

Summary of Literature Study
of Freshwater Ponds
on Assateague Island, MD

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The investigation of natural freshwater ponds on Assateague Island between the more dynamic ocean and the languid bay has been sporadic and of limited duration. An assumption has been made that the freshwater ponds are an important source of freshwater for the various land bound animals that are limited to the island. Migratory birds use the ponds as a source of fresh water, and insect larva and small fish as food. Several texts give definitions to these bodies of waters, variously called pannes (or pans), impoundments, shallow lakes, and ponds. In writing of ponds, William J Clark*1 goes into detail about the history of the definition of ponds. The term is a general one relating to its small size, its shallow depth, its littoral ecology, lack of wind and wave action, and lack of thermal stratification.

For our purposes, a pond on Assateague Island is small, shallow, isolated from marine and estuarine water, permanent or semi-permanent, with freshwater (less than 5 ppt salinity), and of natural origin (excludes roadside ditches). It is recognized, however that the animals on the island do not draw any distinction between water in natural ponds or in roadside drainage ditches.

The origin of these ponds is varied, as outlined by Shawn L. Shotzberger*2. One agent in pond formation could be the closure of marshy areas by the processes of creek or tidal sedimentation. Pans, developed in a marsh, more generally have "abrupt rather than gently shelving shorelines," which hold water after low tide. They could be areas not consolidated by vegetative colonization. Or tussocks of vegetation could grow into the natural outlet of tidal flows, thereby damming the waters.*3 Inlet fill-in could also impound water in an area of high ground. Inland pond building could proceed as a result of rainwater caught between dune swales. In addition, pond formation could result from rainwater or groundwater held in fallen-tree root hollows. Natural springs or ground water upwelling could also form inland ponds. Orientation of the pond to the island topography can give a hint of its causal formation.*3

The origin of the pond will effect the pond chemistry, thereby effecting the ecology of the area.*1, Differences of vegetation and pond bottom material control the productivity of ponds.*1,4 Ponds with sandy bottoms and no decomposed organic material tend to have less salinity. "Silt and clay materials tend to retain more salt than does sand."*7

Since the environment of the barrier island has extreme fluxuations in daily and seasonal temperatures, the ponds' chemistry may change with rainfall, evaporation, and storm

events. Wind speed and length of open water on which wind can operate (fetch) determine the mixing potential. Ponds are highly variable due to storm tracking and vegetative wind breaks. Two ponds within the same geographical area can not be assumed to be equally effected by the same storm. Biological activity can vary between ponds but are usually consistent within one pond.*1 Ponds of limited duration, especially vernal ponds, can provide a specialized habitat whose contribution should not be overlooked.*4 Sand acts as a magnifier of light and temperature, especially in the interdune zone. Ponds located in this zone are effected by in the arid microclimate of the inner dunes.

The hydrology of the groundwater in the Delmarva peninsula was delineated in 1992 by Donna L. Richardson. Among other analysis, she presented mapping of four wells from Toms Cove and east. The water table there is part of the Columbia aquifer. The first vertical barrier is the Upper Yorktown-Eastover confining unit beginning at about 40 feet below sea level. see figure. It is assumed that the north part of Assateague Island conforms to that of the Tom's Cove area. Chloride concentrations less than 250 mg/L are prevalent in the Columbia aquifer on Chintoteague Island interior. Chloride concentrations are at the same level in the upper Yorktown-Eastover aquifer. The chloride concentration changes to above 250 mg/L in the middle of the Yorktown-Eastover aquifer. Chloride Concentrations are stratified in the lower Yorktown-Eastover aquifer, low on top, high near the bottom. High demand for water resources has led to the leakage of water from the unconfined aquifer into the confined region. It has also reduced the freshwater recharge flow into the Chesapeake Bay and the Atlantic Ocean.

Several observation wells and production wells have been placed in the unconfined aquifer in the upper Maryland region. One in Ocean Pines and one at North Ocean City are of particular interest for our purposes. Pumpage from Ocean Pines rose from 10 million gallons per year in 19xx to 163 million gallons in 1986. When yearly precipitation drops below 40 inches for the year, the recharge of the unconfined water table can not keep up with demand. In 1986 chloride concentrations were 13 to 15 mg/L: pH was 5.83. The specific conductance was 73 and 77 uS/cm. At North Ocean City, flow rate of the unconfined aquifer dropped from 150 gal/min in 1973 to 50 gal/min in 1986. Chlorine concentrations were 39mg/L and 46 mg/L for the aforementioned years; pH was 6.69 for 1986. Specific conductance was steady 338 and 370 uS/cm. It is assumed that the data from North Ocean City has the most relevance to the ground water table on Assateague Island. Updated information should be acquired.

The staff at the National Park has information that a mixed seawater-freshwater layer is lensed or perched over the unconfined Columbia aquifer under the island surface. It is suspected that is the direct source for the recharge to some of the freshwater ponds, in addition to the watershed and direct precipitation. In unrelated work, I encountered water at about 4 feet at the location of the state/federal boundry at the center width of the island.

The difference in densities of freshwater and saline water

effects the physics of flow. Densities of saline water is greater than the density of freshwater, therefore freshwater floats on top of saline water. In the estuarine context, fresh water grades into saline water with the steady increase in the contents of dissolved solids. The zone of dispersion is often thin in respect to the overall thickness of the freshwater lens. I would expect a similar reaction to occur in ponds in which freshwater and saline water meet.*6 Island ponds could vary in salinity depending on the mechanism of pond formation and its relationship to tidal influences, (also in relationship to a lensed or perched mixed water and topography affecting rainwater runoff).

Beefink (1977) defines "a saltmarsh as a natural or semi-natural halophytic grassland and dwarf brushwood on the alluvial sediments bordering saline water bodies whose water fluxuates either tidally or non-tidally." There are aspects of the freshwater ponds that relate to the adjacent tidal marshes. Ponds on Assateague Island can be influenced by tidal estuarine or marine overwash, which adds salinity during the event. If not accompanied by rains, the pond water may go from freshwater to oligohaline. "Tidal action must be strong enough to maintain salinities above about 5 ppt: otherwise the salt marsh is replaced by reeds, rushes and freshwater aquatic plants." "The upper marsh is flooded irregularly and has a minimum of at least 10 days of continuous exposure to the atmosphere, while the lower marsh is flooded nearly daily with never more than 9 days continuous exposure." "If the adjacent body of water is less than 5%, the salt marsh vegetation is replaced by freshwater plants."*7

I would suggest that the inland ponds of freshwater can be located on a line that grades in salinity from marine through estuarine to inland fresh, depending on origin, connectedness with saline water, and age.

The first study of 21 natural ponds in Assateague Island National Seashore was done by Roman Jesien, March and April 1986. Seasonal factors may be at play in the results of data obtained in this study. Jesien located the ponds from information that already existed among the staff of the park service. Ponds were shallow, around 2 meters. They were biologically active, well oxygenated, near neutral. The conductivity was the single delineator, from

LOW at 125-550 umhos conductivity: ponds C,F,H,I,J,S,T

MEDIUM at 950-2350 umhos/cm conductivity: ponds D,G,L,N,P,U

HIGH at 630->10,000 umhos/cm conductivity: ponds A, E,

O(mosquito ditch),B,K(low in marsh)

He provides text directions and aerial photographic information of the pond locations. A10

J. W. Portnoy studied vernal ponds in kettle depressions (located on USGS topographical map, 10 ft deep) of Cape Cod National Seashore to distinguish the acids present that might affect successful *Ambystoma* breeding. The results attribute pond acidity to the dissolved organic acids, rather than acids from mineral or atmospheric sources. The Gran graphical method makes it possible to distinguish relative amounts of mineral vs. organic acids that make up the total acidity. "Generally low

conductivity...reflects low concentrations of strong electrolytes and a preponderance of weakly conductive organic solutes." These organic compounds produce the conspicuous "humic acid" color of swamp waters." In addition, high chemical oxygen demand is the result of high levels of dissolved organic acids. Major constituents of seawater are present in these vernal ponds *4

Terry Bashore had a class project for graduate students at the U of MD-Eastern Shore compare and build onto the previous study by Jesien in the Fall of 1988. Parameters investigated were similar to those of Jesien, although more vegetative identification was conducted. There were some differences in the levels of the parameters but seasonal differences could contribute to that difference. Spring investigation of the water quality might register the slower activity of winter, with fall study showing summer activity. Dissolved oxygen and conductivity were the two significant differences. *9 see figure

Dr. Lawrence Hoyer was another scientist that studied the ponds on Assateague, his work done with high school students in June 1989. Twenty three ponds were investigated for water quality parameters, flora and fauna associated with them. Mosquitofish, *Gambusia affinis*, was selected to compare from different ponds on the island and with another population in Texas for which data existed. Data was not present in this file. *11

Freshwater pond investigation file by Pagan is details of his work to find and delineate the ponds in 1991. His work built on the preceeding investigations and on the knowledge of the staff. There are notes that several of his ponds no longer exist due to the storm of 1992.

Included here is a comparison of Ocean water analysis with bay and river water analysis, from Estuarine Ecology text by John W. Day, et al., table 3-1, after Nicol 1960, Burton 1976, and Liss 1976.

	OCEAN *12	BAY	RIVER	AQUIFER
Salinity	35g per Kg	30.4g	-	-
Chloride	19,353mg/L		8mg/L	6-100mg/L
Sodium	10,770		6	
Sulfate	2,712		11	
Magnesium	1,294		4	
Calcium	412		15	
Potassium	399		2	
Bicarbonate	140		58	
Bromide	65		-	
Strontium	9		-	
ELEMENTS				
Boron	4,500		10	
Fluoride	1,400		100	
Silicon	5,000		13,100	
Nitrogen	250		230	
Phosphorous	35		20	
pH				
DO				
Sp. Cond.				

NOAA's Estuarine Living Marine Resources Project proposed a Estuarine Classification of species by salinity ranges researched from existing Chesapeake Bay catch data in May 1990. This study analyzed field distribution of species including many larval and juvenile stages as well as adults. However quantitative data was not taken. It also proposes a new salinity designation based on biogeographic ordination along a gradient, that can compare to the Venice system. The author uses multivariate technique called Principal Component analysis.

It appears that the fish species sampled from the freshwater ponds are ones known to tolerate a wide range of salinity, ie mummichug is found in waters that range from fresh to total marine of 35 ppt. These fish are also dwellers of the littoral areas. The NOAA information lists salinity zone and species adult or larva present in salinity gradients. It is assumed that the fish found in the island ponds come out of the parent stock from the bay. Methods of transport could be eggs on the legs of mobile animals or from bay water overwashes. These fish are not migratory nor pelagic species. Also the more isolated ponds and ponds with extreme conditions may not support fish during the entire year.

DR. HOYER sampling	NOAA ELMR data
species present in ponds	salinity range of larva
Gambusia affinis, Mosquitofish	f-18 ppt
Lucania parva, rainwater killifish	0-30 ppt
Cyprinodon variegatus, sheepshead	0-30 ppt
Fuvdulus heteroclitus, mummichug	0-30 ppt
Anguila rostrata, American eel	

There is a potential many other bay fish may be found in the island ponds. However they would have to negotiate the bay salinity range to take advantage of the niche.

Shawn Shotzberger working in August 1992 revisited the Jesien ponds and located others. In a more systematic approach he delineated the size and circumference and UTM coordinates for each of 36 ponds. He then identified vegetation, animal use, and bottom sediment. Submerged vegetation, when found, was Ruppia maritima. The emergent vegetation was Scirpus, Juncus often together, Eleocharis albidia (?), Spartina patens, Phragmites and Typha angustifolia. There were a range of trees and shrubs around the ponds that characterize the various habitats on Assateague Island.

