchoker, Trinectes maculatus, in the Patuxent River estuary, Md. Ches. Sci. 10(2): 104-119.

Edsall, T. A. 1970. The effect of temperature on the rate of development and survival of alewife eggs and larvae. Trans. Am. Fish. Soc. 99(2): 376-380.

Fitz, E. S. 1956. An introduction to the biology of Raja eglanteria Bosc 1902 and Raja erinacea Mitchell 1825 as they occur in Delaware. Master's thesis, University of Delaware. 93 pp.

Fournier, P. and E. Magnien. 1975. Reproduction of the banded killifish, Fundulus diaphanus. Nat. Can. (Que.) 102(2): 181-188.

Fowler, W. H. 1917. Some notes on the breeding habits of some catfishes. In: Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes in the Chesapeake Bay region.

Gray, I. E. 1954. Comparative study of the gill areas of marine fishes. Biol. Bull. 61: 427-456.

Harmic, J. L. 1958. Some aspects of the development and ecology of the pelagic phase of the gray squeteague, Cynoscion regalis (Bloch and Schneider) in the Delaware estuary. Ph.D. dissertation. University of Delaware. 164 pp.

Hider, H., W. H. Rosenburg, K. G. Drobech, A. J. McErlean and J. A. Mihursky. 1973. Thermal tolerance of oyster larvae, Crassostrea virginica Gmelin as related to power plant operations. Proc. Nat. Shellfish Assoc. 64: 102-170.

Hildebrand, S. F. 1922. Notes on the habits and development of eggs and larvae of the silversides, Menidia menidia and Menidia beryllina. In: Breder, C. M. and D. E. Rosen. 1966. Modes of reproduction in fishes.

Hildebrand, S. F. 1963. Family Clupeidea. In: Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes in the Chesapeake Bay region.

Hildebrand, S. F. and L. E. Cable. 1934. Reproduction and development of whitings or kingfishes, drums, spot, croaker, and weakfishes or sea trouts, family Sceanidae of the Atlantic coast of the United States. In: Breder, C. M. and D. E. Rosen. 1966. Modes of reproduction in fishes.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of the Chesapeake Bay. Bull. of U. S. Bureau of Fish., No. 43.

Hoff, J. H. and J. R. Westman. 1966. The temperature tolerances of three species of marine fishes. J. Mar. Res. 24: 131-140. In: Kinne, O. Vol. I, Part I.

Holsapple, J. G. and L. E. Foster. 1975. Reproduction of white perch in the lower Hudson River. N. Y. Fish Game J. 22(2): 122-127.

LaRivers, I. 1962. Fishes and fisheries of Nevada.

Lawrence, G. C. 1975. Laboratory growth and metabolism of the winter flounder, Pseudopleuronectes americanus, from hatching through metamorphosis at three temperatures. Mar. Biol. (BERL) 32(3): 223-229. (Bio. Absts. 61(4): 18973).

Leim, A. H. 1924. The life history of the shad, Alosa sapidissima (Wilson), with special reference to the factors limiting its abundance. Contribu. to Canadian Biol., New Series, Vol. 2, No. 11. pp. 161-284.

Leim, A. H. and W. B. Scott. 1966. Fishes of the Atlantic coast of Canada. Fish. Res. B. Canada., Bull. 155.

Lewis. R. M. 1965. The effect of minimum temperature on the survival of larval Atlantic menhaden, Brevoortia tyrannus. Trans. Am. Fish. Soc. 95: 423-425. In: Kinne. O. Vol. I, Part I.

Lewis, R. M. 1966. Effects of salinity and temperature on survival and development of larval Atlantic menhaden, Brevoortia tyrannus. In: Kinne, O. Vol. I, Part I.

Lippson, A. J. 1973. The Chesapeake Bay in Maryland. Nat. Res. Inst. of University of Maryland. The Johns Hopkins Univ. Press., Baltimore, Md.

Loosanoff, V. L. 1937. Spawning of Venus mercenaria (L). Ecol. 18: 506-515.

Loosanoff, V. L. and H. C. Davis. 1963. Rearing of bivalve molluscs. In: Russell, F. S., ed. Advances in Marine Biology. Vol. I. Academic Press, London.

Lossanoff, V. L., W. S. Miller and P. B. Smith. 1951. Growth and setting of larvae of Venus mercenaria in relation to temperature. J. Mar. Res. 10: 59-81.

MacKenzie, C. L., Jr. 1961. Growth and reproduction of the oyster drill. Eupleura caudata in the York River, Virginia. Ecol. 42(2): 317-337.

Mackin, J. G. 1961. Mortalities of oysters. Nat. Shellf. Assoc. Proc. 1959(50): 21-40.

Mansueti, R. 1950. An ecological and distributional study of the fishes of the Patuxent River watershed, Md. In: Bayliff, W. H., Jr. 1950. The life history of the silverside, Menidia menidia (Linnaeus).

Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes of the Chesapeake Bay region. Port City Press, Baltimore, Md. p. 202.

Marcy, B. C., Jr., P. M. Jacobson and R. L. Nankee. 1972. Observations on the reactions of young American shad to a heated effluent. Trans. Am. Fish. Soc. 101(4): 740-743. (Bio. Absts. 56(7): 36332).

Margin, C. P. and L. M. Amende. 1972. Blood osmotic concentrations of blue crabs, Callinectes sapidus (Rathbun), found in freshwater. Ches. Sci. 13(4): 318-320.

McCauley, R. W. and L. A. A. Reed. 1973. Temperature selection by juvenile and adult yellow perch, Perca flauescens, acclimated to 24°C. J. Fish. Res. Bd. Canada 30(8): 1253-1255. (Bio. Absts. 57: 52284).

Moore, R. H. 1973. Energetic responses of striped and white mullet to temperature. Am. Zool. 91(4): 1331. Abstract.

Morrison, G. 1971. Dissolved oxygen requirements for embryonic and larval development of the hardshell clam, Mercenaria mercenaria. Endocrinology 88(6); 379-381.

Morgan, R. P., II and V. J. Rasin, Jr. 1973. Hydrographic and ecological effects on enlargement of the Chesapeake and Delaware Canal. Appendices X, XI, and XIII.

Muncy, R. J. 1962. Life history of the yellow perch, Perca flavescens, in estuarine waters of the Severn River, a tributary of Chesapeake Bay, Md. Ches. Sci. 3(3): 143-159.

Pearson, J. C. 1938. The life history of the striped bass or rockfish, Roccus saxatilis (Walbaum). In: Schubel, J. C. 1973. Effects of exposure to time excess temperature histories typically experienced at power plants on the hatching success of fish eggs.

Perry, W. G. 1973. Notes on the spawning of blue and channel catfish in brackish water ponds. Prog. Fish Cult. 35(3): 164-166.

Petit, G. D. 1973. Effects of dissolved oxygen on survival and behavior of selected fishes of western Lake Erie. Bull. Ohio Biol. Survey 4(4): 1-76.

Schmeltz, G. W. 1970. Some effects of temperature and salinity on the life processes of the striped killifish, Fundulus majalis (Walbaum). Ph.D. dissertation. University of Delaware. 104 pp.

Schubel, J. R. 1973. Effects of exposure to time excess temperature histories typically experienced at power plants on the hatching success of fish eggs. CBI, Johns Hopkins University, Spec. Rept. 35.

Scotton, L. N. 1970. Occurrence and distribution of larval fishes in the Rehoboth and Indian River Bays of Delaware. Master's thesis. University of Delaware. 66 pp.

Sherk, J. A., Jr. 1972. Current status of the knowledge of the biological effects of suspended and deposited sediments on Chesapeake Bay. Ches. Sci. VB. S137-S144.

Sherk, J. A., J. M. O'Conner and D. A. Newmann. 1972. Effects of suspended and deposited sediments on estuarine organisms. Phase II. Dept. of Env. Res., CBL, Prince Frederick, Md. Ref. #72-9E.

Shuster, C. N. 1959. A biological evaluation of the Delaware River estuary. University of Delaware Info. Sci. Publ. 3.

Smith, B. A. 1971. The fishes of four low salinity tidal tributaries of Delaware River estuary. Master's thesis. Cornell University.

Smith, W. G. 1973. The distribution of the summer flounder, Paralichthys dentatus, eggs and larvae on the Continental Shelf between Cape Cod and Cape Lookout, 1965-66. U. S. Nat. Mar. Fish. Serv., Fish. Bull. 71(2): 527-548.

Springer, V. G. and K. D. Woodburn. 1960. An ecological study of the fishes of Tampa Bay area. In: Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes of the Chesapeake Bay region.

Swartz, F. J. 1964. Natural salinity tolerances of some freshwater catfishes. In: Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes of the Chesapeake Bay region.

Sylvester, J. R., C. E. Nash and C. R. Emberson. 1975. Salinity and oxygen tolerances of eggs and larvae of Hawaiian striped mullet, Mugil cephalus L., J. Fish Biol. 7(5): 621-630. (Bio. Absts. 61(1): 1472).

Thornton, L. L. 1975. Laboratory experiments on the oxygen consumption and resistence to low oxygen levels of certain estuarine fishes. Master's thesis. University of Delaware. 82 pp.

Tinsman, J. C. 1974. The effects of thermal effluent of the American oyster, Crassostrea virginia Gmelin, in Indian River Bay, Delaware. Master's thesis. University of Delaware.

Turner, J. L. and T. C. Farley. 1971. Effects of temperature, salinity and dissolved oxygen on the survival of striped bass eggs and larvae. Calif. Fish. Game 57(4): 268-273. (Bio. Absts. 53(6): 30794).

Ursin, E. 1963. On the incorporation of temperature in the von Bertalarffy growth equation. In: Kinne, O. Vol. I, Part I.

Vernburg, F. J. and I. E. Gray. 1953. A comparative study of the respiratory metabolism of excised brain tissue of marine teleosts. Biol. Bull. 104: 445-449.

Vladykov, V. D. 1955. A comparison of Atlantic sea sturgeon with a new subspecies from the Gulf of Mexico (Acipenser oxyrhynchus de sotoi). J. Fisheries Res. Bd., Canada 12(5): 754-761.

Walburg, C. H. 1960. Abundance and life history of the shad, St. Johns River, Florida. In: Schubel, J. R. 1973. Effects of exposure to time excess temperature histories typically experienced at power plants on the hatching success of fish eggs.

Welsh, W. W. and C. M. Breder, Jr. 1923. Contribution to the life histories 39(945): 141-201.

Wheatland, S. B. 1956. Oceanography of Long Island Sound, 1952-1954. In: Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes of the Chesapeake Bay region.

Wright, A. H. and A. A. Allen. 1913. Field notebook of fishes, amphibians, reptiles and mammals. In: Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes of the Chesapeake Bay region.

Zimmerman, J. H. 1969. Toxicity of Paris green, methoxychlor and new organophosphate insecticides to salt marsh killifish and crustaceans. Master's thesis. University of Delaware. 80 pp.

GENERAL REFERENCES FOR FISHES

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service, Vol. 53. U. S. Government Printing Office, Washington, D. C.

Goode, G. B. 1888. Popular treatise upon the game and food fishes of North America. Standard Book Company, N. Y.

Hildebrand, S. F. and W. C. Schroeder. 1972. Fishes of Chesapeake Bay. T. F. H. Publications, Inc., Neptune, N. J.

Jordan, D. S. and B. W. Evermann. 1896. The fishes of North and Middle America. Bulletin of the U. S. Nat. Museum #47. Reprinted T. F. H. Publications, Inc., Jersey City, N. J.