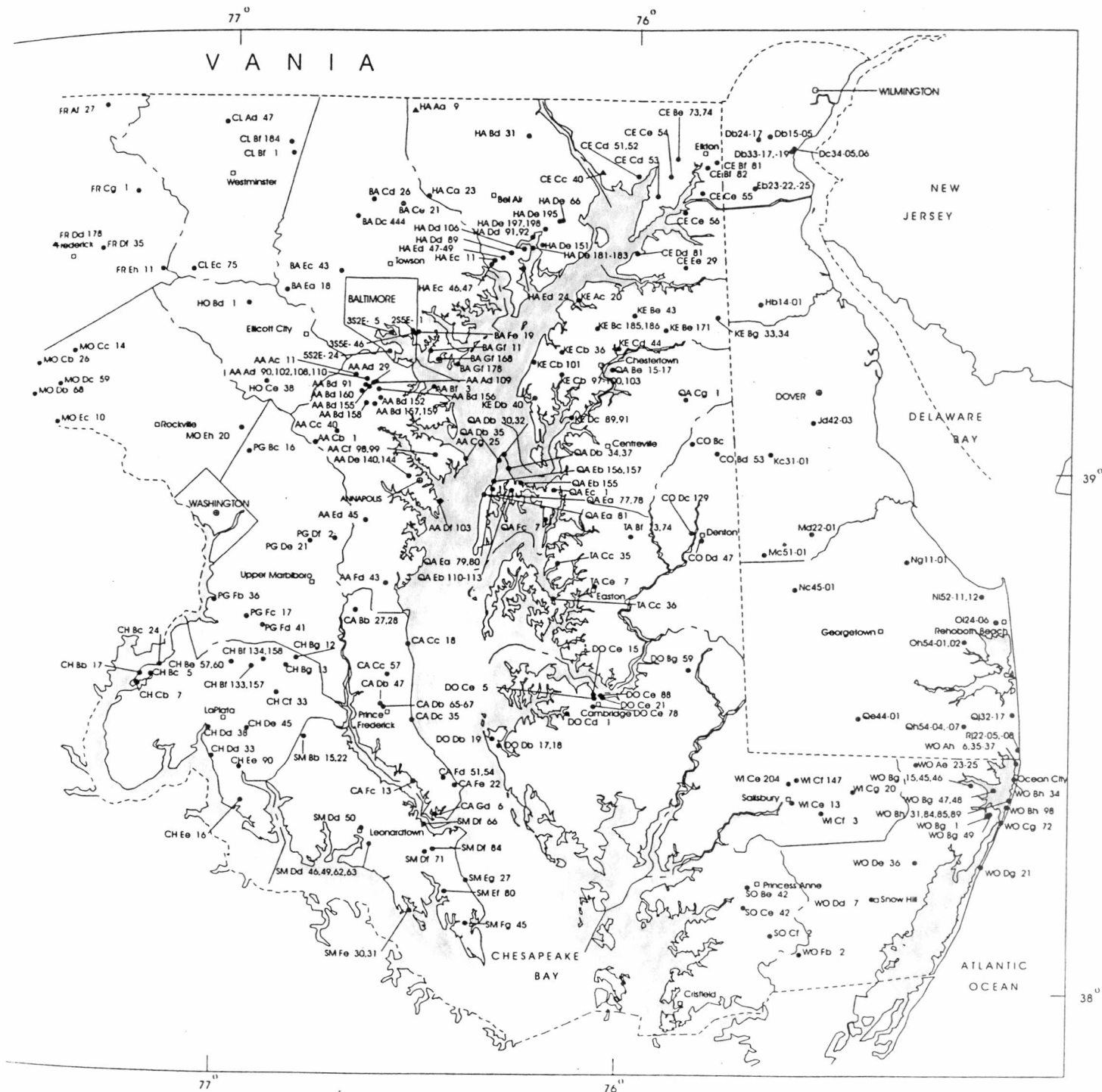
The study of ponds on Assateague would be interesting to continue. From a cursory look several ponds have shrunk considerably. An intensive look at the water budgets for these ponds would be helpful in determining the cause of the decrease. Pond storage is equal to the input (recharge) minus the output (discharge). Input comes from precipitation, watershed, groundwater, and overwash or bay intrusion. Output is usually by evaporation, transpiration, outlet, and percolation. Another aspect of study could be the use of the habitat by insects, fish, amphibians, birds and mammals on the island and migratory species. Vegetative use of the freshwater habitat could be studied. No study has been ongoing or a repeat of the previous work to verify data. Parameters studied have not been consistent.

The value of these ponds is an understood but the need to study them seems less certain until there is a problem that needs to be addressed.

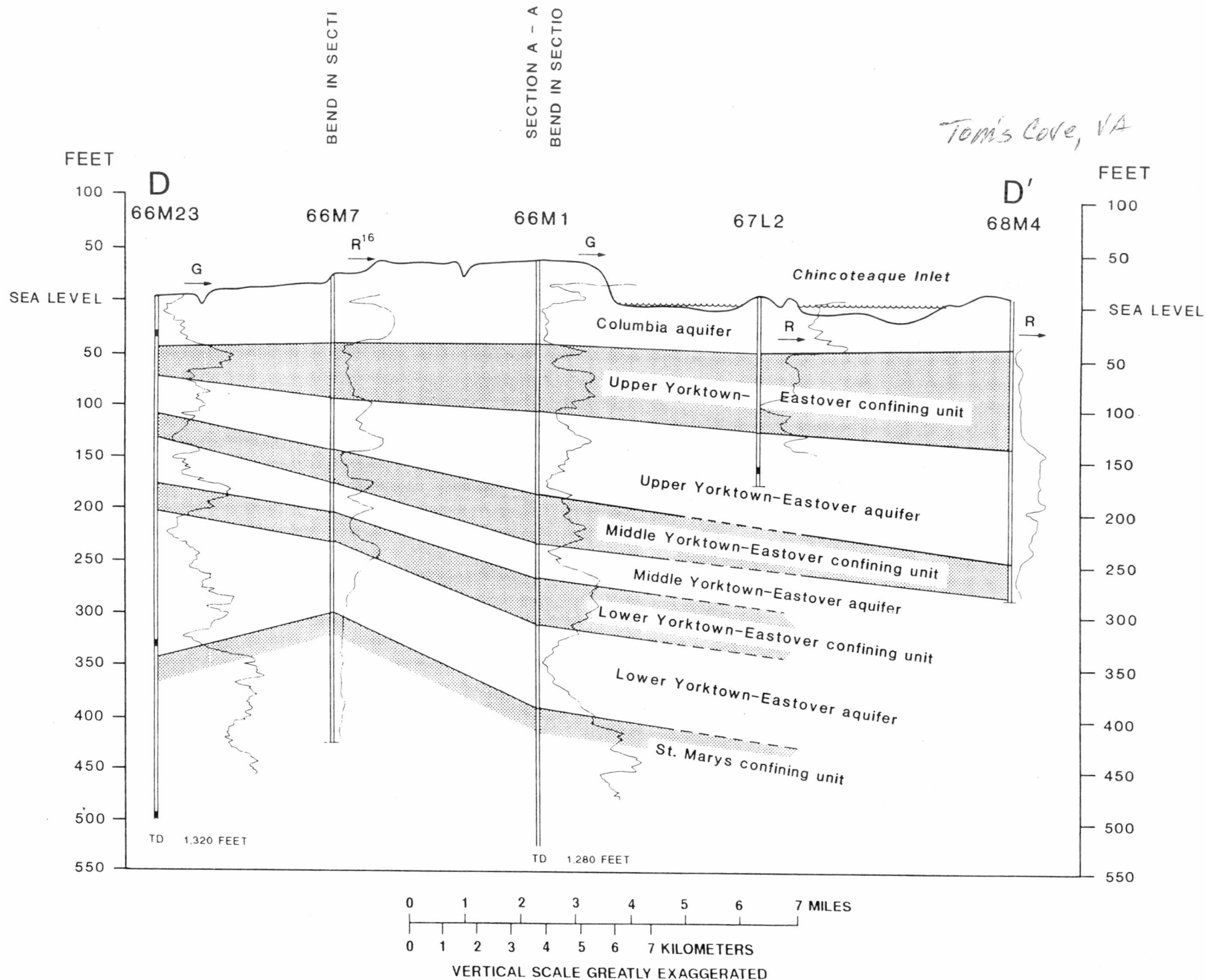
POND A	JESIEN-3-89	BAYSHORE-9-92
DEPTH	1 M	40 cm
AREA		
TEMPERATURE-WATER	14 C	21 C
TEMPERATURE-AIR		
DISSOLVED OXYGEN	8.3 mg/L	7.4
%SATURATION	80%	
CONDUCTIVITY	3700 uMHOS/cm	6000 OHM
SALINITY	2.5 ppt*	0
pH		6.57
NITRITE		0.015 mg/L
NITRATE & NITRITE		0.45 mg/L
AMMONIUM		1.90 mg/L
ORTHO-PHOSPHATE		0.157 mg/L
FISH PRESENT	YES	

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12. Sierra Club Naturalist guide, Middle Atlantic Coast, Bill Perry.

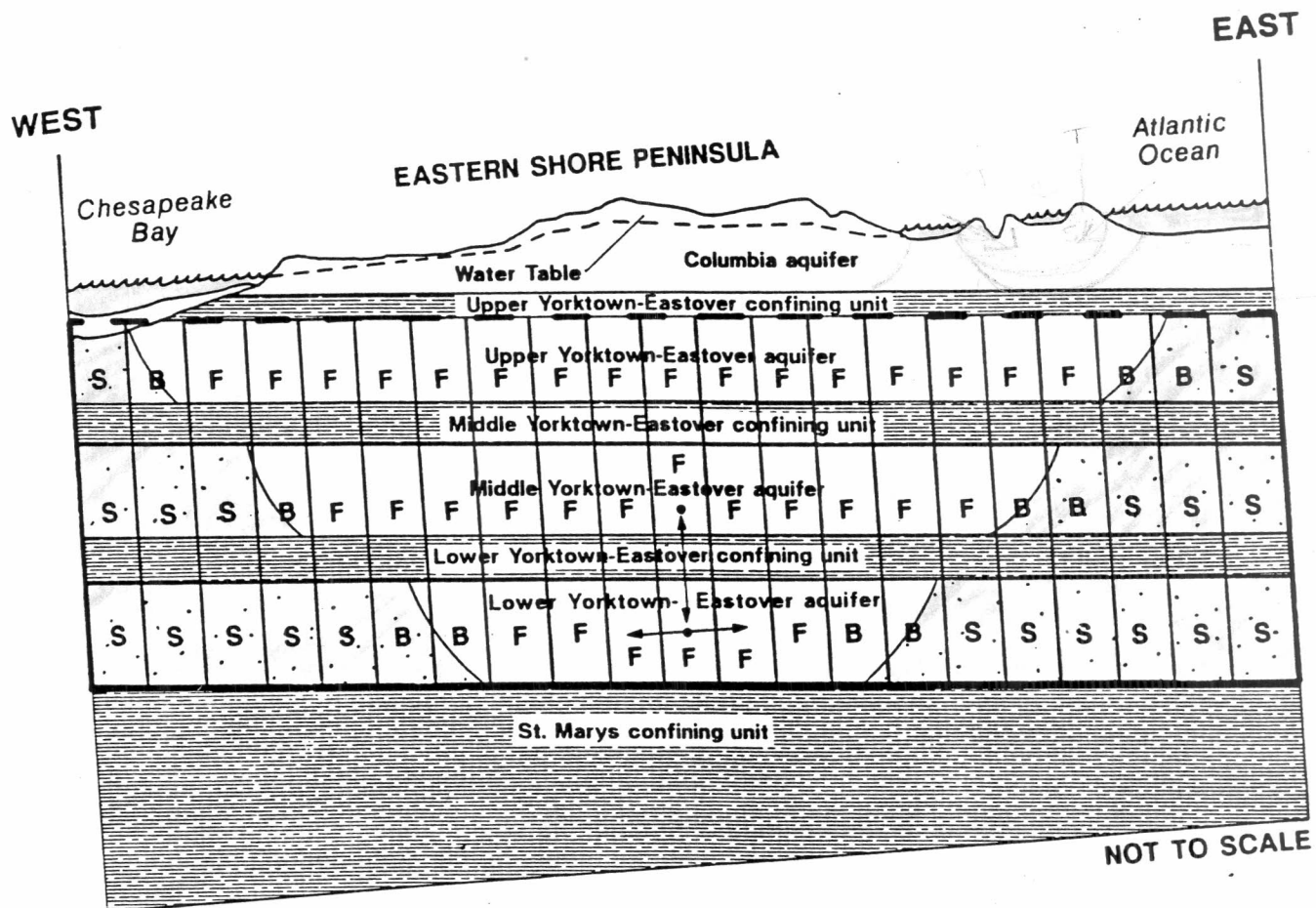


Tom's Cove, VA



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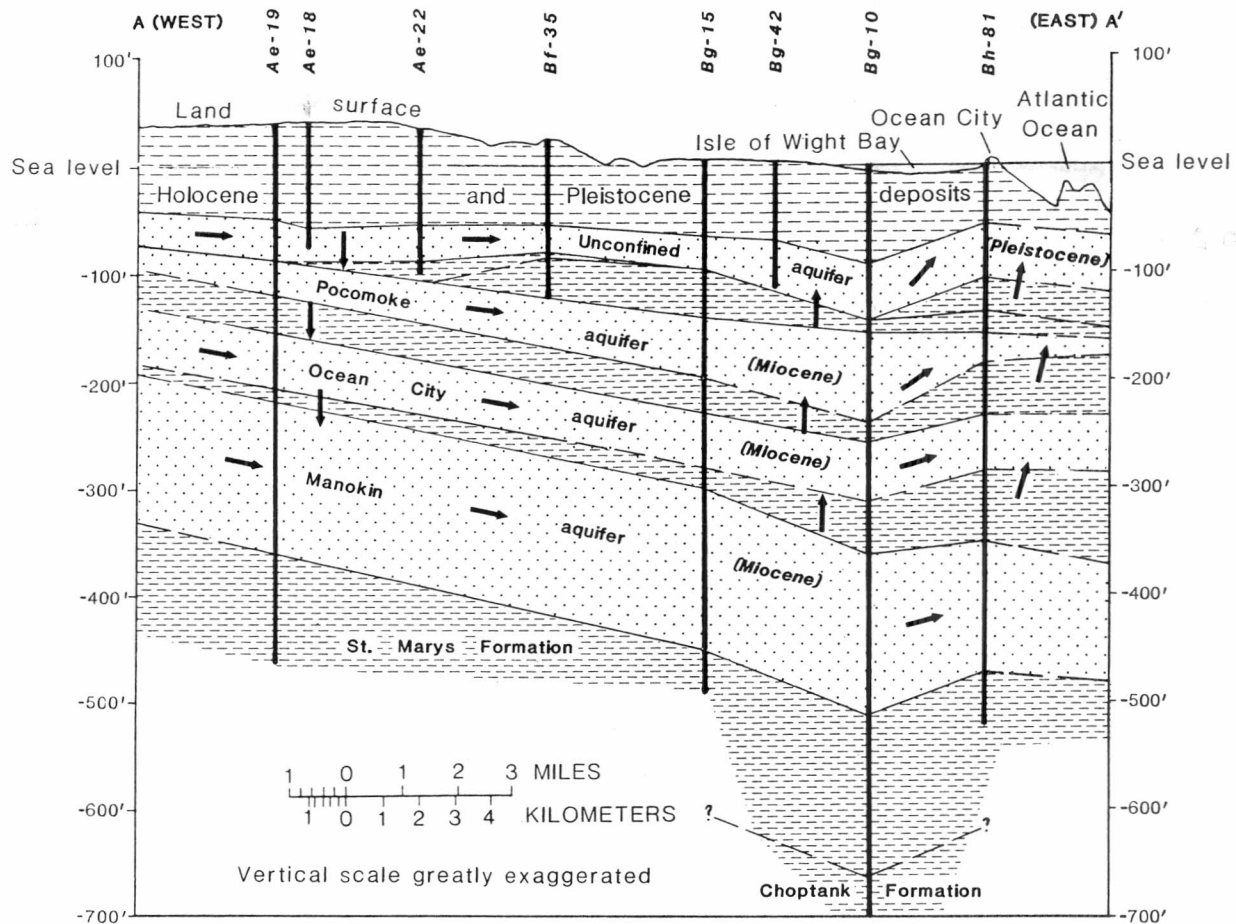
1992



EXPLANATION

- F FRESHWATER VARIABLE-HEAD NODE
- B VARIABLE-HEAD NODE CONTAINING BOTH SALTWATER AND FRESHWATER
- S SALTWATER VARIABLE-HEAD NODE
-  SALTWATER-FRESHWATER INTERFACE
-  NO-FLOW BOUNDARY
-  CONSTANT-HEAD BOUNDARY-- REPRESENTS LONG-TERM HEADS IN COLUMBIA AQUIFER
-  DIRECTION OF FLOW WITHIN AQUIFER (HORIZONTAL)
-  CONFINING-UNIT LEAKANCE (VERTICAL)

Figure 25.—Physical and model conceptualizations of ground-water-flow system.



EXPLANATION

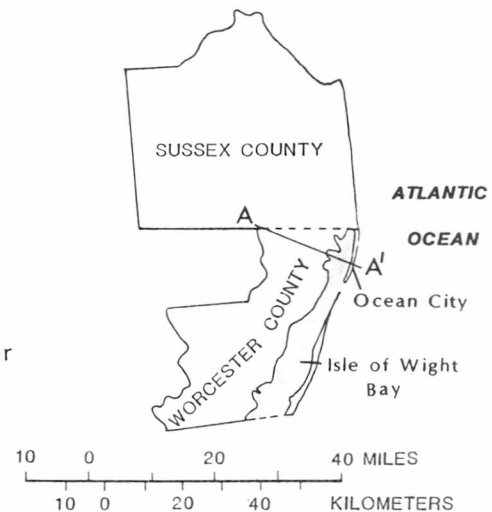
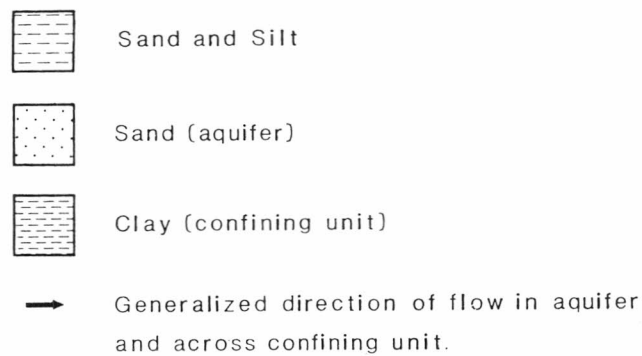


Figure 2.--Generalized geologic section trending east-southeastward across study area, and generalized directions of steady-state ground-water flow. (Modified from Weigle and Achmad, 1982, p.5.)

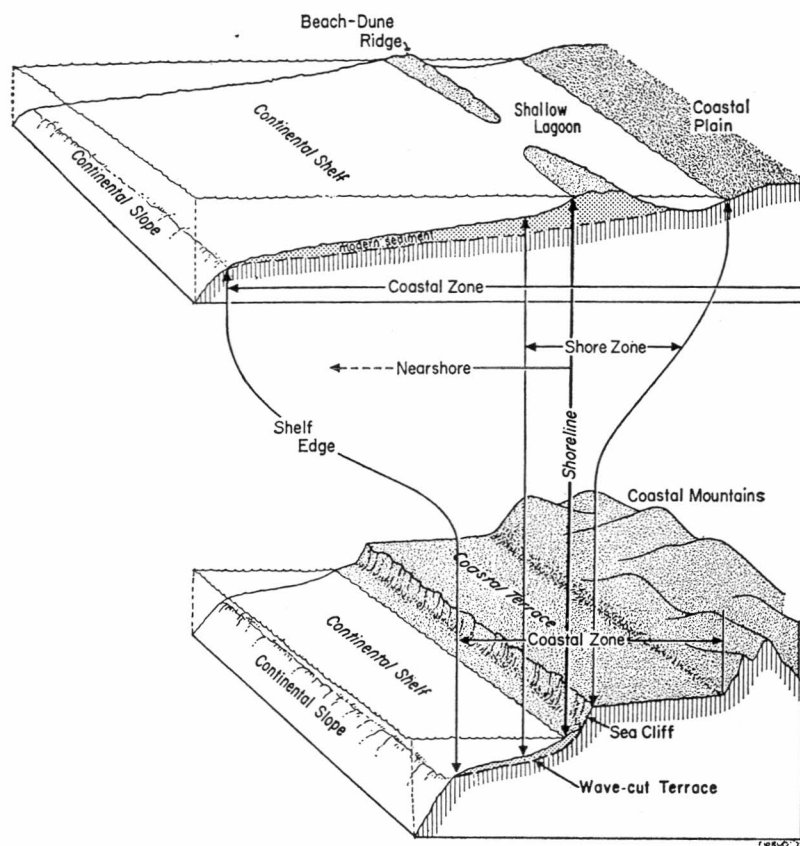


Figure 1.1 Wide-shelf plains coast (upper) characteristic of the U.S. east coast (trailing edge), and narrow-shelf mountainous coast (lower), characteristic of the U.S. west coast (collision edge). (source: Reference 1.)

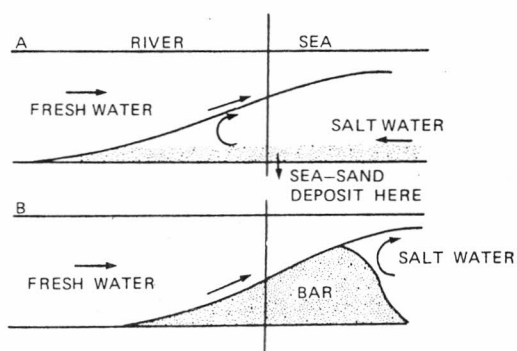


Figure 1.2 Formation of an estuarine sand bar. (source: Reference 3.)