Leim, A. H. and W. B. Scott. 1966. Fishes of the Atlantic coast of Canada. Fisheries Research Board of Canada, Ottawa.

Trautman, M. B. 1957. The Fishes of Ohio. The Ohio University Press.

New Jersey State Museum, Annual Report. 1905. Part I - Fresh and salt-water fish found in the waters of New Jersey. MacCrellish and Quigley, State Printers. Trenton, N. J.

Fishes of the Western North Atlantic, Part II - Sawfishes, Guitarfishes, Skates, Rays and Chrmaeroids. Sears Foundation for Marine Research, New Haven, Conn. 1953.

Smith, H. M. 1907. The Fishes of North Carolina. North Carolina Geological and Economic Survey. E. M. Uzzel and Company, State Printers and Binders, Raleigh, N. C. 1907.

INTRODUCTION TO AVES-LIFE HISTORIES

Many of the species of birds common to Delaware can be considered inhabitants of the wetlands and tidewaters of the state. Other migratory species use the wetlands and tidewaters of Delaware as way stations on their long, arduous journeys. Drawn by the plentiful food and water resources of these systems and by the shelter and nesting sites that abound there, these birds compose one of the most interesting, colorful, and important groups of the wetlands-dependent animals. While some birds found in the wetlands can be considered truly upland species, whose ranges are generally confined to the drier upland areas, it is the waterbirds like the herons, egrets, rails, ducks and geese that are inextricably characteristic of wetlands and tidewater areas. These are waterfowl that are familiar to muskrat trappers, crabbers, and fishermen and whose large flocks draw attention during the spring and fall migrations. In this section we have chosen to describe species that are important members of the coastal zone ecosystem and ones that the casual wetlands visitors would most likely encounter.

While most of us may not be able to identify a bird by its specific name, we can usually determine to what family a bird belongs by looking for some of the characteristics it displays. Each of the several families of waterbirds with representatives in Delaware, notably the families Ardeidae, Herons, Rallidae, Rails, Anserinel, Geese, Anatinae, Dabbling Ducks, and Aythyinae, Diving Ducks, have some distinctive characteristics which can be seen to some extent in all of its members. Several of these characteristics are discussed in this section with the hope that they might provide a starting point for the casual bird watcher. For more detail on any of several common

water birds of Delaware, please refer to the individual life histories following this section.

The Heron Family - Ardeidae

The Heron family is composed of some of the more majestic marsh birds like the herons, bitterns and egrets. Common members of the family found in Delaware include the Great Blue Heron, the Green Heron, the Black-Crowned Night Heron, the Cattle Egret, the Snowy Egret and the Common Egret. Generally all stork-like in appearance, these birds possess long necks, long spindly legs and elongated pointed beaks. The wings of most are also fairly large and assume a bowed shape when the birds are flying. Further, the heads of the birds are kept tucked into their bodies resulting in the neck being shaped into an "S" with the legs stretched out behind the body when the bird is in flight.

Most herons are wading birds and are usually found close to the edges of tidal creeks, streams, and bays, where the small fish that form the basis of their diet are plentiful. Members of the family are also very social birds, at least during the breeding season. While some herons are commonly found singly or only in small groups during much of the year, during the breeding season the majority of the herons can be found in nesting colonies often containing hundreds or thousands of individuals.

The Rail Family - Rallidae

Somewhat similar in appearance to the herons are the rails, for these birds generally possess long beaks and long legs like the herons. However, the rails have very short necks and stout-plump bodies like that of a chicken. The wings of the rails are also very short and are beaten in very rapid fashion

when the birds take to the air, and therefore, their flight does not have the elegance displayed by the flight of the herons.

While it is common to see some members of the heron family, it is only with careful observation that one ever spots a rail. All rails are very shy birds who choose to remain well hidden within the marsh grasses. When they take to the air they do so with an upward burst, flying close to the ground for only a short distance and then re-alighting on the marsh to again disappear into the grass.

Duck and Geese Families - Anserinae, Anatinae and Aythyinae

All ducks and geese generally resemble each other and are easily distinguished from the previous families. Ducks and geese are stout-bodied birds with short legs, webbed feet and generally flattened beaks. Most are ground nesters unlike the herons which generally nest in trees.

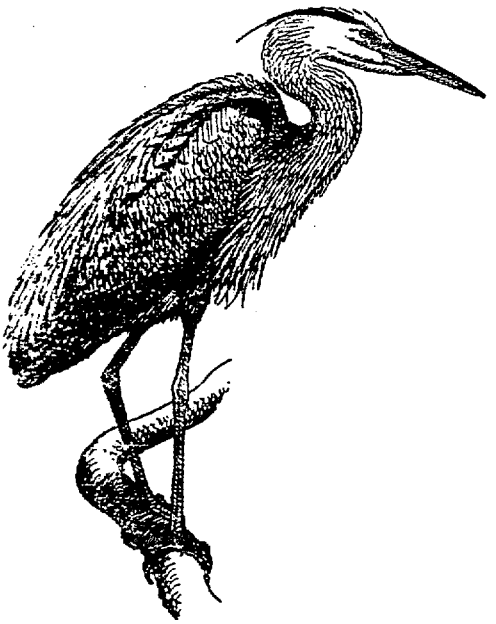
The geese, Anserinae, are the largest members of the waterfowl group, and are represented in Delaware primarily by the Canada Goose and the Snow Goose. Geese are generally noisy in flight and somewhat more terrestrially oriented than are most ducks for geese will feed exclusively on land while ducks prefer to feed in the water. The sexes in geese are also alike at all seasons so that once the birds are mature, the sexes are difficult to distinguish.

The common duck families can be separated, generally, by observing the feeding habits of the birds. Members of the family Anatinae, notably the Mallard, Black, Gadwall, Pintail, Blue and Green-Winged Teals and the Wood Duck, are called dabbling ducks. They feed in shallow water areas by rotating their bodies on the water surface so that their beaks and necks are below the water and their tails up in the air - an activity known as "tipping up".

Members of the Aythyinae, including the Canvasback, the White-Winged American and Surf Scoters, and the Scaups, are called diving ducks. These birds actually dive completely below the surface when they feed. The dabbling ducks, then, can be found more commonly in marshy, shallow water areas and the diving ducks in open, deeper water areas. Sometimes these two groups of ducks are referred to as marsh ducks and bay ducks, respectively.

Dabbling ducks take to flight by springing directly into the air, while diving ducks tend to take to flight by pattering along the surface of the water for some distance before rising. The groups can further be distinguished by the presence or absence of the speculums - metallic-like patches located near the hind edge of the wing; dabbling ducks possess speculums while diving ducks do not.

The wetlands of Delaware are important to these ducks as well as many other groups of birds by providing both year-round homes for many and seasonal homes for others. Delaware is located in the middle of the Atlantic flyway, one of the major north-south routes used by birds migrating to and from winter and summer residences. Wetlands areas have always been used by such birds during flights for they provide ample food and water for their needs as well as the isolation that affords the birds protection. The many birds who spend most of the year here producing and raising their young within our own wetlands are attracted by the same factors. These birds are not only important to the character and stability of the wetlands systems; many are directly used by man. The 40,000 ducks and 20,000 geese harvested each year in Delaware are ample evidence of this.



THE GREAT BLUE HERON

Ardea herodias herodias

The Great Blue Heron is, without question, one of the most impressive marsh birds of the State. It is a large bird and its great wing span and graceful, elegant flight are quite distinctive. The Great Blue Heron is probably the most widely distributed of the herons of the North American continent for its range includes all areas of the United States and much of Canada. In the northern portions of the range, the bird is migratory and these populations travel to southern heronries during the winter. While many areas of Delaware do have resident heron populations, it is during the fall and spring migrations that one has a better opportunity to see these birds, for they use refuges like Bombay Hook during their migratory flights.

Adult herons are up to 127 centimeters (49 inches) tall making them the largest of the American herons. They are characteristically a slate-blue color above with black underbelly and crested head. The blue coloration and the general appearance of the bird accounts for its common name of blue crane.

Adults also have various patches of white on the head, stomach and tail and they have a yellowish beak. The young lack the long crest feathers of the adult and tend to be more brownish or ashy in color.

Great Blue Herons are generally solitary birds except during nesting season when large colonies of nesting birds develop. Delaware is fortunate in having two heronries located within the State. One is found on Pea Patch Island and contains up to 2,000 nests of various herons, including the Great Blue Heron, the Common Egret, Snowy Egret, Black-Crowned Night Heron, Little Blue Heron, Cattle Egret and Glossy Ibis. Another smaller heronry is located in the Augustine Creek area. It is known as the J. Gordon Armstrong Heronry, after the man who first purchased land in the area specifically for use by nesting blue herons. This area contains over one hundred Great Blue Heron nests. It is considered unique for its is one of the few areas in the United States which contains more than one hundred Great Blue Heron nests situated in such a small area; the nesting site extends over only one acre of woodland and is adjacent to the marsh. Both of these areas are extremely important in sustaining the Delaware populations of Great Blue Herons.

The Great Blue Herons typically build their nests in trees near the water, but will also build them in bushes or on the ground. Nests are constructed of branches and twigs and sometimes grass which are all thrown together in a rather bulky structure often several feet in diameter. Trees seem to be the preferred nest sites for the protection they afford the eggs which can be heavily preyed upon. Once established, a particular nesting area is commonly used for many years and birds might even occupy the same nest year in and year out if it has been well built and properly situated.

Both parents are usually involved in the nest building activities. The nest is started by the male and after the appropriate courtship rituals, he is joined by the female. In the Great Blue Heron and in many other heron species, it is common for egg laying to begin before the nest is completed. Because of this, many of the early eggs will fall out of the nest and be lost. However, Great Blue Herons are indeterminate layers; that is, they continue to lay eggs until the normal compliment of three to four eggs are in the nest for incubation. Some birds have been known to lay two full clutches if the first has been completely lost through early predation or breakage. Why egg laying begins before nest completion and how the birds arrive at a suitable clutch size though capable of laying many more eggs are interesting questions. The answers have both species survival and evolutionary-behavioral aspects.

Eggs are on the order of 2.5 to 6 centimeters in size and generally oval in shape, somewhat rough skinned and bluish in color. Most seem to be laid in the period from April to June in Delaware, but no data is available on the yearly total productions of Great Blue Heron eggs in the State. Eggs that survive hatch in about twenty-seven days. Predation of eggs can be very heavy with gulls, terns, ravens, crows, and mammals such as the raccoon often destroying eggs and young nestlings.

Hatching success is generally 70 to 80 per cent of the incubated clutch but this figure can vary greatly. In certain areas where the use of pesticides has been heavy, for instance, hatching success can be very low. Compounds such as DDT, DDE, DDD, Dieldrin, Endrin, Aldrin and polychlorinated biphenyls (PCB's) are known to seriously affect the egg laying process in birds, particularly in fish eating birds. These compounds become concentrated in the fish tissue and then are incorporated into various systems of the birds when

the fish are eaten. As has been found in other species, the thickness of the egg shells of the Great Blue Heron has decreased as much as 30 per cent in the last twenty years in some populations and these changes have been definitely linked to the effects of these pesticides on the egg laying process. Thin eggs lead to more breakage of eggs which then accounts for population reduction. Fortunately, Great Blue Herons eat other things besides fish so their losses due to pesticides have not been as large as those of some other species.

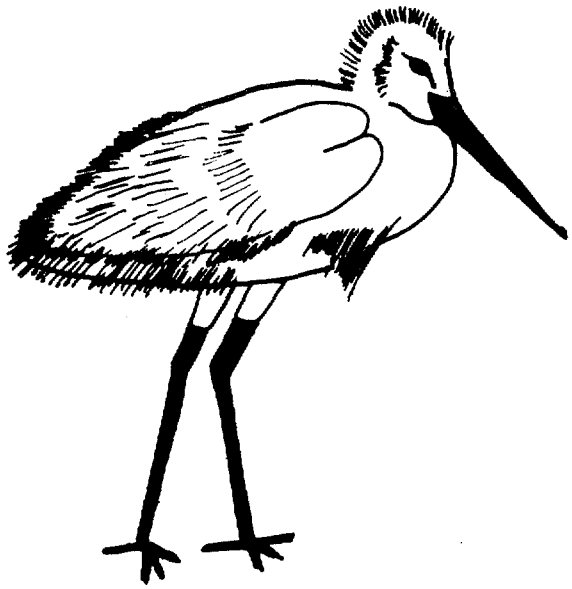
Young Great Blue Herons are fairly feeble when first born and are cared for by both parents who feed and watch them in turn. Competition among the nestlings for food can lead to losses of 8 to 40 per cent of the young, for the strongest ones will be able to get most of the food. Adults will not partition food among the brood. The food is merely deposited in the nest for their consumption.

In approximately forty-five days, the young are ready to fly, though they have been actively moving about since after the first two weeks. This of course increases their mobility and decreases the occurrences of nest predation but also increases the number of hazards to which they become exposed. Mortality of first year individuals is as high as 70 per cent and much of this comes during the first migration period. After the first year, the annual mortality decreases to about 30 per cent. Young do not mature for several years and maturing birds can be distinguished by the various types of plummages they display.

Although the herons eat insects, seeds and some small mammals, their principle food is fish and they have developed very distinct techniques to capture them. The most common involve waiting motionless among the banks in shallow waters or walking very slowly in these areas. When a fish is spotted,

the bird quickly plunges its head downward and usually catches the fish along the middle of the body. It then flips the fish around and swallows it head first. The birds are extremely proficient in their hunting and very interesting to watch while stalking their prey. Any fish that is in the area is suitable food for the herons for they are not very particular about what they catch. Some accounts are available which tell of these birds diving from the air for their prey or even of eating dead fish, but these do not seem very common.

As for predators of Great Blue Herons, they have few natural enemies, for their large size and sharp powerful beaks make them formidable opponents. Decreases in the numbers of these birds are usually the results of habitat losses, changes in food supplies, the hunting of these birds which was once a common practice, or the introduction of toxic materials such as the pesticides and mercury containing compounds into the environment. These are the types of conditions that man has control over, and which we should strive to make suitable for these animals so that truly magnificent birds like the Great Blue Heron can always be found in the wetlands of Delaware.



CATTLE EGRET

Bubulcus ibis

The Cattle Egret is the most recent member of the heron family to invade the North American continent. One hundred years ago these birds were not to be found on this side of the Atlantic ocean. They were strictly an Old World species, relegated to the countries of the European and Asian continents. Somehow, a small flock of these birds survived a trans-Atlantic flight and settled in South America between 1880 and 1900. They spread throughout South America and finally into the United States where their first recorded sighting was about 1950.

Since then, Cattle Egrets have survived to become one of the most successful of all of the heron species in the United States. While others of the heron family seem to be extending their ranges, they are not doing so as quickly or as successfully as is the Cattle Egret, which has now become the most common ardeid (heron) in many parts of the country. Where only a

short time ago the bird was not even to be found, the Cattle Egret now is breeding successfully. Cattle Egrets now appear in great numbers in some of the refuges in the coastal zone areas of Delaware. In 1974, for example, Bombay Hook recorded a fall population of 950 Cattle Egrets which was more than the populations of the Great Blue Heron, the Green Heron, the Snowy Egret, of the Common Egret, and double the 1972 Cattle Egret population.

It is the phenomenal success of this bird which has scientists extremely interested for it is seldom that the processes involved in the spread of an introduced species can be directly observed. It has been suggested that in several areas of the country there are potential niches which the Cattle Egrets will probably fill in due course. Scientists hope to investigate the effect of the Cattle Egret expansion both on the egrets themselves and on the new areas and ecosystems the egrets exploit. With enough study devoted to this phase of the Cattle Egret life history, scientists are common to learn much about the processes involved in species developed and ecosystem interactions and maintenance.

Cattle Egrets are small herons reaching 50 centimeters (20 inches) in length as adults. Except for tinges of tan on the crown feathers and breast during the mating season, all of the feathers are pure white. A stout yellow bill and yellowish legs and feet provide the only contrasting colors. In general body design, they resemble all other members of the heron family with their long spindly legs and prominent, pointed beaks.

Cattle Egrets are extremely social birds both in their feeding and breeding behavior, for solitary Cattle Egrets are rarely seen. Flocks are often found which contain literally hundreds of individuals, especially in the southern portions of their range where they have resided longer.

Unlike most other herons, Cattle Egrets confine themselves more to fields and grasslands than to areas directly bordering the water. They get their common name, in fact, from their habit of associating with cattle and other domestic animals in the pasture lands. Where both animals are found, cattle are accompanied by the egrets wherever they go. The relationship was at first thought to be mutually beneficial to both animals, called a symbiotic relation by scientists. Cattle are usually plagued by ticks, flies and other insects, and it was thought that the egrets picked these off the cattle. The cattle are relieved of some of their pests and the egrets are provided with a relatively constant, easily collected food source.

Recent study, however, indicates that the egrets do not really pick insects from the back of cattle, at least not generally. They merely follow the cattle and catch any insects, frogs, toads, snakes, etc., that the lumbering cattle might scare up from the grass. It is apparently a very one-sided relationship.

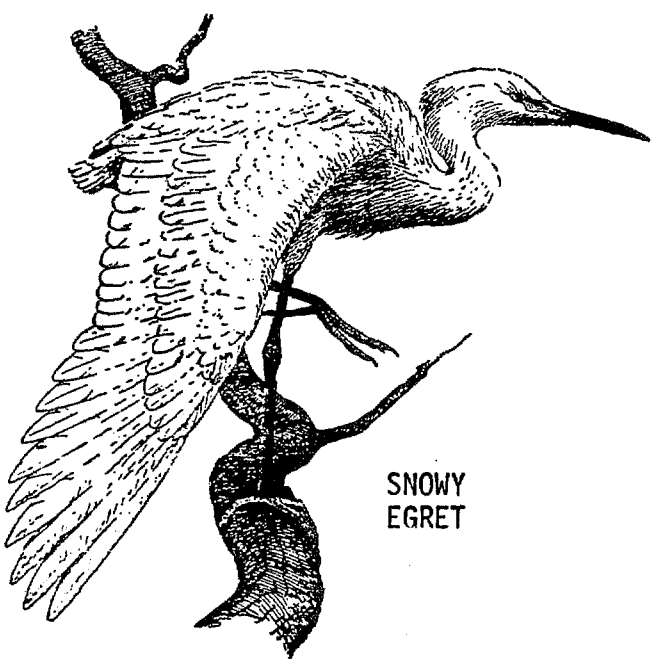
It was also thought that the egrets would do poorly without such animals as the cattle to flush their prey for them. This is not so, for scientists have found that the Cattle Egrets have devised interesting ways of flushing insects on their own. They have named it the leap-frog method for it does resemble the children's game of leap-frog. The first few egrets of a flock walk through the fields ahead of the rest and try to scare the insects out of the grasses. In this sense they are acting like the cattle themselves. The egrets following them jump into the air anytime the insects are flushed. In doing so, they usually travel over the first line of egrets and land some distance ahead of them. These egrets who have just successfully captured their prey then perform the flushing actions for the other egrets. Such a

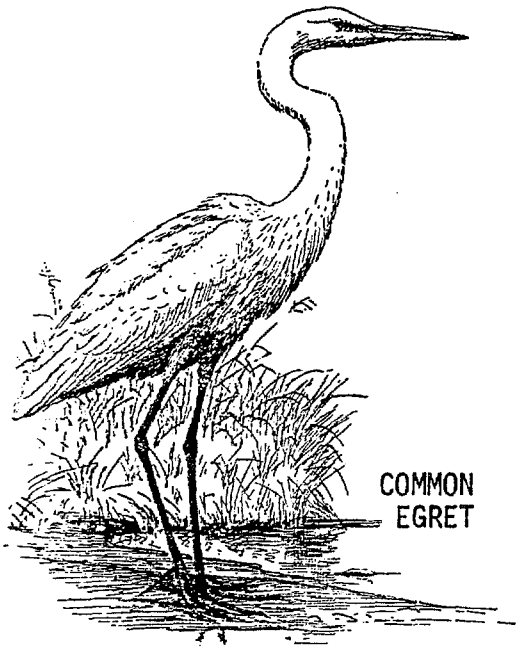
pattern can continue hour after hour until all the egrets have fed. The Cattle Egrets can very definitely exist without the cattle; it is simply that the Cattle Egrets have learned that large animals like the cattle flush many more insects than can their fellow egrets.

During the breeding season, the Cattle Egrets, while still social animals, do display certain territorial instincts. Males initially defend the area which is about five yards in radius surrounding the area wherein he will begin his nest. Nests are built in trees or bushes and generally closer to the ground than those of other herons. They are usually within six meters of the ground and more common within two or three. Nests are fairly complete by the time egg laying commences, so few of the early eggs are lost because of unfinished nests. Three to four eggs seem to be the most common number laid, and they are incubated by both parents for twenty-two to twenty-three days before hatching.

Adult birds are attentive to the eggs and nestlings, so few are lost to predators. However, as with all of these birds, there is great competition among the nestlings themselves for food and this competition often leads to the death of the latter born, weaker chicks. Such competition usually accounts for about 20 per cent mortality of the nestlings.

Scientists know little else about the yearly life histories of the Cattle Egrets. How long they live, when they mature, what is the yearly production of young, how and where they migrate are a few of the many yet unanswered questions. The fact that these birds are becoming more common, though, means that more study will probably be devoted to them, and these questions soon may be answered.





THE EGRETS

(Snowy Egret) - Leucophoyx thula
(Common Egret) - Casmerodeus alba

Unlike the Cattle Egrets which are relatively recent inhabitants of America, Snowy Egrets, Leucophoyx thula, and Common Egrets, Casmerodeus alba, have long been members of the community of marsh birds of the United States. Members of these two species, however, have not always been as common as they were in the late 1800's or as they are today. In the first quarter of this century, Snowy and Common Egrets were hunted almost to extinction -- sought not for the taste of their flesh, but for the pure white, elegant plumes that are part of their breeding dress. It was very fashionable for attire of the period to include the plumes of these and other bird species, and consequently, a very profitable market developed for the feathers of Snowy and Common Egrets.

The plume hunter, unfortunately, had very little regard for the survival of these species and wantonly devastated large populations of both of these birds. Such destruction was all the more appalling, for the plume hunters were interested only in breeding birds. Adult birds were often shot out of a nest

containing eggs or fledglings, and more often than not, the parentless chicks died from starvation or predation.