*could also be at work where
fresh water spring/stream meet
salt water marsh?*

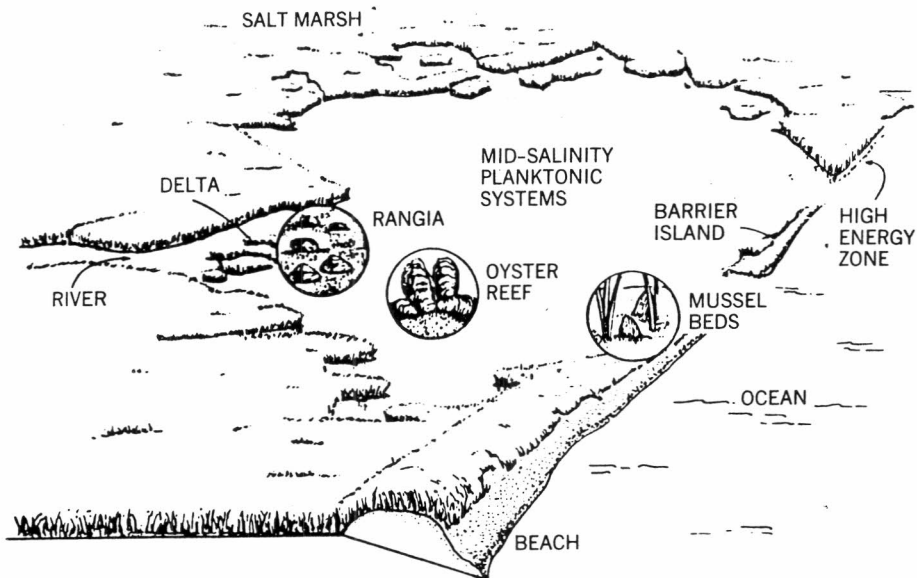


Figure 1.4 Idealized top view of a typical estuary showing some of the major subsystems.

energy levels (current and turbulence), water clarity, salinity, biota, chemical concentrations, oxidizing and reducing conditions in the sediments, and so on. In intertidal and subtidal areas with significant currents there are often worm flats or mollusc beds. These filter feeding organisms depend on currents to transport oxygen and food and carry away wastes.

In shallow subtidal waters of somewhat reduced currents where light reaches the bottom, submerged marine meadows or seagrass beds often occur. Water clarity is high and sediments are finer, partially as a result of the grass's ability to trap sediments. The reduced zone of the sediments extends to within a centimeter or less of the surface. In high-salinity tropical waters these submerged grass beds are often dominated by turtle grass, *Thalassia testudinum*, and in the temperate zone by eel grass, *Zostera marina*. In lower-salinity waters (less than 5 ppt) genera such as *Ruppia*, *Potamogeton*, and *Valisneria* are common.

In this typical estuary, the salinity decreases steadily from the ocean to the river. The high-salinity area of the estuary (30–35 ppt) is called polyhaline, middle salinities around 15 ppt constitute the mesohaline, and the very low-salinity region (0–5 ppt) is called the oligohaline zone.

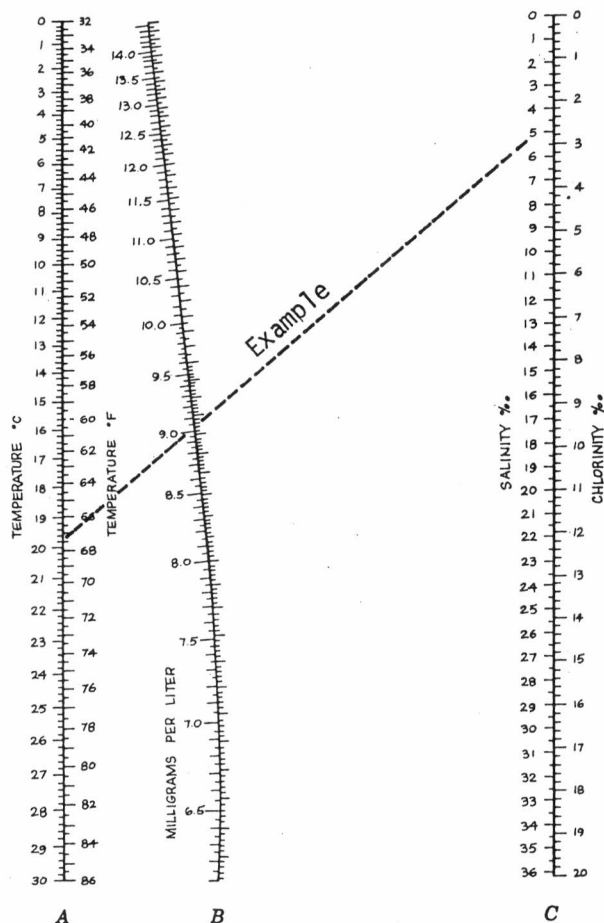
Bordering the estuary in areas of mild to sluggish currents are intertidal wetlands where salt marshes occur in the temperate zone and mangrove swamps occur in the tropics. These are areas of turbid waters and highly reducing and very fine sediments. The vegetation has very high growth rates and the animals tend to be deposit feeders.

CEM

11. SOLUBILITY OF OXYGEN
IN WATER

Nomograph relating the solubility of oxygen in water (B) to temperature (A) and salinity (C). Example: For water at 5 parts per thousand (‰) salinity and 20°C the solubility of O_2 is 8.95 milligrams per liter.

SOURCE. Milo C. Bell, *Fisheries Handbook of Engineering Requirements and Biological Criteria*, U.S. Army Corps of Engineers, Fisheries-Engineering Research Program, Portland, Oregon, February 1973.



Fish need: cold water type 4.0 mg/L
warm water type 5.0 mg/L

water) are relatively scarce in the waters of a natural coastal ecosystem because they are taken up rapidly by the plant life present (page 673). The major plant nutrients are nitrate and phosphate, with the content of nitrogen in plant tissue higher than that of phosphorus.⁹ In coastal waters (but not fresh waters) the amount of available nitrate (a form of nitrogen) is generally believed to be the nutrient factor that controls the abundance of plants.¹¹ The governing Ecological Principle is: *The primary productivity and carrying capacity of coastal waters are normally limited by the amount of available nitrogen* (No. 5).

Inorganic trace elements of importance in plant nutrition are iron, manganese, molybdenum, cobalt, and zinc. Other dissolved inorganic substances of importance are sulfate, carbonate, calcium, magnesium, sodium, and potassium. Certain organic substances may also be critically involved, such as vitamins, organic compounds of nitrogen, and simple sugars.

Salinity

The salinity of coastal waters reflects a complex mixture of dissolved salts, the most

abundant being the common salt, sodium chloride. Salinity throughout the coastal ecosystem fluctuates with the amount of dilution by precipitation and by land drainage or river inflow. Typically, there is a gradient in salt content that starts with a value of about 35 ppt (parts of salt per thousand parts of water) offshore, drops to about 30 ppt in nearshore waters and in the seaward ends of estuaries, and then falls to less than 0.5 ppt at some distance up the tributary rivers. In estuaries, where more saline and heavier water is entering beneath fresher runoff water at the surface, a powerful two-layered circulation pattern is established (see Figure 1.10).

Some coastal species can tolerate a wide range of salinity, whereas others require a narrow range to live and reproduce successfully. Some species require different salinities at different phases of their life cycles, such as are provided by regular seasonal rhythms in salinity in estuaries from spring runoffs and summer drought.

Figure 1.11 shows the range of salinity tolerance characteristic of some estuarine plants and animals. Most of those with a narrow tolerance can nevertheless withstand short-term exposure to a much wider salinity

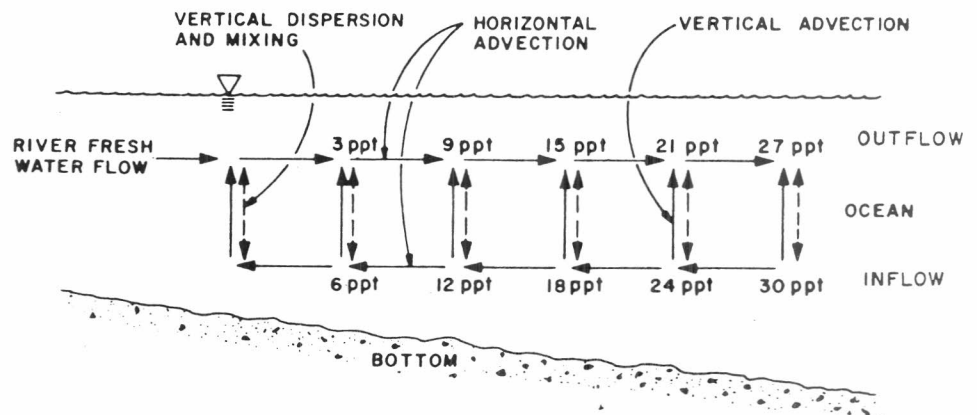


Figure 1.10 Salinity distribution in parts of salt per thousand of water (ppt) and flow pathways in a typical stratified estuary. (SOURCE: Reference 10.)

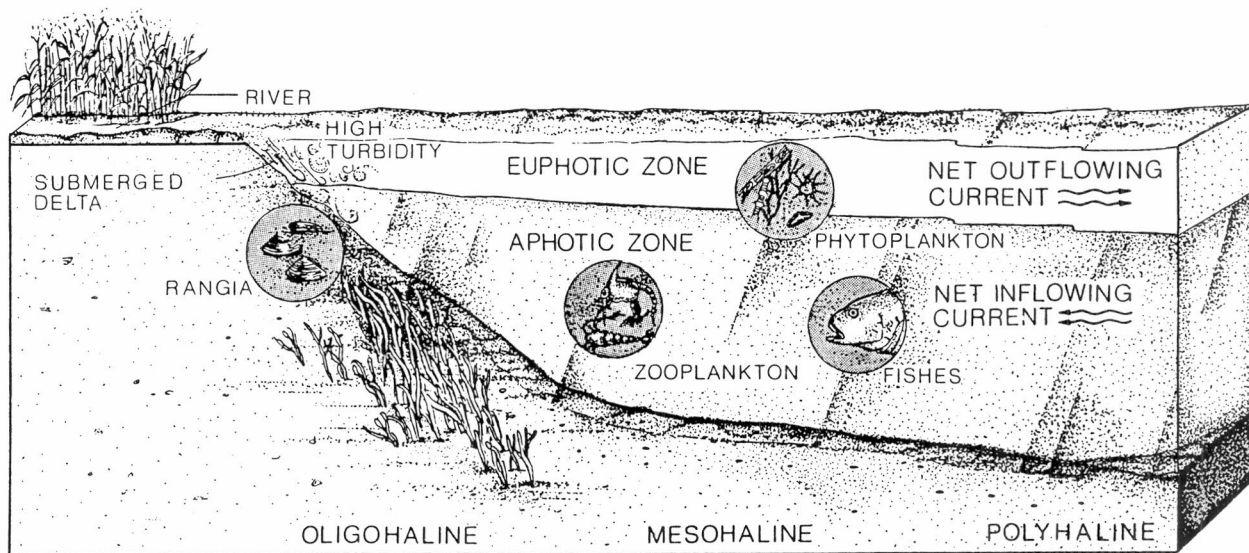


Figure 1.6 Idealized longitudinal section through a typical estuary from river to the sea. The vertical scale is exaggerated. The darker area near the sediment surface indicates an oxidized zone.

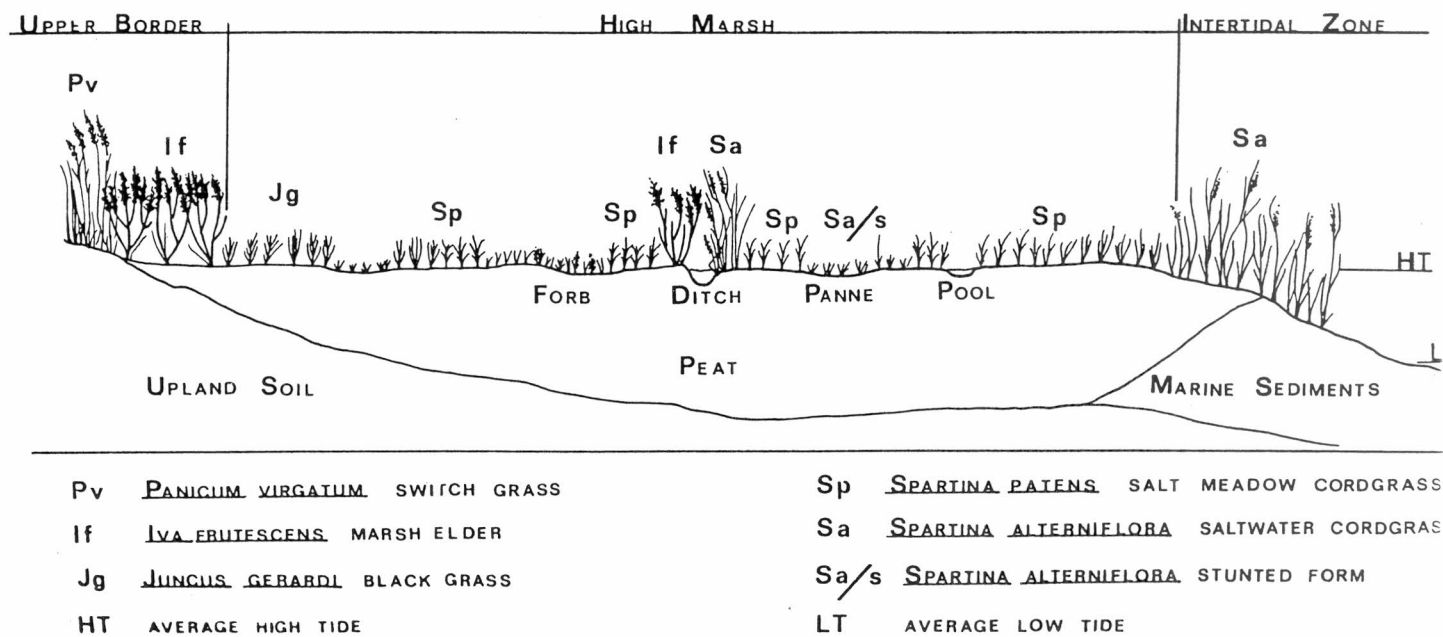


Figure 7.29.1 Typical vegetative "belting" pattern characteristic of New England salt marshes.

The salinity in the marsh soil water depends on several factors (Adapted from Morss, 1927, and Chapman, 1960):

1. Frequency of tidal inundation—The lower marsh soils that are flooded frequently will tend to have a fairly constant salinity approximating that of the flooding seawater. On the other hand, the upper marsh that is only occasionally flooded will have long periods of exposure that may lead to either higher or lower salt concentrations.
2. Rainfall—Frequent rainfall tends to leach the upper soil in the high marsh of its salts (Ranwell et al., 1964); frequent periods of drought, on the other hand, lead to higher salt concentrations in the soil.
3. Tidal creeks and drainage slope—The presence of tidal creeks and steep slopes that drain away saline water can lead to lower soil water salinity than that which would occur under poorly drained conditions.
4. Soil Texture—Silt and clay materials tend to retain more salt than does sand.
5. Vegetation—The vegetation itself has an influence on soil salinity. Evaporation of water from the marsh surface is reduced by vegetation cover, but transpiration is increased. The net effect depends on the type of vegetation and the environmental setting. Salt marsh vegetation also changes the ion balance in soils when roots take up ions selectively from the surrounding soil solution (Smart and Barko, 1980).
6. Depth to Water Table—If groundwater is close to the surface, soil water salinity fluctuations will be less.
7. Fresh water inflow—The inflow of fresh water, in rivers, as overland flow, or in groundwater, tends to dilute the salinity in both the salt marsh and the surrounding estuary. The early spring flood periods along much of the eastern United States coastal plain leads to significant reductions in the salinity of downstream coastal marshes.

In marshes, where the average soil salinity varies from freshwater to seawater strength, it often controls the general zonation pattern of vegetation and its productivity. Within the salt marsh zone itself, however, all plants are salt tolerant, and it is misleading to account for plant zonation and productivity on the basis of salinity alone. The salinity, after all, is the result of many hydrodynamic factors, including tides, rainfall, freshwater inputs and groundwater, as described above. When *Spartina* grows better in the intertidal zone, it is growing better because of tides that reduce the local salinity, remove toxic materials, supply nutrients, and modify soil anoxia. All of these factors collectively contribute to different productivities and different growth forms in the intertidal and high marshes.

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Appendix 3. Table of salinity ranges, factor scores, and percent of range enclosed by each salinity zone.

Case #	Common name	Latin name	Salinity range, ppt.	Component factor scores:					Percent of range enclosed by each zone:				
				1	2	3	4	5	F-4	2-15	11-19	15-28	23-M
Invertebrates from Wass (1972):													
1	bryozoan	<i>Victorella pavidia</i>	3 - 27	1.535	1.557	-0.578	-1.364	-1.781	8	52	36	52	20
2	boring sponge	<i>Cliona celata</i>	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
3	boring sponge	<i>Cliona lobata</i>	14 - 27	1.834	-1.213	-0.016	-0.624	-2.212	0	14	43	93	36
4	boring sponge	<i>Cliona truitii</i>	3 - 27	1.535	1.557	-0.578	-1.364	-1.781	8	52	36	52	20
5	boring sponge	<i>Cliona vastifica</i>	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
6	lacy bryozoan	<i>Electra crustulenta</i>	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
7	copepod	<i>Calanus finmarchicus</i>	28 - M	-2.153	-0.662	-0.042	-0.954	0.695	0	0	0	25	100
8	copepod	<i>Eucalanus pileatus</i>	24 - M	-1.450	-0.451	-0.810	-0.527	1.476	0	0	0	63	100
9	copepod	<i>Paracalanus crassirostris</i>	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
10	copepod	<i>Paracalanus indicus</i>	21 - M	-0.221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
11	copepod	<i>Paracalanus quasimodo</i>	21 - M	-0.221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
12	copepod	<i>Pseudocalanus minutus</i>	8 - M	-0.063	0.195	1.337	-0.922	0.723	0	33	38	58	38
13	copepod	<i>Temora longicornis</i>	19 - M	0.590	-0.474	-1.661	-0.427	0.495	0	0	8	77	69
14	copepod	<i>Temora stylifera</i>	29 - M	-1.994	-0.685	-0.101	-1.145	0.148	0	0	0	0	100
15	copepod	<i>Eurytemora affinis</i>	F - 20	-0.393	0.297	1.593	1.052	-1.534	30	61	39	26	0
16	copepod	<i>Centropages furcatus</i>	24 - M	-1.450	-0.451	-0.810	-0.527	1.476	0	0	0	63	100
17	copepod	<i>Centropages hamatus</i>	8 - M	-0.063	0.195	1.337	-0.922	0.723	0	33	38	58	38
18	copepod	<i>Canuella canadensis</i>	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
19	copepod	<i>Euterpina acutifrons</i>	19 - M	0.590	-0.474	-1.661	-0.427	0.495	0	0	8	77	69
20	copepod	<i>Hemicyclops adhaerans</i>	22 - 30	-0.298	-0.356	-1.570	-0.520	0.680	0	0	0	78	89
21	copepod	<i>Farranula gracilis</i>	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
22	barnacle	<i>Loxothylacus panopaei</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
23	mud crab	<i>Neopanope texana sayi</i>	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
24	Atlantic mud crab	<i>Panopeus herbstii</i>	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
25	Harris mud crab	<i>Rhithropanopeus harrisi</i>	0 - 24	1.190	0.707	0.358	0.804	-1.848	23	54	35	38	8
Adult fish from Musick (1972):													
26	Least brook lamprey	<i>Lampetra aepyptera</i>	F - 2	-1.097	-1.604	0.054	1.382	-1.090	100	20	0	0	0
27	Sandbar shark	<i>Carcharhinus milberti</i>	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
28	Smooth dogfish	<i>Mustelus canis</i>	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
29	Spiry dogfish	<i>Squalus acanthias</i>	20 - M	0.217	-0.391	-1.679	-0.452	0.762	0	0	0	75	75
30	Atlantic angel shark	<i>Squatina dumerilii</i>	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
31	Southern stingray	<i>Dasyatis americana</i>	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
32	Bluntnose stingray	<i>Dasyatis sayi</i>	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
33	Spiry butterfly ray	<i>Gymnura altavela</i>	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
34	Smooth butterfly ray	<i>Gymnura micura</i>	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
35	Bullnose ray	<i>Myliobatis freminvillei</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
36	Cownose ray	<i>Rhinoptera bonasus</i>	13 - M	0.541	-1.198	1.037	-0.072	0.295	0	16	37	74	47
37	Longnose gar	<i>Lepisosteus osseus</i>	F - 23	0.836	0.384	0.853	1.138	-1.964	27	54	35	35	4
38	Conger eel	<i>Conger oceanicus</i>	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
39	Atlantic herring	<i>Clupea harengus</i>	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
40	Gizzard shad	<i>Dorosoma cepedianum</i>	0 - 29	1.157	0.874	0.036	1.493	0.067	19	45	29	45	23
41	Threadfin shad	<i>Dorosoma petenense</i>	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
42	Round herring	<i>Etrumeus teres</i>	28 - M	-2.153	-0.662	-0.042	-0.954	0.695	0	0	0	25	100
43	Atlantic thread herring	<i>Opisthonema oglinum</i>	26 - M	-1.972	-0.553	-0.339	-0.715	1.284	0	0	0	50	100
44	Striped anchovy	<i>Anchoa hepsetus</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
45	Bay anchovy	<i>Anchoa mitchilli</i>	1 - 30	0.873	1.377	-0.183	0.276	0.391	13	47	30	47	27
46	Rainbow trout	<i>Salmo gairdneri</i>	F - 19	-0.831	0.324	1.722	1.063	-1.250	32	64	41	23	0
47	Eastern mudminnow	<i>Umbra pygmaea</i>	F - 4	-0.818	-1.343	-0.385	1.894	-1.077	100	43	0	0	0
48	Redfin pickerel	<i>Esox americanus</i>	F - 9	-0.816	0.516	-1.630	1.088	-1.143	58	67	0	0	0
49	Chain pickerel	<i>Esox niger</i>	F - 22	0.472	0.351	1.116	1.045	-1.933	28	56	36	32	0
50	Goldfish	<i>Carassius auratus</i>	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
51	Carp	<i>Cyprinus carpio</i>	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
52	Eastern silvery minnow	<i>Hybognathus regius</i>	F - 14	-1.595	1.119	0.036	0.647	-0.536	41	76	24	0	0
53	Golden shiner	<i>Notemigonus crysoleucas</i>	F - 5	-0.689	-1.030	-0.701	1.852	-1.144	88	50	0	0	0
54	Satinfin shiner	<i>Notropis analostanus</i>	F - 2	-1.097	-1.604	0.054	1.382	-1.090	100	20	0	0	0
55	Bridle shiner	<i>Notropis bifrenatus</i>	F - 12	-1.156	1.131	-0.994	0.682	-0.783	47	73	13	0	0
56	Spotail shier	<i>Notopis hudsonius</i>	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
57	Quillback carpsucker	<i>Carpionodes cyprinus</i>	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
58	Northern redborse	<i>Moxostoma macrolepidotum</i>	F - 5	-0.689	-1.030	-0.701	1.852	-1.144	88	50	0	0	0
59	Northern hogsucker	<i>Hypentelium nigricans</i>	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
60	White catfish	<i>Ictalurus catus</i>	F - 15	-1.853	0.949	0.595	0.747	-0.541	39	78	28	6	0
61	Blue catfish	<i>Ictalurus furcatus</i>	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
62	Brown bullhead	<i>Ictalurus nebulosus</i>	F - 8	-0.581	0.135	-1.498	1.314	-1.193	64	64	0	0	0
63	Channel catfish	<i>Ictalurus punctatus</i>	F - 15	-1.853	0.949	0.595	0.747	-0.541	39	78	28	6	0
64	Inshore lizardfish	<i>Synodus foetens</i>	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
65	Oyster toadfish	<i>Opsanus tau</i>	1 - 30	0.873	1.377	-0.183	0.276	0.391	13	47	30	47	27
66	Skilletfish	<i>Gobiesox strumosus</i>	4 - 28	1.406	1.422	-0.306	-1.819	-2.186	4	52	39	52	17
67	Goosefish	<i>Lophius americanus</i>	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
68	Red hake	<i>Urophycis chuss</i>	7 - M	-0.007	0.583	1.053	-1.093	0.697	0	36	36	56	36
69	Spotted hake	<i>Urophycis regius</i>	2 - M	0.523	1.522	-0.061	-0.293	0.760	10	47	30	47	30
70	Silver hake	<i>Merluccius bilinearis</i>	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45

Case #	Common name	Latin name	Salinity range, ppt.	Component factor scores:					Percent of range enclosed by each zone:				
				1	2	3	4	5	F-4	2-15	11-19	15-28	23-M
Adult fish from Musick (1972), continued:													
71	Striped cusk-eel	<i>Rissola marginata</i>	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
72	Halfbeak	<i>Hyporhamphus unifasciatus</i>	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
73	Sheepshead minnow	<i>Cyprinodon variegatus</i>	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
74	Banded killifish	<i>Fundulus diaphanus</i>	F - 20	-0.393	0.297	1.593	1.052	-1.534	30	61	39	26	0
75	Mummichog	<i>Fundulus heteroclitus</i>	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
76	Spotfin killifish	<i>Fundulus luciae</i>	0 - 28	1.410	0.874	-0.089	1.336	-0.538	20	47	30	47	20
77	Striped killifish	<i>Fundulus majalis</i>	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
78	Rainwater killifish	<i>Lucania parva</i>	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
79	Mosquitofish	<i>Gambusia affinis</i>	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
80	Rough silverside	<i>Membras martinica</i>	3 - 24	1.157	1.393	-0.072	-1.705	-2.524	9	59	41	45	9
81	Tidewater silverside	<i>Menidia beryllina</i>	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
82	Atlantic silverside	<i>Menidia menidia</i>	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
83	Fourspine stickleback	<i>Apeltes quadracus</i>	3 - 26	1.525	1.511	-0.486	-1.497	-2.140	8	54	38	50	17
84	Lined seahorse	<i>Hippocampus erectus</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
85	Dusky pipefish	<i>Syngnathus floridae</i>	15 - 30	1.337	-1.164	-0.229	-0.119	-0.533	0	6	31	88	50
86	Northern pipefish	<i>Syngnathus fuscus</i>	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
87	Black sea bass	<i>Centropristis striata</i>	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
88	Flier	<i>Centrarchus macropterus</i>	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
89	Bluespotted sunfish	<i>Enneacanthus gloriosus</i>	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
90	Bluegill	<i>Lepomis macrochirus</i>	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
91	Pumpkinseed	<i>Lepomis gibbosus</i>	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
92	Smallmouth bass	<i>Micropterus dolomieu</i>	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
93	Largemouth bass	<i>Micropterus salmoides</i>	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
94	White crappie	<i>Pomoxis annularis</i>	F - 2	-1.097	-1.604	0.054	1.382	-1.090	100	20	0	0	0
95	Black crappie	<i>Pomoxis nigromaculatus</i>	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
96	Swamp darter	<i>Etheostoma fusiforme</i>	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
97	Tessellated darter	<i>Etheostoma olini</i>	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
98	Yellow perch	<i>Perca flavescens</i>	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
99	Bluefish	<i>Pomatomus saltatrix</i>	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
100	Sharksucker	<i>Echeneis naucrates</i>	9 - M	-0.053	-0.202	1.541	-0.703	0.705	0	30	39	61	39
101	Blue runner	<i>Caranx fuscus</i>	21 - M	-0.221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
102	Creville jack	<i>Caranx hippos</i>	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
103	Bigeye scad	<i>Selar crumenophthalmus</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
104	Lookdown	<i>Selene vomer</i>	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
105	Rough scad	<i>Trachurus lathami</i>	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
106	Pigfish	<i>Orthopristis chrysoptera</i>	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
107	Scup	<i>Stenotomus chrysops</i>	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
108	Pinfish	<i>Lagodon rhomboides</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
109	Sheepshead	<i>Archosargus probatocephalus</i>	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
110	Spotted seatrout	<i>Cynoscion nebulosus</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
111	Banded drum	<i>Larimus fasciatus</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
112	Southern kingfish	<i>Menticirrhus americanus</i>	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
113	Northern kingfish	<i>Menticirrhus saxatilis</i>	4 - M	0.364	1.447	0.169	-1.094	0.556	4	43	32	50	32
114	Red drum	<i>Sciaenops ocellata</i>	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
115	Star drum	<i>Stellifer lanceolatus</i>	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
116	Atlantic spadefish	<i>Chaetodipterus faber</i>	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
117	Tautog	<i>Tautoga onitis</i>	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
118	Striped mullet	<i>Mugil cephalus</i>	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
119	White mullet	<i>Mugil curema</i>	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
120	Northern stargazer	<i>Astroscopus guttatus</i>	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
121	Feather blenny	<i>Hypsoblennius hentzi</i>	12 - 30	0.659	-1.093	1.225	-0.225	-0.140	0	21	42	74	42
122	Striped blenny	<i>Chasmodes boequeianus</i>	12 - 25	1.173	-1.204	1.191	-0.974	-2.511	0	29	57	79	21
123	Naked goby	<i>Gobisoma boeckii</i>	0 - 27	1.588	0.871	-0.149	1.145	-1.085	21	48	31	45	17
124	Seaboard goby	<i>Gobisoma ginsburgi</i>	15 - 30	1.337	-1.164	-0.229	-0.119	-0.533	0	6	31	88	50
125	Code goby	<i>Gobisoma robustum</i>	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
126	Clown goby	<i>Microgobius gulosus</i>	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
127	Green goby	<i>Microgobius thalassinus</i>	11 - 30	0.466	-0.902	1.466	-0.349	-0.013	0	25	45	70	40
128	Atlantic cutlassfish	<i>Trichiurus lepturus</i>	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
129	Atlantic bonito	<i>Sarda sarda</i>	10 - M	0.002	-0.583	1.673	-0.477	0.655	0	27	41	64	41
130	King mackerel	<i>Scomberomorus cavalla</i>	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
131	Harvestfish	<i>Peprius paru</i>	4 - M	0.364	1.447	0.169	-1.094	0.556	4	43	32	50	32
132	Butterfish	<i>Peprius triacanthus</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
133	Northern searobin	<i>Prionotus carolinus</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
134	Striped searobin	<i>Prionotus evolans</i>	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
135	Longhorn sculpin	<i>Myoxocephalus octodecemspineus</i>	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
136	Fringed flounder	<i>Etropus crossotus</i>	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
137	Smallmouth flounder	<i>Etropus microstomus</i>	7 - M	-0.007	0.583	1.053	-1.093	0.697	0	36	36	56	36
138	Summer flounder	<i>Paralichthys dentatus</i>	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
139	Winter flounder	<i>Pseudopleuronectes americanus</i>	5 - 30	0.560	1.299	0.192	-1.366	0.008	0	42	35	54	31

Appendix 3, continued. Table of salinity ranges, factor scores, and percent of range enclosed by each salinity zone.

Case #	Common name	Latin name	Salinity range, ppt.	Component factor scores:					Percent of range enclosed by each zone:				
				1	2	3	4	5	F-4	2-15	11-19	15-28	23-M
Adult fish from Musick (1972), continued:													
140	Hogchoker	<i>Trinectes maculatus</i>	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
141	Blackcheek tonguefish	<i>Symphurus plagiusa</i>	7 - M	-0.007	0.583	1.053	-1.093	0.697	0	36	36	56	36
142	Orange filefish	<i>Aluterus schoepfi</i>	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
143	Gray triggerfish	<i>Balistes capricus</i>	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
144	Planehead filefish	<i>Stephanolepis hispidus</i>	19 - M	0.590	-0.474	-1.661	-0.427	0.495	0	0	8	77	69
145	Northern puffer	<i>Sphoeroides maculatus</i>	9 - M	-0.053	-0.202	1.541	-0.703	0.705	0	30	39	61	39
146	Striped burrfish	<i>Chilomycterus schoepfi</i>	2 - M	0.523	1.522	-0.061	-0.293	0.760	10	47	30	47	30
147	Roughtail stingray	<i>Dasyatis centroura</i>	20 - M	0.217	-0.391	-1.879	-0.452	0.762	0	0	0	75	75
148	Cunner	<i>Tautoglabrus adspersus</i>	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
149	Windowpane	<i>Scopthalmus aquosus</i>	13 - M	0.541	-1.198	1.037	-0.072	0.295	0	16	37	74	47
Invertebrates from Gosner (1979):													
150	entoproct	<i>Pedicellina cernua</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
151	bryozoan	<i>Anguinella palmata</i>	13 - M	0.541	-1.198	1.037	-0.072	0.295	0	16	37	74	47
152	creeping bryozoan	<i>Bowerbankia gracilis</i>	10 - M	0.002	-0.583	1.673	-0.477	0.655	0	27	41	64	41
153	Red beard sponge	<i>Microciona prolifera</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
154	pinnate bryozoan	<i>Aevertillia armata</i>	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
155	bryozoan	<i>Crisia eburnea</i>	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
156	lacy bryozoan	<i>Electra pilosa</i>	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
157	bryozoan	<i>Bugula turrita</i>	20 - M	0.217	-0.391	-1.879	-0.452	0.762	0	0	0	75	75
158	red bryozoan	<i>Schizoporella unicornis</i>	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
159	Arrow worm	<i>Sagitta elegans</i>	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
160	phoronid worm	<i>Phoronis architecta</i>	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
161	Atlantic oyster drill	<i>Urosalpinx cinerea</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
162	American oyster	<i>Crassostrea virginica</i>	5 - 30	0.560	1.299	0.192	-1.366	0.008	0	42	35	54	31
163	Carolina marshclam	<i>Polymesoda caroliniana</i>	F - 15	-1.653	0.949	0.595	0.747	-0.541	39	78	28	6	0
164	Hard clam	<i>Mercenaria mercenaria</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
165	Amethyst gemclam	<i>Gemma gemma</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
166	Baltic macoma	<i>Macoma baltica</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
167	Softshell clam	<i>Mya arenaria</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
168	twelve-scaled worm	<i>Lepidonotus squamatus</i>	20 - M	0.217	-0.391	-1.879	-0.452	0.762	0	0	0	75	75
169	twelve-scaled worm	<i>Lepidonotus sublevis</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
170	twelve-scaled worm	<i>Lepidonotus variabilis</i>	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
171	fifteen-scaled worm	<i>Harmothoe imbricata</i>	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
172	fifteen-scaled worm	<i>Harmothoe extenuata</i>	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
173	clam worm	<i>Platynereis dumerilii</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
174	bamboo worm	<i>Asychis elongata</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
175	Parchment worm	<i>Chaetopterus variopedatus</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
176	sand-builder worm	<i>Sabellaria vulgaris</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
177	Trumpet worm	<i>Pectinaria gouldii</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
178	American lobster	<i>Homarus americanus</i>	20 - M	0.217	-0.391	-1.879	-0.452	0.762	0	0	0	75	75
179	Longwrist hermit crab	<i>Pagurus longicarpus</i>	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
180	Flatclaw hermit crab	<i>Pagurus pollicaris</i>	9 - M	-0.053	-0.202	1.541	-0.703	0.705	0	30	39	61	39
181	Atlantic rock crab	<i>Cancer irroratus</i>	22 - M	-0.655	-0.379	-1.334	-0.437	1.261	0	0	0	70	90
182	Green crab	<i>Carcinus maenas</i>	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
183	Blue crab	<i>Callinectes sapidus</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
184	mud crab	<i>Neopanopeus sayi</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
185	Flatback mud crab	<i>Eurypanopeus depressus</i>	4 - 20	-0.516	1.169	1.111	-2.199	-2.158	6	71	53	35	0
186	hydroid	<i>Ectopleura dumortieri</i>	5 - 18	-1.488	1.109	1.480	-2.403	-1.574	0	79	57	29	0
187	Channeled whelk	<i>Busycan canaliculatum</i>	20 - M	0.217	-0.391	-1.879	-0.452	0.762	0	0	0	75	75
188	acorn worm	<i>Saccoglossus kowalewskii</i>	19 - M	0.590	-0.474	-1.661	-0.427	0.495	0	0	8	77	69
189	Golden star tunicate	<i>Botryllus schlosseri</i>	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
190	sea grape	<i>Molgula manhattensis</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
191	larvacean	<i>Oikopleura species</i>	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
Juvenile fish from DFMA (1978):													
192	Winter flounder	<i>Pseudopleuronectes americanus</i>	4 - 30	0.721	1.470	-0.067	-1.177	-0.024	4	44	33	52	30
193	Hogchoker	<i>Trinectes maculatus</i>	0 - 9	-0.587	0.792	-1.863	0.667	-1.045	55	73	0	0	0
194	Blackcheek tonguefish	<i>Symphurus plagiusa</i>	5 - 22	0.189	1.052	0.893	-2.398	-2.524	0	61	50	44	0
195	Scrawled cowfish	<i>Lactophrys quadricornis</i>	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
196	Trunkfish	<i>Lactophrys trigonis</i>	21 - M	-0.221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
197	Northern puffer	<i>Sphoeroides hispidus</i>	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
198	Checkered puffer	<i>Sphoeroides testudineus</i>	0.5 - M	0.513	1.107	0.234	1.057	1.142	16	44	28	44	28
199	Striped burrfish	<i>Chilomycterus schoepfi</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
200	Oyster toadfish	<i>Opsanus tau</i>	13 - 29	1.182	-1.175	0.655	-0.316	-0.916	0	18	41	82	41
201	Atlantic tomcod	<i>Microgadus tomcod</i>	2 - 10	-0.688	1.805	-2.372	-1.574	-1.476	33	100	0	0	0
202	Horse-eye jack	<i>Caranx latus</i>	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
203	Atlantic bumper	<i>Chloroscopus chrysurus</i>	9 - M	-0.053	-0.202	1.541	-0.703	0.705	0	30	39	61	39
204	Leatherjacket	<i>Oligoplites saurus</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27

Appendix 3, continued. Table of salinity ranges, factor scores, and percent of range enclosed by each salinity zone.

Case #	Common name	Latin name	Salinity range, ppt.	Component factor scores:					Percent of range enclosed by each zone:				
				1	2	3	4	5	F-4	2-15	11-19	15-28	23-M
Juvenile fish from DFMAF (1978), continued:													
205	Lookdown	<i>Selene vomer</i>	8 - M	-0.063	0.195	1.337	-0.922	0.723	0	33	38	58	38
206	Florida pompano	<i>Trachinotus carolinus</i>	10 - M	0.002	-0.583	1.673	-0.477	0.855	0	27	41	64	41
207	Permit	<i>Trachinotus falcatus</i>	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
208	Rough scad	<i>Trachurus lathami</i>	29 - M	-1.994	-0.685	-0.101	-1.145	0.148	0	0	0	0	100
209	Irish pompano	<i>Diapterus olisthoestomus</i>	0.5 - M	0.513	1.107	0.234	1.057	1.142	16	44	28	44	28
210	Spotfin mojarra	<i>Eucinostomus argenteus</i>	4 - 29	1.005	1.470	-0.213	-1.338	-0.655	4	46	35	54	27
211	Silver jenny	<i>Eucinostomus gula</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
212	Tomtate	<i>Haemulon aurolineatum</i>	18 - 30	1.219	-0.592	-1.896	-0.451	-0.311	0	0	15	85	62
213	Yellow chub	<i>Kyphosus incisor</i>	28 - M	-2.153	-0.662	-0.042	-0.954	0.695	0	0	0	25	100
214	Sargeant major	<i>Abudefduf saxatilis</i>	29 - M	-1.994	-0.685	-0.101	-1.145	0.148	0	0	0	0	100
215	Atlantic bonito	<i>Sarda sarda</i>	5 - 10	-1.007	1.559	-1.882	-2.564	-1.647	0	100	0	0	0
216	Spanish mackerel	<i>Scomberomorus maculatus</i>	13 - M	0.541	-1.198	1.037	-0.072	0.295	0	16	37	74	47
217	White perch	<i>Morone americana</i>	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
218	Striped bass	<i>Morone saxatilis</i>	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
219	Blueback herring	<i>Alosa aestivalis</i>	F - 28	1.380	0.598	0.144	1.756	-0.636	23	45	29	45	19
220	Menhaden	<i>Brevoortia tyrannus</i>	0 - 15	-1.624	1.224	0.362	0.327	-0.443	35	82	29	6	0
221	Atlantic thread herring	<i>Opisthonema oglinum</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
222	Silver perch	<i>Bairdiella chrysoura</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
223	Spotted seatrout	<i>Cynoscion nebulosus</i>	0.5 - M	0.513	1.107	0.234	1.057	1.142	16	44	28	44	28
224	Banded drum	<i>Larimus fasciatus</i>	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
225	Spot	<i>Leiostomus xanthurus</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
226	Atlantic croaker	<i>Micropogonias undulatus</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
227	Black drum	<i>Pogonias cromis</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
228	Northern Kingfish	<i>Menticirrhus saxatilis</i>	6 - M	0.075	0.983	0.744	-1.241	0.656	0	38	35	54	35
229	Great barracuda	<i>Sphyrna barracuda</i>	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
230	Red drum	<i>Sciaenops ocellata</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
231	Striped mullet	<i>Mugil cephalus</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
232	White mullet	<i>Mugil curema</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
233	Rough silversides	<i>Membras martinica</i>	0 - 28	1.410	0.874	-0.089	1.336	-0.538	20	47	30	47	20
234	Tidewater silverside	<i>Menidia beryllina</i>	0 - 15	-1.624	1.224	0.362	0.327	-0.443	35	82	29	6	0
235	Atlantic silverside	<i>Menidia menidia</i>	1 - 14	-1.566	1.898	-0.563	-1.151	-0.745	29	93	29	0	0
236	Bay whiff	<i>Citharichthys spilopterus</i>	2 - M	0.523	1.522	-0.061	-0.293	0.760	10	47	30	47	30
237	Summer flounder	<i>Paralichthys dentatus</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
238	Windowpane	<i>Scopthalmus aquosus</i>	15 - 29	1.621	-1.163	-0.375	-0.280	-1.163	0	7	33	93	47
239	Fringed flounder	<i>Etropus crossotus</i>	0.5 - M	0.513	1.107	0.234	1.057	1.142	16	44	28	44	28
240	Orange filefish	<i>Aluterus schoepfi</i>	23 - M	-1.086	-0.417	-1.073	-0.434	1.445	0	0	0	67	100
241	Bandtail puffer	<i>Sphoeroides spengleri</i>	10 - M	0.002	-0.583	1.673	-0.477	0.655	0	27	41	64	41
242	Shortnosed sturgeon	<i>Acipenser brevirostrum</i>	F - 20	-0.393	0.297	1.593	1.052	-1.534	30	61	39	26	0
243	Ladyfish	<i>Elops saurus</i>	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
244	Tarpon	<i>Megalops atlantica</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
245	Inshore lizardfish	<i>Synodus foetens</i>	10 - M	0.002	-0.583	1.673	-0.477	0.655	0	27	41	64	41
246	Goldfish	<i>Carrasius auratus</i>	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
247	White catfish	<i>Ictalurus catus</i>	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
248	Channel catfish	<i>Ictalurus punctatus</i>	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
249	Sheepshead minnow	<i>Cyprinodon variegatus</i>	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
250	Marsh killifish	<i>Fundulus confluentus</i>	0 - 4	-0.788	-1.067	-0.618	1.474	-0.979	100	50	0	0	0
251	Spotfin killifish	<i>Fundulus luciae</i>	15 - 30	1.337	-1.164	-0.229	-0.119	-0.533	0	6	31	88	50
252	Striped killifish	<i>Fundulus majalis</i>	20 - 30	0.574	-0.368	-1.915	-0.536	0.181	0	0	0	82	73
253	Spotted hake	<i>Urophycis regia</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
254	Fourspine stickleback	<i>Apeltes quadracus</i>	3 - 30	0.840	1.560	-0.247	-0.855	0.021	7	46	32	50	29
255	Dusky pipefish	<i>Syngnathus floridae</i>	19 - 27	1.642	-0.455	-2.228	-1.020	-1.869	0	0	11	100	56
256	Northern pipefish	<i>Syngnathus fuscus</i>	2 - 22	0.508	1.297	0.403	-1.406	-2.353	14	67	43	38	0
257	Rock sea bass	<i>Centropomus philadelphica</i>	7 - M	-0.007	0.583	1.053	-1.093	0.697	0	36	36	56	36
258	Jewfish	<i>Epinephelus itajara</i>	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
259	Red grouper	<i>Epinephelus morio</i>	21 - M	-0.221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
260	Warsaw grouper	<i>Epinephelus nigritus</i>	29 - M	-1.994	-0.665	-0.101	-1.145	0.148	0	0	0	0	100
261	Tripletail	<i>Lobotes surinamensis</i>	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
262	Mutton snapper	<i>Lutjanus analis</i>	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
263	Red snapper	<i>Lutjanus campechanus</i>	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
264	Cubera snapper	<i>Lutjanus cyanopterus</i>	4 - M	0.364	1.447	0.169	-1.094	0.556	4	43	32	50	32
265	Gray snapper	<i>Lutjanus griseus</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
266	Pumpkinseed	<i>Lepomis gibbosus</i>	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
267	Warmouth	<i>Lepomis gulosus</i>	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
268	Largemouth bass	<i>Micropterus salmoides</i>	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
269	White crappie	<i>Pomoxis annularis</i>	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
270	Black crappie	<i>Pomoxis nigromaculatus</i>	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
271	Tessellated darter	<i>Etheostoma olmstedii</i>	F - 0.5	-1.130	-1.421	-0.010	0.251	-1.460	100	0	0	0	0
272	Yellow perch	<i>Perca flavescens</i>	F - 10	-0.724	0.858	-1.659	0.876	-1.056	54	69	0	0	0
273	Bluefish	<i>Pomatomus saltatrix</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
274	Cobia	<i>Rachycentron canadum</i>	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27

Name of pond (if any):

Location: About miles north of McCabe boathouse, roughly across bay (and slightly north) from orange airport runway markers.

Date of Visit: 9/1/82

Time: 12⁰⁰ Noon

Weather: Partly cloudy, slightly breezy

General Description: Pond is roughly circular, approx. 200 feet across

Plant species found:

Spartina alterniflora (Cordgrass)
Salicornia europaea (Slender Glasswort)
Limonium carolinianum (Sea-Lavender)
Fimbristylis castanea
Distichlis spicata (Spike grass)
Scirpus americanus (Three-square)
Gerardia purpurea (Purple Gerardia)
Pluchea purpurascens (Salt-marsh Fleabane)
Sabatia stellaris (Sea pink)
Salt-marsh Sand-Spurrey (*Spergularia marina*)
Atriplex patula var. *hastata* (Seabeach Orach)
Solidago sempervirens (Seaside goldenrod)

Salinity readings:

6/25/82 : 11 p.p.t.
7/10/82 : 13.2 p.p.t.
8/4/82 : 8.4 p.p.t.
9/1/82 : 9.2 p.p.t.

Other observations, Comments:

Shore is bare of vegetation to a distance of 1-2 meters on N, S, + E sides, while vegetation grows down to water's edge in places on W. shore. Salt marsh vegetation is dominated on W. side by *Spartina alterniflora*, with *Salicornia* and *Limonium*, to about 10 meters from water's edge. A zone dominated by *Scirpus americanus*, *Fimbristylis*, and *Distichlis* extends to 10-13 m. on W. side. Shore vegetation on N. side dominated by Cordgrass and *Pluchea* to 5 m.

Observer:

Richard Parisio (Seasonal Resource Management Specialist)

from 1982 study

Name of pond (if any):

Location: Vicinity (NW of) McCabe House (among low secondary dunes)

Date of Visit: 9/2/82

Time: 2⁰⁰ PM

Weather: Partly cloudy, breezy

General Description: Pond is ca. 50 yds. wide, 100 yds. long, appears to be quite shallow.

Plant species found: *Phragmites communis* (Common reed)

Woodwardia virginica (Virginian Chain Fern)

Osmunda regalis (Royal Fern)

Baccharis halimifolia (Groundsel Bush)

Myrica cerifera (Wax Myrtle)

Rhus radicans (Poison Ivy)

Iva frutescens (Marsh Elder)

Teucrium canadense (American Germander)

Hypericum virginicum (Marsh St. Johnswort)

Hydrocotyle sp. (Water-penny-wort)

Scirpus americanus (Three-square)

Eleocharis obtusa (Spike-rush)

Spartina patens (Salt-meadow Hay)

Salinity readings:

7/10 : 4 p.p.t

8/3 : 4 p.p.t

9/2 : 4.5 p.p.t.

Other observations, Comments:

There is a stand of *Phragmites communis* on the SW shore. The pond is most thickly wooded on the SE shore. A path (probably a deer trail on the E + NE leads to the point of easiest access on the NW shore.

Many deer and raccoon tracks were seen in the mud along the shore on the date of visit. A pair of Black-crowned Night Herons was flushed from the SE shore.

Observer:

Richard Parisio (Seasonal Resource Management Specialist)

from L. Hoyer

Fig. 1
Pond Locations
on Assateague

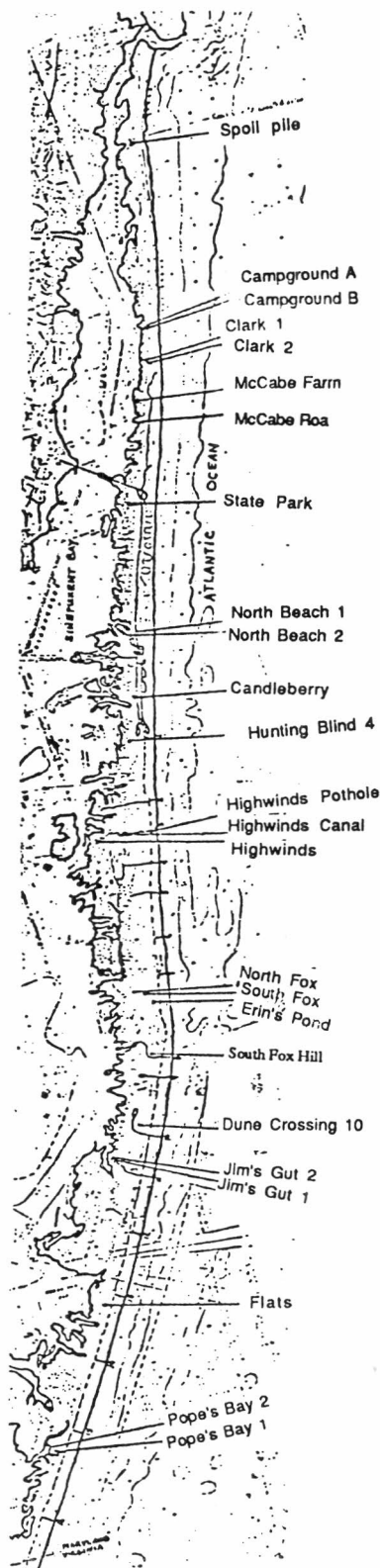


Fig. 2
Precipitation for Assateague Island
(Days of Precipitation)

Month	1985	1986	1987	1988	1989	1990	1991	Average
January		3.28 (9)	9.49 (10) ¹	4.14 (10)	1.84 (10)	4.40 (15)	3.79 (13)	4.49 (11.2)
February		2.77 (15)	Missing	3.12 (10)	4.07 (18) ³	3.94 (14)	1.43 (12)	3.07 (13.8)
March		0.38 (4)	4.59 (12)	Missing	7.70 (15)	3.59 (11)	4.36 (13)	4.12 (11.0)
April		2.13 (13)	3.92 (13)	3.45 (6)	4.60 (11)	3.39 (12)	5.42 (11)	3.82 (11.0)
May		1.24 (4)	3.58 (8)	2.86 (13)	2.69 (11)	4.39 (11)	0.76 (6)	2.59 (8.8)
June		1.71 (10)	2.10 (9)	1.07 (6)	2.86 (13)	1.47 (3)	6.06 (7)	2.55 (8.0)
July	3.53 (11)	2.02 (10)	5.24 (9)	4.75 (11)	6.64 (10)	2.26 (10)	4.12 (13)	4.08 (10.60)
August	12.73 (7)	9.40 (10)	1.52 (10)	4.27 (17)	20.88 (17) ⁴	5.13 (11)	2.78 (7)	8.10 (11.3)
September	5.66 (7)	1.52 (7)	1.39 (10)	4.80 (11)	4.40 (10)	1.51 (7)	2.88 (9)	3.17 (8.7)
October	2.64 (9)	1.71 (9)	3.37 (11)	3.25 (9)	5.12 (10)	2.40 (5)		3.08 (8.8)
November	3.57 (13)	3.54 (17)	3.56 (11)	3.78 (13) ²	4.33 (10)	2.27 (7)		3.51 (11.8)
December	1.81 (8)	7.12 (16)	3.37 (17)	0.64 (6)	1.55 (7) ⁵	3.29 (14)		2.96 (11.3)

Ave/Month 4.99 (9.20) 3.07 (10.3) 3.8 (10.2) 5.55 (11.8) 3.17 (10) 3.5 (10.1)

Total Precipitation 29.94 (6mo) 36.82 (12mo) 41.88 (11mo) 36.13 (11mo) 66.68 (12mo) 38.04 (12mo) 31.6 (9mo)

1. January 1987 6" snow = N 1/2" water
2. November 1988 1/2" snow
3. February 1989 13.65" snow = N 1.92" water
4. August 1989 Gloria 10** in one day
5. December 1989 9.41" snow = N 1.40" water

Fig. 3
Fish Populations in the Freshwater
Ponds on Assateague Island

Name of Pond	1988	1989	1990	1991
Spoilpile	1	G,L,C,M	G,L,C,M	G,L,C,M
Campground A	1	C,M	C,M	C,M
Campground B	1	1	C,M,F	C,M
M McCabe Road	L,C,F	G,L,C,F	1	G
M McCabe Farm	G,L,C,M,F	C	C,M	L,C,M
Clark 1	G,L	3	3	3
Clark 2	C	3	3	3
State Park	L,C,M,F,A	L,M	G,L,C,A	G,M
North Beach 1	C,M,F	2	2	2
North Beach 2	C,F	L,M	L,M	L,M
Scotts				
Candleberry	G,L,Fq,G,L	G	G	
Hunting Blind 4	L	L	1	1
Highwinds	1	G	G,F	G
Highwinds Canal	F,L,C,M,F	G	G	G
Highwinds Pothole	3	3	3	3
North Fox	C	G,C	G,C,M,F	G
South Fox	L,D,M,F	4	4	4
Erin's Pond	1	G	G,L	G
Jim's Gut 1	L,F	3	3	3
Jim's Gut 2	1	1	1	1
Jackson's	1	1	1	1
Pope's Bay 1	F	3	3	3
Pope's Bay 2	3	3	3	3
Dune Crossing 10	G,L,D,F	G	1	F,A
Flats	1	1	G,C,F	G,C,F

1. Not Sampled
2. Lost to road construction
3. No Fish
4. Not located

G - *Gambusia affinis*, Mosquitofish
L - *Lucania parva*, rainwater killifish
M - *Cyprinodon variegatus*, sheepshead
F - *Fundulus heteroclitus*, Mummichog
A - *Anguilla rostrata*, American eel

from Jesien

March
1986

Table 2. Results of chemical/physical analysis.

	A	B	C	D	E	F	G	H	I	J	K	L	M
Conductivity (umhos/cm)	3700	5000	340	1100	8150	360	1325	125	280	160		2350	9
Salinity (ppt)	2.5	3.5	0.0	0.3	6.0	0.0	5.0	0.0	0.0	0.0	10.0	1.5	0.
pH (standard units)											7.42	7.46	7.
Temperature (C)	14.0	15.5	21.0	24.0	19.0	20.0	24.0	22.0	16.0	14.8		13.0	13
Dissolved Oxygen (mg/l)	8.3	9.8			13.2	13.0			5.1	7.9		6.8	
D. O. (% saturation)	80	100			140	140			50	77		63	
Nitrite (uMole)		0.54			0.55	0.50							
Nitrate & Nitrite (uMole)		1.36			0.89	0.77							
Ammonium (uMole)		1.30			2.33	1.14							
Ortho-Phosphate (uMole)		0.00			0.00	0.00							
Approx. Max. Depth (m)	1.0	0.8	0.3	0.2	1.2	0.6	0.1	0.6	1.8	1.2	2.0	1.0	0.
Fish present (Y/N)	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N

March 1986

marker 19 baywater
sample #2

cond. umhos/cm	46,700 umhos/cm (46.7 mS/cm)
salinity ppt	30.4 ppt
pH	8.33
temperature	9.04 C°
DO mg/l	11.03 mg/l
ammonium uM	0.56 uM
orthophosphate uM	0.11 uM

$$1 \text{ mS/cm} = 1 \text{ mM/cm} \\ \text{mhos}$$

CFH 15 ST. low cond.
ABEO high cond.