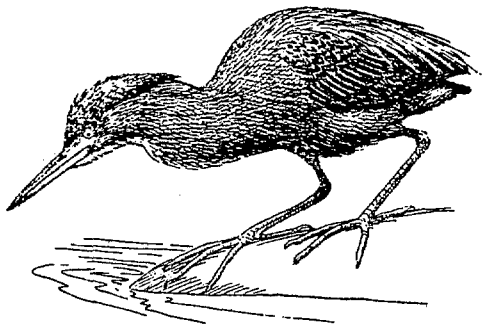
Fortunately, some enlightened individuals convinced government agencies to pass legislation protecting Snowy and Common Egrets and this legislation has been very successful. Today, these birds are again plentiful in many areas of the country, although because of some habitat destruction their ranges have been reduced in extent.

In appearance, these two birds are very similar for both possess white plumages and long necks, beaks and legs. Snowy Egrets, however, are much smaller than Common Egrets (also known as Great Egrets); adults reach only 61 centimeters (24 inches) in height while those of the latter attain 102 centimeters (40 inches) in height.

Unlike Cattle Egrets, the Snowy and Common Egrets are predominantly marsh birds. They feed mainly in marshes along the shallows bordering the tidal creeks and bays, and they are expert hunters, proficient in capturing small fish fry, crabs, snails, and insects with rapid and accurate thrusts of their beaks. While most herons prefer the wait-and-wade technique of food gathering, the egrets exhibit active hunting patterns more often than not, eagerly pursuing their prey instead of waiting motionless for the prey to pass by them. The Snowy and Common Egrets will also eat some vegetable matter.

Both of these species are spring, summer and fall residents of the Delaware area with the majority moving to more southerly areas during December, January and February. Most East Coast Snowy and Common Egrets breed from South Carolina southward through Central and South America.

Snowy and Common Egrets are affected by habitat destruction and pesticide poisoning. Pesticides tend to disrupt reproductive cycles in egrets as in other fish-eating bird species.



THE GREEN HERON

Butroides virescens virescens

The Green Heron is a small heron usually somewhat smaller than a crow, reaching 37.5-42.5 centimeters (15 inches) as an adult. It is characteristically greenish-black in color with a chestnut throat and some bluish-grey tints on its feathers. Unlike many of the other herons, the Green Heron is not a particularly social bird, for while a few nesting pairs are occasionally found together there are not large rookeries of Green Herons.

Green Herons are common in the United States but their general range is more limited than that of the Great Blue Heron. They are seldom found west of the Rocky Mountains, although they are found north into Canada, east of the mountains and in most southern states.

The nests of the Green Heron are built in trees, although they are smaller and usually found closer to the ground than those of the Great Blue Heron. They are normally 3 to 6 meters off the ground and 25.4 to 30 centimeters

in diameter. Like the nests of other herons, those of the Green Heron are composed of twigs and grass thrown together in what seems to be a rather haphazard manner. They do not appear to be very sturdy and it is a wonder that all the eggs are not lost from them.

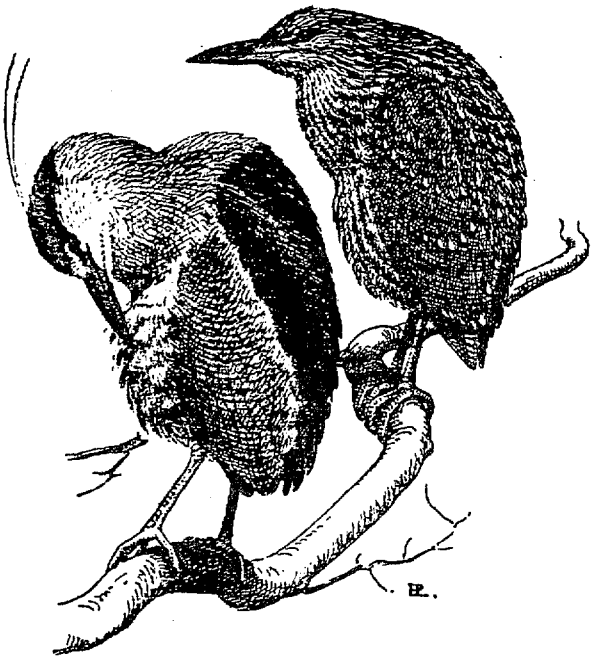
Green Herons usually lay four to five eggs a season but they are capable of producing more. The eggs are oval in shape, smooth-shelled, pale green in color and usually about 3 to 4 centimeters long.

Eggs hatch in approximately seventeen days although this varies somewhat from place to place. No information is readily available on their reproductive success, egg predation and breakage or mortality rates, but these birds probably experience the same kind of pressure that other herons do. As fish eaters, they are susceptible to pesticide poisonings, but it is not known how extensive pesticide damage has been to these birds.

The young of the Green Heron are expert climbers. Shortly after hatching they move around the trees using their bills, wings and feet to pull themselves from branch to branch. They are even able to swim as are the adults, which is advantageous to birds who chose to nest along the margins of streams and ponds.

Since the birds are found both in salt and freshwater areas, food items depend partially on their locality. Minnows or fish fry of all types are the chief food of the saltwater birds, while those living primarily in fresher areas prey upon worms, crickets, grasshoppers, snakes, frogs, salamanders and even some small mammals. Like all herons, the Green Heron is an expert hunter who patiently stalks its prey along the shallows or through the grasses. The best time to observe the feeding of these birds would be during the very early morning hours or very late in the afternoon.

In this area, the birds are migratory and move south to the Carolinas to winter. Most leave by October, although some individuals are still found in the Bombay and Prime Hook Refuges in November and December. They return in April. Most of their migratory flights are at night and therefore they are not commonly seen by the casual bird watcher. When one does happen to stumble upon them in the marsh, they often freeze, remaining completely motionless until the last moment when they take flight to a point a little farther up the creek. Through such an action they have been given the popular name of the "Fly-up-the-creek".



THE BLACK-CROWNED NIGHT HERON

Nycticorax nycticoras

The Black-Crowned Night Heron is widely distributed across the continent. It is intermediate in size between the Great Blue Heron and the Green Heron. Adults reach about 61 centimeters (24 inches) in height and possess a black crown, back and beak, gray wings and tail, and a white underbelly. A few white plumes emerge from the head and extend 6 to 8 inches down the back.

These birds get their name from the black head feathers and from their habit of doing most of their feeding and flying at night. During the breeding season when many young are present, however, the adults will feed all day in order to bring back enough food for the chicks.

Like other herons, Black-Crowned Night Herons are primarily fish eaters that use both the wade-and-wait technique and one involving very active searching. The birds often seem to move relentlessly, scaring up their prey from the shallow water and catching them quickly before they escape. Again, these herons will consume whatever type of food is available. The habit of

hunting mostly at night allows these birds to exist in areas inhabited by other shallow water fish eaters who are active mostly in the daytime. All can then utilize the same feeding areas but reduce competition by eliminating direct contact.

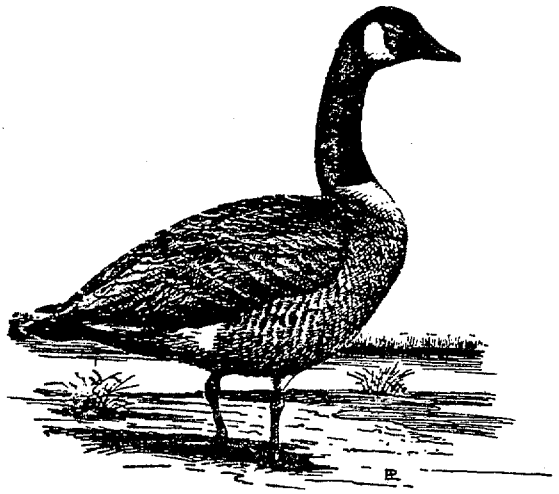
Night Herons exhibit different types of flying patterns that distinguish them from other herons. They are stout-bodied and use much quicker, shorter wing beats that are likened to those of the gulls. The neck of the Black-Crowned Night Heron is somewhat shorter than that of other herons, but it is not folded back during flight.

Night Herons are primarily tree nest builders and are extremely gregarious. Large rookeries containing hundreds of nests are not uncommon in some areas of the country. The nests are usually higher than those of the Green Heron, but lower than those of the Great Blue Heron with whom the Black-Crowned Night Heron often shares a nesting area. If trees are not near the sources of food, the Black-Crowned Night Heron will nest on the ground or in the reeds and bushes of the marshes wherever food is plentiful. Nests are made of twigs and grass, and they are very often poorly put together. It appears that many eggs are lost from nests that are blown to the ground during storms. However, some nests do seem to be very well constructed and are in fact used year after year.

The eggs are bluish-green in color and oval or slightly cylindrical in outline. The shells are smooth skinned and non-glossy like those of the Green Heron but are slightly larger, measuring about 5.0 x 3 to 4 centimeters. Usually three to five eggs are laid by each female, but as few as one or as many as seven or eight have been noted. As much as a week might elapse between the laying of the first and last egg, but incubation usually starts immediately after the first egg has been produced. Incubation lasts about twenty-five to twenty-six days and both parents are involved in keeping the eggs warm.

The young are fairly helpless and do not leave the nest for two to three weeks. When they do, they prove to be expert climbers like the young of the Green Heron, using their beaks, wings and feet to move along the branches. The young do not get full plumage for fifty to sixty days after birth so they are not able to fly until this time. The chicks are preyed upon by many predators as are the adults. Crows, hawks, vultures and gulls at times attack the nests as do raccoons and other mammals. Crows and man seem to be the worst enemies. In several parts of the country, these birds have been hunted and eaten like other game birds, a practice which has resulted in the disappearance of some of the rookeries in certain areas.

Most of the northern Night Herons, as they are commonly called, migrate south during the winter and the refuges of Delaware are often used by these birds in their flights. Consequently, Night Heron populations can often be found in the Delaware area all year long.



CANADA GOOSE

Branta canadensis

Fifteen years ago, the annual population of Canada geese in Delaware numbered only a few hundred individuals. While Delaware is situated in one of the major migration routes of geese and other waterfowl, areas to the south of Delaware had attracted most of the wintering individuals. Today, the situation is quite different for the population of wintering geese in Delaware now numbers about 90,000-100,000 individuals. The wetlands areas of Delaware and Maryland together serve as the wintering grounds for approximately 90 per cent of the geese using the Atlantic flyway.

Such increases have been realized because of the great amount of effort that has been put into active waterfowl management programs. Federal, state, and local agencies as well as private landowners have all been involved in the success of these programs. The rewards to bird watchers and waterfowl hunters alike have been numerous. Many people are drawn to the wildlife refuges like Bombay Hook simply to observe the geese during the migration

periods. The great numbers of birds have also attracted large numbers of hunters who annually shoot 18,000-20,000 Canada geese. While many other species of waterfowl are hunted in Delaware, it is the Canada Goose that is by far the most sought after.

Management officials have attracted the larger numbers of geese by providing more watering and feeding sites for waterfowl. Geese do not need exceptionally large wetland areas for their purposes. As long as sufficient water for washing and drinking is nearby, migrant populations can be lured exclusively to fields for the winter. Impoundments can be created near grain fields, and as long as there is a minimum of disturbance, the geese will be perfectly contented in such unnatural situations. Further, once geese find a suitable area, they are likely to return to it year after year.

Canada geese are exceptionally impressive fowl as anyone who has seen them will attest. Adults can be as much as three feet tall with a wing span of several feet; young attain this size several months after they are hatched. Canada geese are all northern breeders that nest in the northernmost parts of the country from coast to coast. While few broods are produced in Delaware, the importance of this area to the geese populations is still great.

After the first few months of growth, it becomes difficult for the sexes to be distinguished for they are about the same size and possess the same coloration. The head and neck of adult geese is totally black except for a prominent white patch that extends from check to check behind the eye. The breast and belly are a grey color and the back and wings are brown.

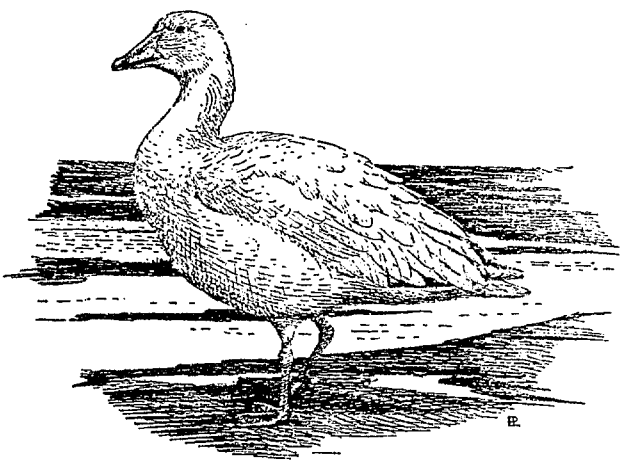
Canada geese mate for life and they express very strong family instincts. While the gander never sits on the eggs, he is always near the nest and aggressively definds his territory against any intruders. This behavior

continues even as the young grow strong enough to take care of themselves and prepare for the approach of the first fall migration.

Geese eat many different types of food but are predominantly plant eaters. In this area they feed on wild rice, bullrush, widgeon grass, cordgrass, sedges, pondweed, algae and other aquatic plants as well as the grains scattered in the fields from harvesting operations. Any animal materials geese consume seem to be only incidental items on the diet, consumed while the geese forage through the plants. Once geese have settled in an area, they adopt a fairly regular pattern of feeding: moving to feeding sites for several hours in the very early morning and again just before sunset. The rest of the time they spend resting in the nearby ponds, lakes and bays.

A large number of geese can at times cause serious problems to crops and to natural grass communities because of their feeding activities. Goose "eat outs" are not uncommon in marshes, and crop damage does occur occasionally when the geese eat too many young shoots of the spring crops. The solution to these problems lies in sound management programs in which the numbers of feeding sites developed can provide sufficient food for the population being attracted to any area.

The success that has been achieved with developing geese populations in Delaware has been extremely rewarding. They are magnificient birds that have become an integral part of the character of Delaware's wetlands. The loud honking and V-shaped formations of the migrating flocks are now as much announcers of winter and spring as are the first coverings of ice on the ponds and the new shoots of the marsh grasses.



SNOW GOOSE

Chen hyperborea atlantica

There are two subspecies of Snow Goose found in North America, but only one of these, the Greater Snow Goose, Chen hyperborea atlantica, is common in the Delaware area. This subspecies migrates to the mid-Eastern and southern coastal states during the winter from its summer breeding grounds in Greenland. Its cousin, the Lesser Snow Goose, Chen hyperborea hyperborea, occupies a much wider range in the United States than does the Greater Snow Goose, for it migrates to the Pacific coast, Western Plains, mid-Western and Gulf coast states in the winters. Occasionally, individuals of each subspecies can be found in areas frequented by the other, but for the most part, the ranges of the Lesser and Greater Snow Goose are fairly distinct. Essentially, all Snow Geese in Delaware belong to the subspecies Atlantica.

As their name implies, Snow Geese are mostly white, and so are easily distinguished from the Canada Geese, also found in Delaware. Only the pink

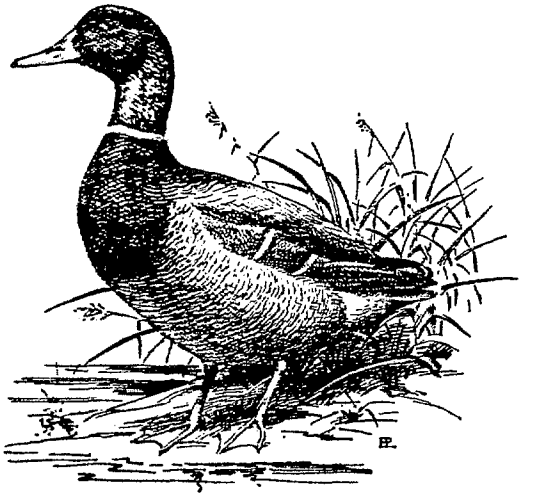
of the feet and gill, and the black of the primary wing feathers lend contrast to the general white body coloration.

Like Canada Geese, Snow Geese are plant eaters subsisting almost totally on the shoots, roots and seeds of marsh grasses in the area. Sedges seem to be the favorite food item, but many other marsh plants are consumed as are cultivated grains. Occasionally, flocks of Snow Geese cause damage to some marsh areas, consuming all of the shoots of a particular plant in a small area. Usually, however, their use of the marsh areas cause no substantial damage, and the Snow Goose is a welcome winter resident of the coastal marshes.

Snow Geese begin arriving in Delaware during October and November, remaining until April and May. Those individuals arriving in the early part of the season probably move farther south to the Virginia and North Carolina coasts before the winter sets in and only use the wetlands of Delaware as resting and feeding sites. Geese arriving in January or February, however, probably remain in this area until April. In the winter months, peak population in the refuges often reach five or six thousand individuals, and past accounts of flocks of ten thousand Snow Geese utilizing a particular marsh area along Delaware Bay are not uncommon. A recent bird census showed the population of Snow Geese in Delaware to be 1,023 in October, 5,183 in November, and 4,550 in December. However, the migration behavior is still largely unknown because of the remoteness of the breeding grounds in the northern Arctic and the narrow migration corridor from the Arctic to North Carolina.

To the hunter, the Snow Goose is not as important as is the Canada Goose; it is not as plentiful as the Canada Goose, and is somewhat protected

by hunting regulations. Some hunters rate the eating quality of the Snow Goose very low, thus affording some additional relief from hunting pressures. However, to those who appreciate the color and elegance that these geese bring to the wetlands landscape, the Snow Goose is an important and valuable species.



MALLARD

Anas platyrhynchos

With its greenish-yellow bill, deep glossy green head and neck, white neck band and tail, purple and chestnut breast, and green, violet, black and ash body, the male of the Mallard, Anas platyrhynchos, is one of the most colorful of the ducks of Delaware. The females, as is often the case with species of birds, possess more subdued body coloration being a mottled brown and buff color overall with a distinct gray tinge at the top of the head. The green head of the male and the grey head of the female account for their respective common names of Green Head and Gray Duck, but they are most widely known as the Mallard or Common Wild Duck.

It is probable that Mallards are the most common and widespread of all the ducks in the United States for they can be found in large numbers in most areas of the country. They are more prominent in the plains and northern Great Lakes regions than they are on the East coast, but the Mallard is still

one of Delaware's most common species. To the duck hunters of Delaware, the Mallard is second only to the Black Duck in number harvested each year with 8,000 to 10,000 bagged annually in the State.

Mallards do exhibit a north-south seasonal migration and it is during the winter season that the largest number of Mallards can be found in the wetlands areas of Delaware. Individuals can, however, be found in all areas of the country during all seasons, and broods are known to be produced in Delaware during the spring and summer. Their widespread distribution and the fact that Mallards are the most common domesticated duck account for this species being the most familiar to a large number of people.

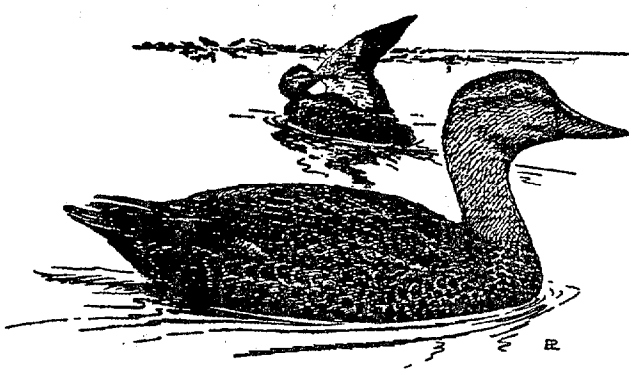
Adult Mallards are up to 60 centimeters (23 inches) in length and strong flyers, making them good game birds. Like Black Ducks, they are dabbling or surface ducks who tip-up to root for insects, crustaceans, molluscs, fishes and the roots of such plants as pondweed, duckweed and salt grasses. They also consume large amounts of the seeds of these plants as well as those of smartweeds and sedges and the nuts of pine, white oak and beech.

Mallards prefer freshwater areas and are one species of duck that has benefited from the establishment of impoundments in this and other states. Some reductions in population have been noted in past years in wetlands areas that have been ditched and these reductions have been related to the replacement of many food plants by other less preferable plant species. The corn planted in refuges to attract geese serves as a food source for the Mallard, and management practices such as creating impoundments and feeding sites have led to the restoration of populations in many areas.

When the spring nesting season arrives, male and female Mallards become some of the earliest birds to fly to the nesting areas and have commonly been

hailed as the announcers of spring. Pairs build their nests in the most solitary areas of marshes and wetlands and lay twelve to sixteen dull, greenish-white eggs. These are incubated by the female for twenty-three to twenty-nine days depending on how long the actual egg laying period is. Incubation will not start until the last egg has been laid so that they will all hatch at the same time. Unlike some other duck species, the drake remains with the nest and is very attentive of the eggs and the hatchlings, although most of the burden of raising the young still rests with the female.

Mallards have a tendency to hybridize with other common duck species especially the Black Duck. Individuals of these species are often seen flocking together as are occasional hybrids resulting from cross-mating between these populations. Such hybrids produce interesting and often unidentifiable individuals. The pure Mallard, however, with its prominent white neck band and ruddy breast can be confused with few other species.



BLACK DUCK

Anas rubripes

The Black Duck, Anas rubripes, is probably the most important of the duck species to the Delaware duck hunter. Over 10,000 Black Ducks are harvested annually from the marshes and bays, particularly in areas located in Kent County. The Black Duck, in fact, is probably the most prominent and important duck throughout the entire eastern portion of the United States.

Black Ducks are dabbling ducks, feeding in shallow water areas by "tipping up" and collecting food from the bottom of ponds and shore zone areas with their outstretched heads and beaks. Black Ducks exhibit both a north-south movement and onshore-offshore movement throughout the year, dictating what type of materials they will be feeding on at any time. In the spring and summer, they tend to move northward and inland to large ponds and lakes where they will feed on aquatic insects, insect larvae, salamanders, tadpoles, worms and small frogs. In the fall and winter they tend to move south and to coastal areas where they consume large numbers of shellfish and snails. Black Ducks

also consume large amounts of vegetable material including the seeds and rootstocks of pondweed, bullrush, eelgrass and widgeon grass as well as cultivated grains if available.

Black Ducks are not really marsh ducks for they tend to prefer open water areas of the ocean and the bays when they are utilizing our coastal areas. As the colder weather leads to icing over of inland ponds and lakes, the Black Ducks move to shore areas where they find open water. Typically, they retreat to offshore or bay areas during the day, returning to shores and sometimes the marshes at night to feed. If the seas are particularly rough, large numbers of Black Ducks can be found during the day in sheltered coastal areas, but they seem to prefer the safety of the open water when the weather conditions are not severe.

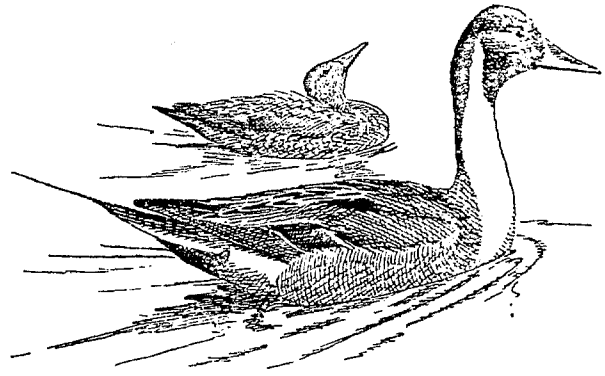
The Black Duck is about twenty inches tall as an adult and is one of the duck species in which the sexes appear to be very similar. Males and females are both a dark, sooty brown color with a somewhat lighter yellowish brown head, a yellow bill and a violet-colored metallic patch on the wing. When they are flying, they can be accurately identified from other similarly appearing species by the white-wing linings they expose with each wing beat.

This species is one of the major brood-producing ducks that visit Delaware, although most of the breeding occurs in more northerly areas. The nests of the Black Ducks are usually very hard to locate for there seems to be no preferable type of nesting habitat, making it difficult to know where to look for nests. Further, the nests are usually very well concealed. Whatever the vegetation is in which the nest is located, it is usually constructed on dry ground, but not far from a water source.

Six to twleve eggs are usually laid with the most common range being

eight to ten. The eggs are incubated completely by the female for twenty-six to twenty-eight days, and when hatched it is the female along who is responsible for protecting, feeding and teaching the young. Males leave the nest immediately after the eggs are laid, flying with other males until migration and breeding seasons again return.

While Black Ducks can be found in Delaware year-round, it is during the fall and winter months that they are most commonly seen. During December or January, it is possible to find as many as 5,000 Black Ducks at a time in areas like Bombay Hook Refuge. While other duck species may be present in similar numbers, none is more important to the duck hunter of Delaware's wetlands than the Black Duck.



PINTAIL

Anas acuta

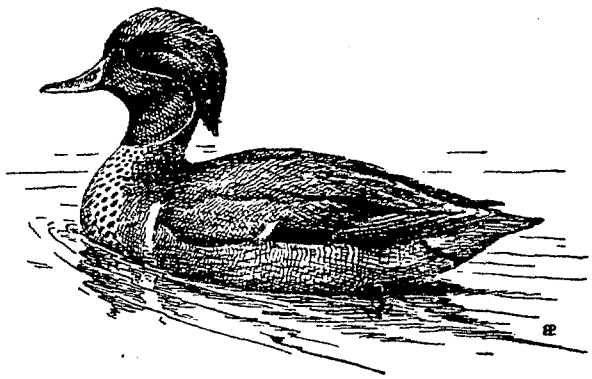
It is difficult to mistake this species for any other, for the very elongated blackish-green tail feathers readily separate the Pintail, Anas acuta, from other common ducks. In fact, the entire body shape is generally more slender than that of similar species, the shape being accentuated by the tail and the long neck. Drakes are also readily identifiable by the white line which extends from the breast and belly up the side of the head to the back of the eye. The females are much less colorful than the male, being buff and brown mottled over all-with a gray bill, but females also possess this slender body shape which aids in their identification.

While the Pintail is not a common breeder in Delaware, the species probably has the widest breeding range of any native American duck. Most nesting is accomplished to the north of Delaware with individuals found in Delaware being mostly winter transients.

There appears to be a noticeable increase in the fall and winter populations of Pintails in Delaware occurring over the last several years. The increase is at least partially due to recent management practices which have been undertaken to provide watering and feeding sites for all species of waterfowl. As with other ducks, researchers had noted decreased usage of wetlands areas by Pintails after the marshes were ditched. Pintails are primarily a freshwater species and the drainage of many areas leading to a loss of freshwater appears to have resulted in the reduction of suage of these areas by Pintails.

The Pintail is a surface feeder, characteristically up-ending during feeding periods. They consume the roots, shoots and seeds of pondweeds, smartweeds, arrow grass, plantains and duckweeds as well as minnows, worms, snails, insects and insect larvae and tadpoles.

While not as important to the hunter as are some other species, Pintails are still considered good sport ducks of excellent table quality. However, because of the low number of Pintails using Delaware's wetlands during the year, only one to two thousand are shot annually in the State.



GREEN-WINGED TEAL

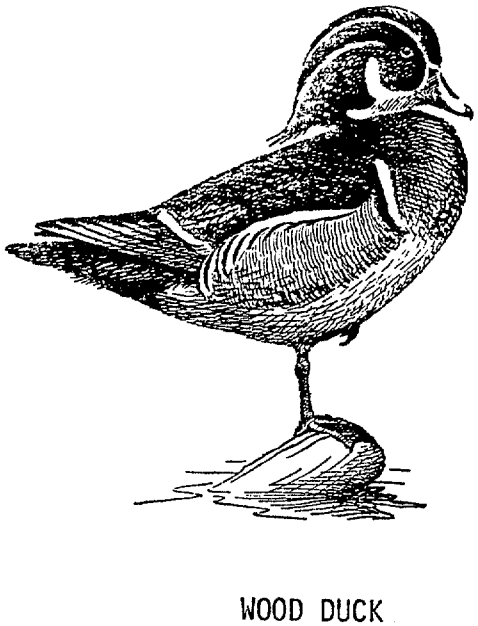
Anas carolinense

The Green-Winged Teal, Anas carolinense, is one of the smaller ducks common to Delaware. Adults average only 38 centimeters (15 inches) in length so they are much smaller than are the Mallards, Blacks and Pintails. Adult drakes also have distinguishing markings including a wide green mark around the eye, a light buff neck and breast, slaty sides and a white line that extends up the sides of the body in front of the wings.

Another characteristic that can be used to identify the Green-Winged Teal is its very rapid flight. It is considered the fastest of all the ducks and easily outflies individuals of other species when they all take to the air together. The Green-Winged Teal is also an expert flier, being able to change directions rapidly at all speeds. It is this flying ability along with its excellent flavor that has made this species a favorite of Delaware's hunters.

The Green-Winged Teal is a freshwater species that is more common inland than along the coast. Teals feed on all types of water plants, insects, and other common animal foods, but they also feed on berries, nuts, and acorns which are thought to add much to the flavor of these birds. They have taken well to areas farmed for grains and readily feed on corn, wheat, oats, barley, buckwheat and especially rice. The rice fields of the Southern Middle States, in fact, attract a large number of wintering birds from many northern areas.

As with the Pintail, the Green-Winged Teal has a very wide breeding range that extends to both coasts of the United States. Breeding pairs, however, are much more prominent in the mid-Western and Western sections of the country than in the East, and few broods are produced in the wetlands of Delaware. However, monthly fall and winter populations of migrating Green-Winged Teals reach into the thousands with the yearly harvest averaging approximately 7,000 individuals.



WOOD DUCK

Aix sponsa

The male Wood Duck, Aix sponsa, is one of the most beautiful ducks of Delaware with its green-plumed head, white throat and belly, buff sides, greenish-black back and chestnut neck and breast. The head is further accentuated by two fine white lines (one of which extends from the beak, over the eye to the back of the plume, the other extending from the eye back to the tip of the plume). In addition, two white marks which extend up the side of the head from the throat to just behind the eye, are very distinguishing characteristics, even in winter when the green color of the head is replaced by gray.

While not quite as colorful as the male, the female Wood Duck is nonetheless quite striking. She has a grayish-brown neck and head, olive colored back, tawny underbody and white throat. The four white markings on each side of the head of the male are replaced in the female by one white mark that

encircles each eye.

Wood Ducks are relatively small ducks that get their common name from their preference for wooded areas. They are excellent flyers that have no trouble winding their ways rapidly between tree trunks and branches that other ducks could not negotiate. Ideally, areas with wooded sections interspersed with ponds and lakes provide the best habitat for this species. Wood Ducks nest in trees but spend much time feeding, resting and raising their young in or around the water.

Wood Ducks produce many new broods in Delaware each spring and summer, but several nesting populations have been forced from some sections of the State due to the destruction of wooded areas. Where such habitats have been destroyed, some success in attracting Wood Ducks back to the disturbed areas has been achieved by providing special raised wooden boxes that can be used by the ducks as nesting sites. The boxes closely resemble the hollowed out cavities of trees that are the preferred natural nesting sites. Citizens in the Dragon Run area of New Castle County, for example, have begun to place nesting boxes on their own land, and it is felt that such practices will help to keep a large nesting population of Wood Ducks in the area. Individuals can do much to preserve the wildlife of the State, and the activities of individuals in the Dragon Run area lend much support to this idea.

Mating, nest building, and egg laying begin as the ducks return from the wintering grounds to the south. A usual clutch will contain ten to fifteen eggs that are incubated for twenty-eight to thirty days, primarily by the female. The male does not incubate the eggs but remains close to the nest and helps care for the young when hatched.

Almost immediately after hatching, the young chicks make their way to the

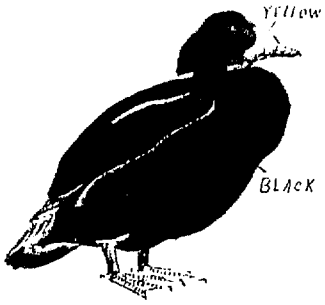
edge of the nest and literally jump or scramble to the ground. The distance from the next to the ground can often be considerable, but the adult birds continually coax the young to leave the nest. As soon as the chicks are on the ground, they are led into the water of a nearby pond where food is usually plentiful. Because of this practice of taking the young directly to the water from the tree nest, it is easy to see why the wooded areas interspersed with small ponds are necessary for attracting and sustaining Wood Duck populations.

The young Wood Ducks grow rapidly feeding on insects and insect larvae, minnows, tadpoles, etc., as well as some aquatic plant materials that they find in the ponds. There are, however, many hazards for the young in the water, for larger fish and turtles often swim under the chicks paddling about in the pond and capture them before the chicks can be led to safety.

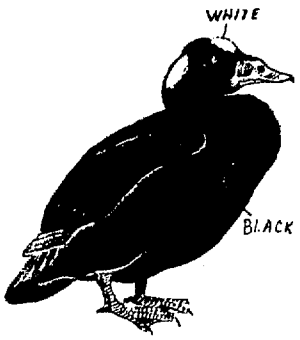
Those birds that survive to adulthood are faced by another predator, man, because Wood Ducks are considered good table birds. The taste of the flesh is enhanced by the acorns, chestnuts, beech nuts, berries and grains that the adult birds eat. It takes skill to bag a Wood Duck because they are such expert flyers, but gunners take advantage of the characteristics of their particular area to increase their hunting success. Wood Ducks usually remain in a secluded pool at night until early morning when they fly to feeding sites. The birds choose a flyway where they can remain close to the ground and not have to fly over the tops of very tall trees. Therefore, Wood Ducks can often be found flying across open areas interspersed throughout the woods, and hunters often place themselves close to such areas where a clear shot at the flying birds is possible.

It is not as a hunter that man has been a major threat to Wood Ducks,

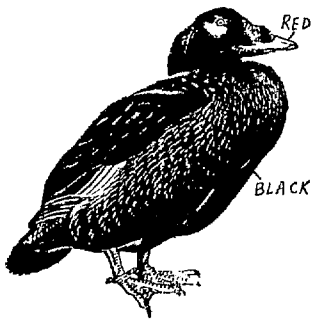
however. As a predator, man has been no more successful in capturing the prey than have been other natural predators of Wood Ducks. As a modifier of habitat, however, man has had much effect on the Wood Duck. The clearing of small, swampy, wooded sites has eliminated the nesting areas of these birds, and Wood Duck populations have declined as a result. The wooded boxes that waterfowl managers are providing for the ducks have greatly improved the situation; but the picture of a Wood Duck nest in a man-made box near an impoundment is not as striking as the one of a next situated in a natural stand of trees. It is, however, a constant reminder of the importance of habitat to all types of wildlife, and of the effect man can have on populations of animals by modifying natural systems.



AMERICAN SCOTER



SURF SCOTER



WHITE-WINGED SCOTER

SCOTERS

(American Scoter) - Oidemia nigra
(Surf Scoter) - Melanitta perspicillata
(White-Winged Scoter) - Melanitta deglandi

These three species of ducks can be considered truly ducks of the sea, for it is very seldom that the American Scoter, Oidemia nigra, Surf Scoter, Melanitta perspicillata, and the White-Winged Scoter, Melanitta deglandi, ever travel inland during their migratory flights. The Surf Scoter is probably the most plentiful in this area but the White-Winged Scoter is also very common. The American Scoter while present does not seem to visit the Atlantic coast in any great numbers and is of little consequence in Delaware. All three species travel in the same flocks, and individuals of each are so similar in appearance that when the birds are flying, it is difficult to distinguish between them.

Scoters are most plentiful here during the fall and spring migrations which usually occur during October and November, and March and April. The

birds remain to the south of Delaware during the dead of winter and are almost completely absent from this area during January and February. In the months that they are here it is not uncommon to see rafts of scoters composed of several hundred individuals floating in the lower portion of the Delaware Bay or out in the Atlantic ocean immediately off the coast. Just as common a sight is the low straight lines of flying scoters moving to and from their feeding and resting areas, or during the migratory flights to and from wintering and nesting sites.

As a group, scoters are fairly distinguishable from other ducks during flight for the scoters possess large heads, short necks and very pointed wings which they beat in rather rapid fashion. Scoters are not colorful ducks for they are totally black except for a few white markings on the heads, and they often appear as specks traveling quickly over the water.

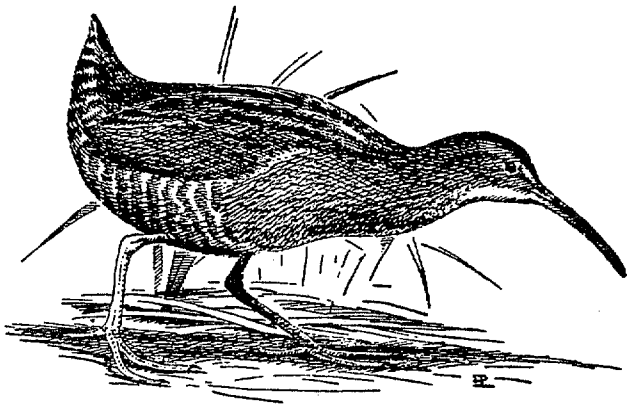
The White-Winged Scoter is the largest of the three, adults reaching 56 centimeters (22 inches) in length. Their total black dress is broken by the white speculums of the wings, one white mark on each side of the head below the eye and an orange bill in the males, and white speculums and a white spot on each side of the head behind the eye in the females. In contrast, the Surf Scoter is slightly smaller than the White-Winged Scoter and lacks the white speculums but the males have a white patch on the forehead and on the nape of the neck; the females have two white patches on each side of the head -- one behind the base of the bill, the other behind and below the eyes. The American Scoter has even less contrast in its coloration than the other two species, for it lacks any white head markings at all, earning it the other common name of the Black Scoter.

Scoters are all diving ducks and can descend 12 to 15 meters below the water surface in search of food. While they might be capable of these depths,

most scoters prefer to feed in much shallower waters, and these ducks usually move from their resting sites out in the ocean to shore zone areas at feeding times. The favorite foods of the scoters are shellfish of all types -- mussels, clams, scallops and razor clams. Scoters have exceptionally strong stomach muscles that can break-up the shells of these bivalves facilitating digestion of the soft inner tissues of the shellfish. The scoters simply dive to the bottom, pull the clams and mussels away with their powerful beaks and swallow the shellfish whole.

There is no breeding of scoters in the Delaware area, for all three species breed exclusively in the northern wildernesses along the United States-Canadian border. In fact, the nesting areas of these ducks are so remote that very few actual accounts of nesting and breeding habits are available, and many questions still remain to be answered about this phase of the life cycles of the scoters.

While scoters are common in the Delaware area during the migration periods, very few are taken by hunters each year. Scoters appear infrequently in the hunter's bag since they do not pass as near the areas most hunters utilize as do other species. In other areas of the country, however, especially in the Cape Cod region, scoters are avidly sought for they are considered good eating and good sport. In these areas, scoters pass over or near land while attempting to shorten their migratory flights, and hunters have good opportunities to shoot them. While not important to Delaware's hunters, scoters are nonetheless important to the character and nature of Delaware's coastal areas.



CLAPPER RAIL

Rallus longirostris

The Clapper Rail, or Marsh Hen, was once an extremely abundant inhabitant of the marsh. It was considered excellent eating and as such was hunted almost to extinction. Reports of hundreds of birds being shot in a day by hunting parties or tens of dozens of eggs being collected were not uncommon in the early part of the century. While Clapper Rails are generally very retiring, once flushed they become easy targets for the gunner because of the habit of these birds to fly only short distances at a time.

Unlike their cousins, the King and Virginia Rails, Clapper Rails are found more often in the saltwater marshes than in the brackish water marshes. Adult Clapper Rails are usually about 37.5 centimeters (15 inches) long and variously colored. Commonly, the general upper body is grey with streaks of olive brown along the back, tinges of pink in the neck and breast feathers, and black and white barred flanks. The juveniles have a very different

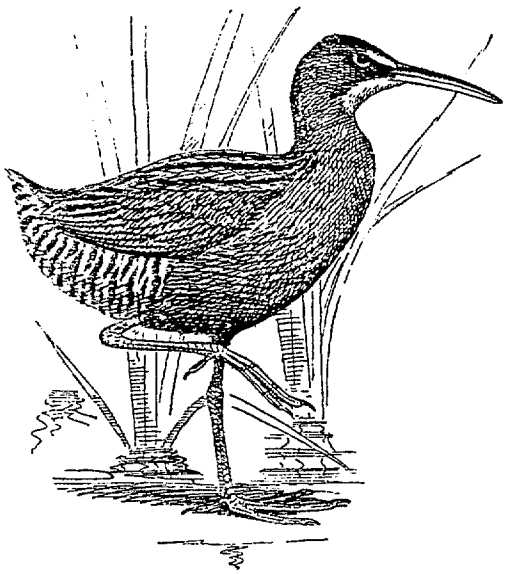
plumage, but they usually molt during the first fall acquiring the adult feathers and colors by their first winter.

Clapper Rails seem to prefer the areas of medium height cordgrass, Spartina alterniflora, which are separated from tital creeks and ditches by zones of tall cordgrass. Such areas provide suitable habitat and a wide variety of food sources. The nests are woven into the stalks of marsh grass, commonly being 17.5-25 centimeters in diameter and 20-30 centimeters above the marsh surface. At this height the nests are above the usual range of high tides, but not always above the range of the higher spring tides leading to the loss of some of the eggs.

As many as fourteen and as few as six eggs have been recorded in Clapper Rail nests but the usual range is between nine and twelve. Eggs are yellowish in color and irregularly spotted. Eggs in the Delaware area are usually laid by the end of May. Hatching takes place in about fourteen days with the young leaving the nests soon after for they are very precocial.

Throughout the cordgrass, Clapper Rails find ample food sources, both animal and vegetable. The most important foods seem to be the various marsh crabs of the genera, Sesarma and Uca, and some of the snails that are common, Littorina and Melampus. Clapper rails will also consume most insects, fish fry and some plant material.

In turn, Clapper Rails are preyed upon by hawks, minks (where these are present), and raccoons. The raccoons account for a large portion of the losses of eggs and young chicks. Since the young are very active and very good swimmers, some are even preyed upon by the larger fishes of the tidal creeks. While these enemies are great, none has been more devastating to the Clapper Rails than man, who is responsible for the large scale slaughtering of these birds and large scale destruction of much of their habitat.



KING RAIL

Rallus elegans

The King Rail is slightly larger than the other two rails common to Delaware, reaching 40.6-45.7 centimeters (16 inches) in length as an adult. The pattern of coloration of the feathers is very similar to that of the Clapper Rail except that the general greyish body shade of the Clapper Rail is replaced by a more reddish brown tint in the King Rail, as it is in the Virginia Rail. King Rails are also more commonly associated with the fresher water areas of the wetlands, for their preferred habitat in this region has been the cattail, rush and pickerel weed zones along the creeks. The King Rail probably uses the salt marshes during the winters and the migration periods.

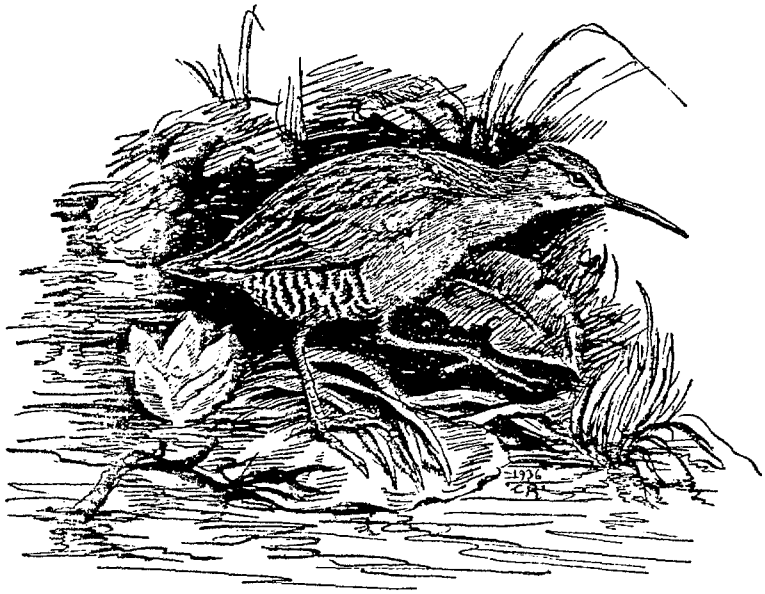
Like all rails, King Rails are generally very shy birds and individuals may easily escape the casual observer. They nest in the damp or wet areas of the marshes, and attempt to conceal their nests, made of pickerel weed or

cattails, by building canopies over them. Nests are usually about 20.3 centimeters in diameter and about 20.3 centimeters above the water level. While the nests are built well above the general high water level, they are often not built where they will escape the occasional, excessively high tide and so many nests are destroyed during these high water periods leading to large egg losses.

King Rails lay anywhere from six to fifteen eggs with eight to eleven being the most common number. Exactly how long these eggs must incubate is unknown but scientists estimate it is about twenty-one to twenty-two days. Most eggs are laid by the end of May in Delaware as the migratory individuals return around April. When the young hatch, the parents are fairly attentive of them and stay with the chicks for as long as a month. Losses of young, however, are still great for they are heavily preyed upon by hawks, crows, owls and raccoons. It is estimated that nine out of every ten eggs laid are successfully hatched but of these only 50 per cent of the nestlings survive the first two weeks.

King Rails are migratory, but little is known of the details of the migrations. Much of the mid- and northern East coast populations overwinter in the south, but there are some year-round resident individuals to be found in all parts of the known range. One area which has seen an increase in the King Rail population has been the rice planting areas of Arkansas and other states. Many Rails have survived or immigrated there because of the food the rice fields provide. King Rails eat seeds and plant matter more so than the other species of rails and thus have found rice fields most suitable. They will, however, eat crabs, fish, insects and frogs both in these rice belt areas and in the more traditional natural wetlands systems.

Again, the greatest enemy of the King Rail has been man, who has caused drastic reductions in King Rail populations in the past through hunting and habitat destruction. King Rails were not considered as good eating as Clapper Rails, but were hunted anyway just because they were plentiful and easily shot. Likewise, much of the draining and spraying of wetland areas in mosquito control projects has lead to population reductions by making the wetlands unsuitable habitat for the King Rail. They are more numerous now then they have been in the recent past but nowhere near as plentiful as they were in the earlier parts of this century.



VIRGINIA RAIL

Rallus limicola

The Virginia Rail, Rallus limicola, is one of the small common rails found in Delaware. Adults of this species reach only 25.4 centimeters (10 inches) in length. It is their small size and slightly more slender bills that distinguish Virginia Rails from the King Rails, for the two species possess almost identical body coloration. The King Rail adult is 40.6-45.7 centimeters (16 inches) in length and possesses a much more prominent bill than does the Virginia Rail, but the brownish-black feathers of the head and back, the rusty brown feathers of the neck and breast, the buff feathers of the chest and the black and white barring of the sides of the King Rail are shared by the Virginia Rail.

The Virginia and King Rails also inhabit the same general zones of the marshes; however, the Virginia Rails seem to be distributed in drier areas of the marsh than are the King Rails. Both these species seem to be

distributed in sections of the wetlands as opposed to the Clapper Rail which is an inhabitant of the more saline marsh area. Further, while both species are widely distributed and well established in the Eastern portion of the country, the Virginia Rail has successfully moved into the central portions of the United States, while the King Rail has not.

Virginia Rails are a migratory species and generally absent from the marshes of Delaware during the winter. There are probably some year-round residents, but the number of these individuals is small. Most of the Virginia Rails are gone by the end of December and remain in the wintering ground until April, when they return to Delaware for the breeding season.

Most of the eggs produced in Delaware are probably laid in May as is common for other species of rails. Usually seven to twelve oval, pale yellow eggs are laid by each female. These eggs are incubated by both parents for approximately fifteen days, although the exact length of the incubation period is unknown. Chicks of the Virginia Rail are very precocial and leave the nests soon after hatching. They are very good swimmers and are found in the water at a very early age.

Virginia Rails are greater predators of invertebrates than are the King Rails for their diet is composed mainly of worms, insect larvae, snails, beetles, amphipods, snakes and fish. Seeds and other plant materials are also consumed but Virginia Rails do not rely on vegetable matter as much as do the King Rails.

Although continually hunted over the years, Virginia Rails have not been as much a favorite of gunners as have been the other species of rails. They are not considered as good tasting a bird as the Clapper or Sora Rails nor as good a sport. Still, the Virginia Rails were extensively hunted in

all East coast marshes. Populations were eliminated from many areas and greatly reduced in others. Like other marsh birds, the species has also experienced destruction of their habitats which has intensified the population reduction caused by widespread hunting. However, enough Virginia Rails have survived in Delaware so that they are common inhabitants of the marshes here and are still hunted during the fall.

References for Shorebirds and Waterfowl

American Ornithologist's Union. 1957. Checklist of North American Birds. A.O.U., Baltimore, Md.

Bent, A. C. 1923. Life histories of North American wildfowl. U. S. Govt. Print. Ofc. Reprinted in 1963 by Dover Publ.

Bent, A. C. 1923. Life histories of North American marsh birds. U. S. Govt. Print. Ofc. Reprinted in 1963 by Dover Publ.

Brewer, T. M. 1840. Wilson's American ornithology. Reprinted in 1970 by Arno Press Inc., N.Y.

Cunningham, R. L. 1965. Predation on birds by the Cattle Egret. Aug. 82: 502-503.

Faber, R. A. and J. J. Hickey. 1973. Eggshell thinning, chlorinated hydrocarbons and mercury in inland aquatic bird eggs, 1969-1970. Pest. Montr. J. 7(1): 27-36.

Faber, R. A., R. W. Rosebrough and H. M. Pratt. 1972. Organochlorines and mercury in common egrets and Great Blue Herons. En. Poll. 3: 111-112.

Hume, R. L. and C. Shoenfeld, eds. 1968. Canada Goose management. Current continental problems and programs. Dembar Educational Research Serv., Inc., Madison, Wis.

Jacques, H. E. and R. Ollivier. 1960. How to know the water birds. Wm. C. Brown Co., Iowa.

Jenni, D. A. 1969. A study of the ecology of four species of herons during the breeding seasons at Lake Alice, Alachua County, Florida. Ecol. Monogr. 39: 245-270.

Johnsgard, P. A. 1965. Handbook of waterfowl behavior. Cornell University Press, Ithaca, N.Y.

Linduska, J. P. 1964. Waterfowl tomorrow. U. S. Dept. Inter., Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Serv.

Linehan, J. T. and R. F. Jones. 1971. The Delaware bird list. Society of Natural History of Delaware.

McAloney, K. 1973. The breeding biology of the Great Blue Heron on Tobacco Island, Nova Scotia. Canad. Field Nat. 87(2): 137-140.

Meanly, B. 1953. Nesting of the King Rail in Arkansas rice fields. Aug. 70: 261-269.

Meanly, B. 1956. Food habits of the King Rail in Arkansas rice fields. Aug. 73: 252-258.

Meanly, B. 1957. Notes on the courtship behavior of King Rail. Aug. 74: 433-440.

Meyerreicks, A. J. 1960. Success story of a pioneering bird. Nat. Hist. 69: 46-57.

Meyerreicks, A. J. 1962. Diversity typifies heron feeding. Nat. Hist. 71: 48-59.

Narrative Report. Bombay Hook National Wildlife Refuge. Fiscal Year 1974.

Narrative Report. Prime Hook National Wildlife Refuge. Fiscal Year 1974.

Owen, D. F. 1969. Mortality of Great Blue Herons as shown by banding recoveries. Aug. 76: 464-470.

Pearson, T. C., ed. 1936. Birds of America. Garden City Publ. Co., Inc., Garden City, N.Y.

Petersen, R. T. 1934. A field guide to the birds. Houghton Mifflin Co., Boston.

Pratt, H. M. 1970. Breeding biology of Great Blue Herons and common egrets in Central California. Condor 72: 409-416.

Pratt, H. M. 1972. Nesting success of common egrets and Great Blue Herons in the San Francisco Bay region. Condor 74: 447-454.

Rand, A. L. 1972. Birds of North America. Doubleday and Company, Inc., N.Y.

Reese, J. C. 1973. Unusual feeding behavior of Great Blue Herons and Common Egrets. Condor 75(3): 352.

Stewart, R. E. 1962. Waterfowl population in the Upper Chesapeake Region. U.S. Fish and Wildl. Serv., Spec. Rept., Wildlife, 65. 208 pp.

Stone, W. 1965. Bird studies at Old Cape May. Dover Publ., N.Y.

U.S. Dept. of the Interior. 1970. Distribution in states and counties of waterfowl species harvested during 1961-1970 hunting seasons. Fish and Wildl. Serv., Spec. Sci. Rept., Wildl. No. 137.

Vermeer, K. 1973. Great Blue Heron and double-crested cormorant colonies in the prairie provinces. Canad. Field Nat. 87: 427-432.

Vermeer, K. and R. W. Risebrough. 1972. Additional information on eggshell thickness in relation to DDE concentrations in Great Blue Heron eggs. Canad. Field Nat. 86: 384-385.

Waterfowl Status Report. 1972. U. S. Dept. Inter., Fish and Wildl. Serv., Spec. Sci. Rept., Wildl. No. 166.

CREDITS

Several illustrations are from The Chesapeake Bay in Maryland, by The Johns Hopkins University.

Copyright © 1973 by The Johns Hopkins University Press. All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, xerography, or any information storage and retrieval system, without permission in writing from the publisher. The Johns Hopkins University Press, Baltimore, Maryland 21218, The Johns Hopkins University Press Ltd., London.

Permission was kindly granted by the Editor and Publisher to use the following illustrations:

Jellyfishes, Sea Nettles and Moon Jellyfish (Page 18)
Hard Clam (Page 20)
American Oyster (Page 22)
Blue Crab, Adult (Page 26)

Several other books were invaluable during the preparation of this report. They are cited in the various bibliographies located throughout the report. Two that were of great graphic value were: Bird Studies at Old Cape May - Volume 1 and 2, Stone; How to Know the Waterbirds, Brown.

Delaware Coastal Management Program

David S. Hugg, III
Benjamin Coston
John Sherman
Kenneth Bessinger
Robert MacPherson
Nancy Pleasanton
Jerry Homer

Graphics and Composition

William F. Fleming
Stephen D. Corazza
Douglas Clendaniel
Cora Bonniwell

ERRATA SHEET

Because of the immensity and the scientific nature of this report, some typographical errors have occurred. Those which were discovered between the printing and binding stages of publication are listed below. The Environmental Policy Unit of the Office of Management, Budget and Planning would appreciate receiving a note from those readers who find further errors.

Page 10, Line 3	"bit" should be "big."
Page 39, Line 22	"is" should be "are."
Page 42, Line 23	"manification" should be "magnification."
Page 52, Line 6	"jerardii" should be "gerardi."
Page 52, Line 31	"panecum" should be "panicum."
Page 59, bottom	"Namifolia" should be "Halimifolia."
Page 63, bottom	"Pontendria" should be "Pontederia."
Page 66, bottom	"Spacata" should be "Spicata."
Page 168, Line 17	"Diaber" should be "Daiber."
Page 214, Line 7	"is" should be "are."
Page 214, Line 27	"phosphorous" should be "phosphorus."
Page 215, Line 8	"spetic" should be "septic."
Page 223, Line 24	"Contro" should be "Control."
Page 225, Line 9	Period after "1972" should be after ")."
Page 228, Line 3	Comma after "considered" should be removed.
Page 241, Line 20	"processes" should be "organisms."
Page 246, Line 21	Figure number "77" should be added.
Page 255, Line 8	"loss" should be "lost."
Page 255, Line 23	"are" should be "were."
Page 259, Line 1	"estuarine" should be inserted in front of "organisms."
Page 263, Line 3	Comma after CO_2 should be removed.
Page 267, Line 23	"nucous" should be "mucous."
Page 268, Line 15	"35-35" should be "30-35."
Page 269, Line 1	"ocean" should be capitalized.
Page 269, Line 8	"organisms" should be "organism."
Page 269, Line 14	"vascular" should be "vacuolar."
Page 269, Line 19	"organisms" should be "organism."
Page 271, Line 15	"stimulate" should be "simulate."
Page 271, Line 21	"Cell A to Cell B" should be "Cell B to Cell A."
Page 271, Line 23	"Cell B to Cell A" should be "Cell A to Cell B."
Page 277, Line 2	"of which" should be inserted after "larvae."
Page 285, Line 19	"morone" should be capitalized.
Page 297, Line 5	"boney" should be "bony."
Page 445, bottom	"SHUOTER" should be "SHUSTER."
Page 447, bottom	"SHUOTER" should be "SHUSTER."
Page 455, bottom	"SHUOTER" should be "SHUSTER."

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES