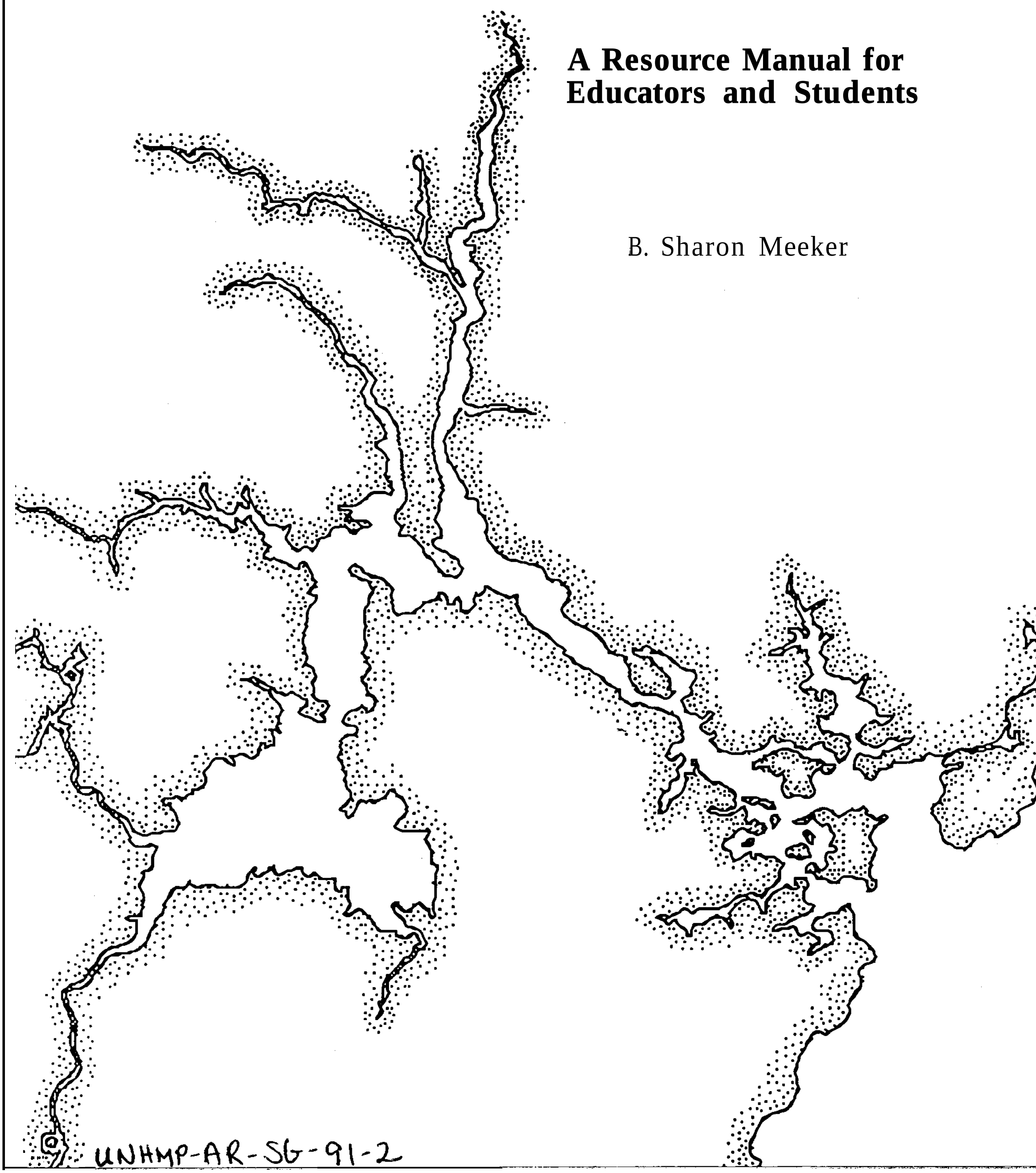
GREAT BAY LIVING LAB

A Resource Manual for Educators and Students

B. Sharon Meeker



THE GREAT BAY LIVING LAB

A RESOURCE MANUAL FOR TEACHERS AND STUDENTS

Grades 7 to 12

by

B. Sharon Meeker

Sponsored by

Sea Grant Extension,
a part of the Cooperative Extension and
Sea Grant College programs
at the University. of New Hampshire

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PREFACE

New Hampshire's coast -- its marshes, estuaries, beaches, rocky shoreline and open ocean -- has been a vital resource since humans began to live there in prehistoric times. It continues to provide food, transportation, jobs and recreation and to attract people who want to live there. By the year 2000, it is predicted that 70% of the world's people will live within 50 miles of some coastline. We can see that trend in New Hampshire now. Population growth and increasing utilization of this area's resources place the future of our coast in jeopardy. Vital decisions will be made in the next few decades by the students who are in our schools today. By increasing their knowledge and appreciation of our coastal resources, we can ensure that those decisions will be enlightened ones, and that the future of New Hampshire's coast will be a bright one.

The Great Bay Living Lab is a program originally funded in part by the National Oceanic and Atmospheric Administration (NOAA) through their National Estuarine Research Reserve Program. In October 1989, Great Bay received its designation as a National Research Reserve for the purpose of enhancing and preserving the natural resources of the Great Bay region through education and wise management practices. The Great Bay Living Lab program aims to enable those who want to learn and educate others about the estuarine system to do so. It is hoped that experiences gained through participation in the program will further the appreciation of and care for this great natural resource -- the Great Bay Estuary.

This curriculum was developed as a part
of the project entitled
"The Great Bay: A Living Laboratory."
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Many people critiqued copies of the book. I would like to especially thank Judy Silverberg and Laura Vincent of the N.H. Fish and Game Department; Peter Wellenberger, Manager of the Great Bay Estuarine Research Reserve; and Dr. Clayton Penniman, formerly of UNH's Jackson Estuarine Laboratory and now senior scientist on Rhode Island's Narragansett Bay Project for their suggestions. Patmarie S. Maher, Program Specialist and Maureen Witkowski, Education Specialist from the NOAA Sanctuaries and Reserves Division also reviewed the book and made helpful suggestions. Steve Adams, Communicator for the UNH/Me. Sea Grant College Program completed an extensive review of the curriculum, also. In addition, volunteers from the UNH Marine Docent Program have worked very hard to make the Great Bay Living Lab program possible. Their names are listed below.

Donna Sale	Jane Jette	Sue McCarthy
Ann Reid	Esther Kennedy	Bill Penhale
Jill Kammermeyer	Kathy Northrop	Bob Tuttle
Bob Hochstetler	Jean Ragonese	

Finally, the willingness of the staff at the Jackson Estuarine Laboratory to open the facility to students and teachers on many occasions is gratefully acknowledged. Captain Paul Pelletier and mate Robert Hochstetler of the University's research vessel, the R/V ***Jere Chase*** , are also recognized for their helpfulness to the program.

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THE GREAT BAY LIVING LAB PROGRAM INFORMATION

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GOALS

The Great Bay Living Lab Program is sponsored by Sea Grant Extension, a part of the Sea Grant College and Cooperative Extension programs at the University of New Hampshire. It was funded as a pilot program in 1990 and continues under multiple funding from several sources. The goals of the program are several:

1) To spotlight the Great Bay Estuarine System and the newly designated Great Bay Research Reserve as both natural and educational resources.

2) To motivate educators and students in their studies relating to estuarine and marine resources.

3) To provide field experiences that will aid in making classroom studies of estuarine and marine resources more realistic.

4) To begin to build a bridge between university research directed toward the world of water and existing educational programs in New Hampshire's middle and secondary schools.

5) To expose students to career possibilities through contact with the Jackson Estuarine Laboratory and university scientists and researchers.

CONCEPTS

The experiences and materials presented through the Great Bay Living Lab Program seek to motivate students and educators to find the answers to the following questions:

1) How did the Great Bay Estuary evolve and how is it related to the bigger evolutionary picture of the Gulf of Maine?

2) What biotic and abiotic factors affect the estuary, and how do they interact?

3) What role do estuaries play in the life cycles of coastal fishes and how does this affect humans?

4) In what other ways are estuaries important to humans?

5) What are the consequences of development in the estuary's watershed and how are those impacts being regulated?

PROGRAM INFORMATION

Teacher Workshop

A day-long workshop will be held before the program begins to acquaint teachers with specific procedures, to enable them to collect water for an estuarine aquarium to set up in their classroom, and to give them a detailed preview of the program. Teachers who plan to participate in the program must attend this workshop. The workshop qualifies for Title II funds and teachers attending may receive staff development credit.

Resource Manual

The Great Bay Living Laboratory: A Resource Manual for Teachers and Students will be given to each participating educator. It is recommended that the manual be used by the educator for background. It is also appropriate to duplicate all, or sections of it, for student use. Concept and vocabulary level, as well as style, have been taken into consideration so that students can benefit from reading the manual. Each chapter contains information and classroom activities, and describes the activities for the Great Bay Living Lab Day, a field trip to the Great Bay.

Resources

Posters, maps, charts, etc. are available for loan from Sea Grant Extension's Marine Education Resource Center (MERC) at the Kingman Farm located on Route 155 in Madbury, N.H. All materials from the MERC are available free of charge to participants in the program. There are several videotapes that relate to the estuary, to research being done there, and to the broader marine region, the Gulf of Maine. The MERC includes three scripted slide programs about the estuary:

The Great Bay: New Hampshire's Treasure
Salt Marshes: Nurseries of the Sea
The Great Bay Estuarine Research Reserve

Additional materials are available from the Great Bay National Estuarine Research Reserve, 37 Concord Road, Durham, N.H.

A complete listing of resources can be found in the appendices at the end of this manual.

The Great Bay Living Lab Day

A four-to-five-hour field trip beginning at 8:30 a.m. is provided as a part of the program during late September and early October, depending upon the tidal schedule. Students, chaperones and teachers travel to Jackson Estuarine Laboratory at Adams Point, Durham, N.H., where they participate in a sequence of three activities: an orientation, a sampling cruise and a field experience.

The orientation to Great Bay includes a short slide program inside the laboratory and is followed by a tour designed to highlight several of the research projects in progress there.

The sampling cruise is conducted aboard UNH's research vessel, the ***Jere Chase,*** and involves the students in taking plankton tows and a core sample of the bottom of the estuary. They also sample the water column and analyze the sample for dissolved oxygen, salinity and temperature. A current meter is used to record current speed in two locations. Students keep records of their findings and these are posted on a large record board so that comparisons can be made.

Each field activity highlights a representative ecosystem: salt marsh, rocky shore, mudflat or uplands. All field activities begin with a short walk from the upland area down to the shore, stopping at several points to observe geologic formations, to talk with oystermen who are often there at this time of year, and to get a "feel" for the over-all panorama of salt marsh, rocky shore and mudflat. The activity can include one of the following, depending upon the wishes of the teacher and the tidal conditions:

1. A transect of the rocky shore, with a subsequent mapping project to be done back in the classroom using the data collected.

2. A salt marsh study that involves making a living marsh mural with plants to illustrate zonation in the marsh, observing bird life and performing elementary water and soil analysis.

3. A walk through the upland area to study the succession of plants from the higher points to the lowland forest at the edge of the salt marsh grasses. This option includes some material on the history of Adams Point and the famous Adams family that lived there.

4. An investigation of mudflat ecology, which includes studying mudsnail behavior, looking for the "burrowers," identifying plants and discussing differences between the mudflat and the adjacent rocky shores and salt marsh.

In addition to these specific activities, bird migrations are in full swing in early fall and there should be opportunities to observe several species.

Because of the limited space available on the boat and in the laboratory, the students are divided into two groups. Each group spends about two hours on the boat and two hours on shore. There is a break between the boat and shore sessions. Then the groups switch, so that by the end of the program everyone will have participated in each activity. During lunch there is a wrap-up stressing what the students have seen and, more importantly, what remains for them to discover from their data and experiences as they continue their study of the estuary back in the classroom.

The Great Bay Living Lab Day is a motivational activity to generate experiences, data and samples to be used with the manual for further study. Educators are urged to read the manual for their own information and to duplicate or adapt appropriate portions for their students. Every attempt will be made to provide easy access for teachers to resources listed in the manual. Technical assistance can be provided when requested.

ACTIVITY SCHEDULE

NOTE: The schedule is subject to change.

8:30 - 8:40 Arrival, Introductions, Outline of the Day (The coordinator will meet the bus and bring everyone down to the Lab.)

8:40 - 10:30 The two groups of students will go to their respective stations:

Group A: Lab Conference Room

Introduction to the estuary with a short slide program and lab tour.

Field component: (One of these will be chosen.)

- •**Salt** Marsh Investigation
- •**Rocky** Shore Transect
- *Rocky Shore Population Study
- •**Mudflat** Study
- *Upland Study

Group B: Boat Dock

Sampling cruise aboard the ***R/V Jere Chase*:**

Water Sampling: Dissolved Oxygen, pH, temperature, salinity

Core Sample, currents, plankton tow

10:35 - 10:50 Break

10:50 - 12:30 Reverse the two groups and repeat the program.

12:30 - 12:45 Wrap-Up

12:45 - 1:30 Lunch, Departure (Students will eat outside or on the bus.)

TEACHER INFORMATION

Because of space limitations aboard the boat and in the laboratory, no more than 25 students and four teachers or chaperones can be accommodated in the program. The adults are expected to function as assistants to the Living Lab staff and to maintain student discipline.

Restroom facilities exist inside Jackson Lab and on the boat, **but they are very limited.** Please try to have a "rest stop" before you arrive if you are traveling some distance.

Remind students that a boat demands respect and can be a hazardous place for those who ignore rules of safe conduct. There must be no running, jumping or horseplay. All participants must know the locations of life jackets, the life ring and the raft. Procedures for their use will be explained on the day of the field trip. Students are expected to stay at their stations and participate fully.

Research is being conducted inside the Lab, and students must **not** handle anything there unless they are invited to do so. They should be attentive and quiet, they should take notes on the experiments that are explained.

Everyone must listen to directions and participate fully and efficiently in each part of the program. Field notes can be taken on the record sheets that will be provided. Students should bring clipboards and pens or pencils.

Everyone, including adults, should sign a release form. There are samples that can be duplicated in the appendices of this book. <u>These forms should be handed to the Living Lab coordinator on the day of the trip.</u>

CHECKLIST OF THINGS TO BRING

Clipboard and pen or pencil. Teachers and chaperones may assist students with record keeping. We will distribute record sheets on the day of the trip.

Coolers for specimens. (We recommend that you take some specimens back for examination in the classroom.) A plant press is useful so that students can press algae and grasses in the field.

Various-sized plastic, covered containers. You may want to bring two or three ‘plastic buckets or several gallon milk jugs for water if you plan to set up an estuarine aquarium, ziplock bags for sediments and thermos bottles for plankton. Equipment may be brought as long as it isn’t too bulky or fragile. Hand lenses are useful.

Release forms for EVERYONE participating. Emergency phone numbers must be listed for everyone, teachers and chaperones included. Give **these to the coordinator on the day of the** trip.

Complete payment for the Living Lab. Send in registration fees as soon as possible to secure your reservation. Then bring the rest of the payment the day of the trip. Or, you can pay all fees in advance if you wish. The Check should be made payable to “Great **Bay Living Lab”.**

Name Tags. Please have students wear name tags. Masking tape with first names is adequate.

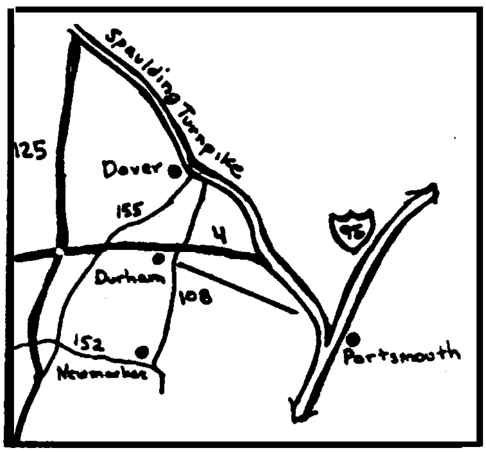
Please remind the students that they will be getting muddy and they **MUST** wear old clothes and sneakers (or rubber boots). **Everyone needs to dress in layers. Remember,** it is always much colder near the water than inland.

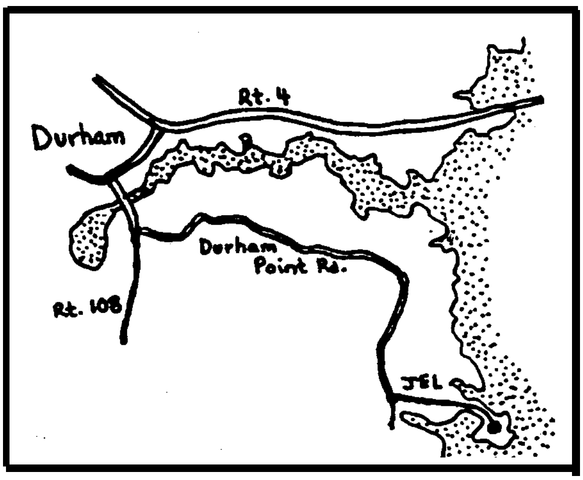
TRIP CANCELLATION

The field trip will not be cancelled unless weather is very severe. (Rain and cool weather are not considered severe). If a trip is to be cancelled, teachers will be notified by 6 a.m. Teachers must notify the other participants. If the weather seems very bad and you are wondering whether the trip will occur, call 603-659-5441. Should the weather be bad, it may be possible to re-schedule, although this is extremely difficult to do.

ARRIVAL AND DEPARTURE TIME

The Great Bay Living Lab program begins at 8:30 sharp and ends at 12:45. PLEASE BE PROMPT. Late arrival means curtailment of some portion of the schedule.





The Great Bay Living Lab takes place on Adams Point at the University of New Hampshire's Jackson Estuarine Laboratory (JEL) which is about four miles from Durham.

PARKING

Please park on the left at the top of the hill, just before you come to the Laboratory. The, program coordinator will meet you there and bring the students down to the Laboratory. We want. to cause as little disruption to Jackson Laboratory as possible.

STUDENT INFORMATION

*Dress in layers. It can be much colder on the water than on the land.

*Wear OLD clothes (long pants are best because there is lots of poison ivy around) and OLD SNEAKERS or rubber boots. You will be working in muddy areas. (Bring some dry socks -- a secret "weapon" if you should get wet.)

•Eat breakfast! Waves on the bay can be rough and eating a light breakfast helps you be prepared. You can bring a snack if you like, but please -- no glass containers.

- While on the boat, follow instructions given by instructors or the captain. A boat can be a dangerous place.

*Bring a clipboard and two pencils or pens.

*Bring lunch, as the program lasts into the lunch hour. Bring your own beverage if you like. The drink and snack machines within the Lab are **off-limits** for the Living Lab participants.

•Do not handle equipment of any sort inside the Jackson Lab unless asked by your instructor to do so. Research is ongoing at the Lab and you could easily ruin experiments.

*Follow first aid procedures: (There will be a first aid kit on the boat, with instructors in the field and inside the Lab.)

If an accident occurs, **immediatelv** notify a teacher, an instructor, the boat captain or any other adult.

If the accident is a fall, **do not move the iniured person**. Get help immediately from the nearest adult.

Most of all, just use your common sense about behavior and know that you will be in places where research is going on and where "fooling around" could be very dangerous.

THE BIG PICTURE: THE GULF OF MAINE

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Gulf of Maine -- A Sea Beside the Sea

The Great Bay Estuary, a place where fresh and salt water meet and mix, is just one of the many estuaries on the shores of the Gulf of Maine. The Gulf of Maine is our own "sea beside the sea." The Gulf is partially enclosed and somewhat separate from the rest of the Atlantic Ocean. The Gulf Stream passes near its southern boundary and meets the strong Labrador Current coming from the north far off the coast of Nova Scotia. There, both currents are deflected toward northern Europe.

Thousands of years ago a huge glacier about one mile thick pushed piles of rock and gravel ahead of it. Sometimes the glacier rolled right over the rocks. Whenever the climate warmed the glacier melted and dropped gravel and rocks, creating sandy moraines and small hills. **Georges Bank** is one such "hill of gravel" in the Gulf of Maine. Georges Bank was above water for hundreds of years. Plants, animals and even humans lived there. It was first a cape, jutting out into the Gulf from the mainland, and then an island. In some places it is only a few meters beneath the surface.

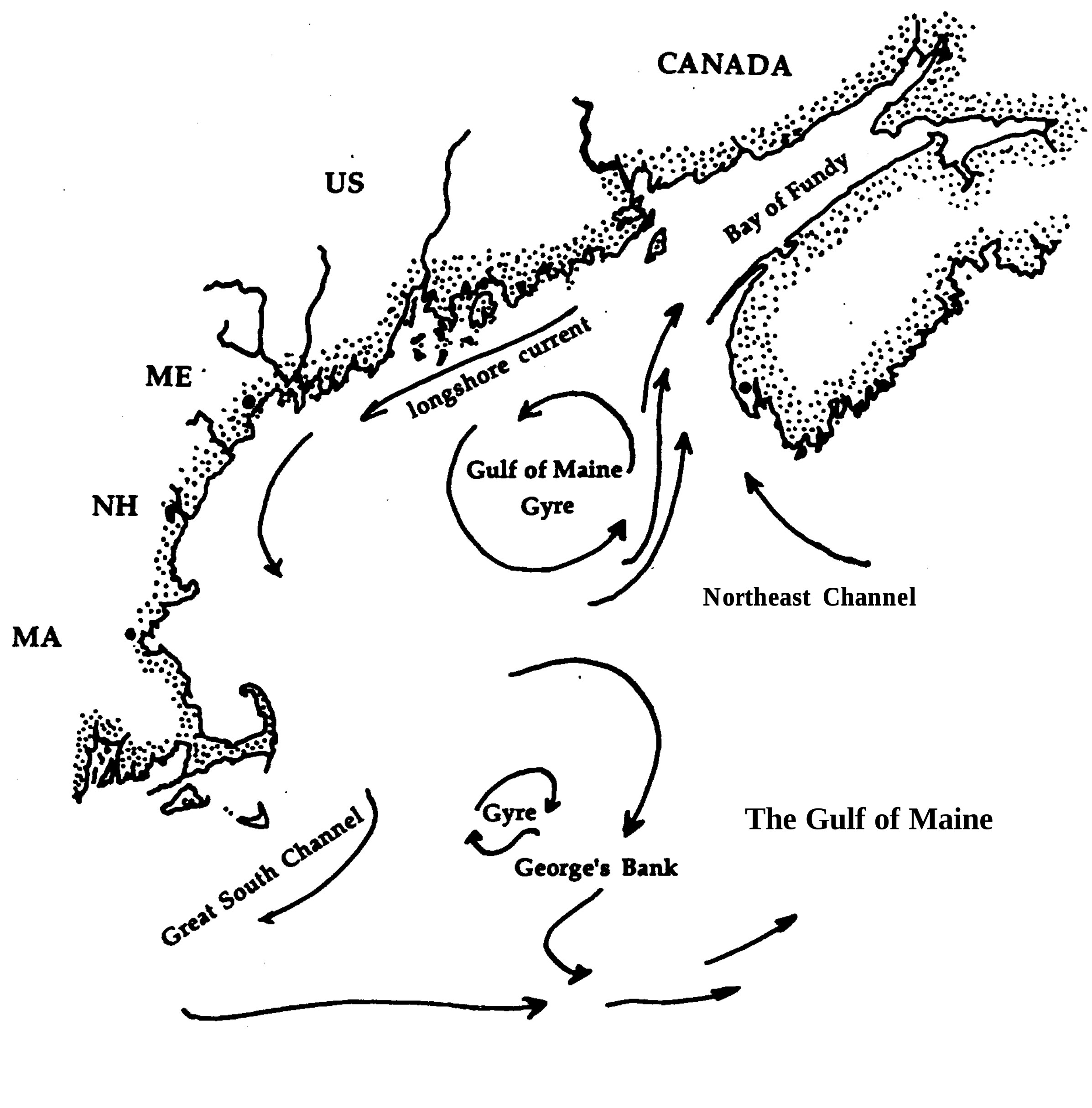
Long ago, streams carved out channels in a low, gently sloping plain and washed out the basin that forms the Gulf. A deep channel was created between what is now Nova Scotia and Georges Bank. It is called the Northeast Channel. This and the Great South Channel are the major passageways for the exchange of waters between the Atlantic Ocean and the Gulf of Maine.

Currents and Tides In the Gulf of Main

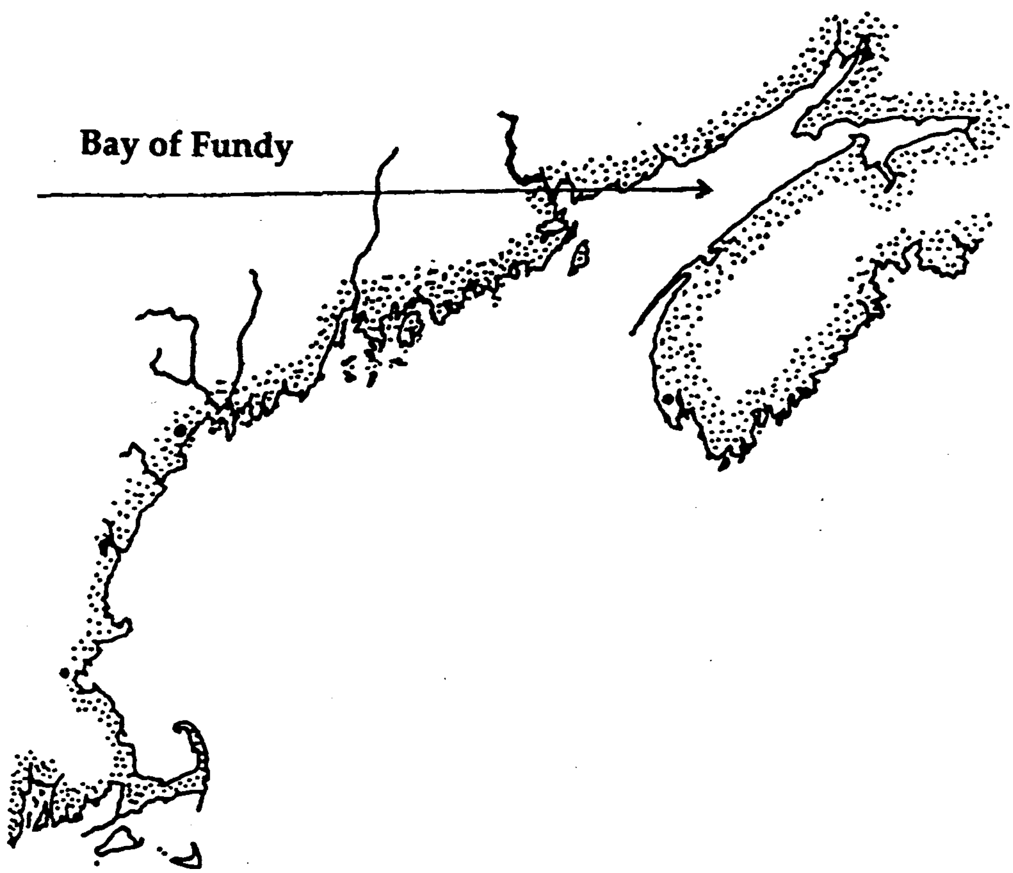
Currents are like rivers of water within the ocean. The currents in the Gulf of Maine move the water completely around it once every three months, distributing nutrients all over the Gulf. Several forces interact to create currents. The sun heats the shallower waters of the Gulf. This warm water rises just as warm air rises from a woodstove and that forces cooler, heavier water to move in and take its place, thus creating circulation.

Waves, powered by the wind, hit the shore at an angle and meet rivers coming into the Gulf. Together they push water against the shore in a generally southerly direction, forming the **Long Shore Current. The Coriolis effect** caused by the earth's rotation on its axis makes the waters to turn toward the right while they are moving south. The waters flow south until they begin to be deflected eastward by the land which curves around to shape Cape Cod. Dense, salty waters coming in from the ocean through the Northeast and Great South channels deflect them even more and help to turn them counter-clockwise to form the giant, slow-moving whirlpool, called the **Gulf of Maine Gyre.** Some waters flow over Georges Bank and form a clockwise gyre.

The Gulf of Maine



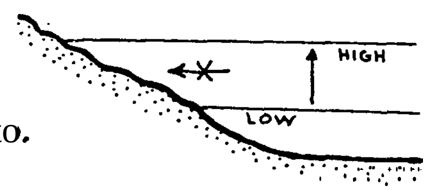
Tides, the twice-daily rising and falling of the waters, affect the currents as well. Depending on the size and shape of each part of the Gulf, tides can have a range of about 5 feet, as they do near Cape Cod, or the range can be much more. When tides push water up into narrow bays like the Bay of Fundy in Nova Scotia, there can be as much as 50 feet difference between high and low tide. The Bay of Fundy is famous for its great tidal range.



What causes the tides? There are many factors that influence tides. Gravity is one. Oceans cover almost 3/4 of the earth's surface and, because they are a liquid, they can be moved by the moon and sun's gravity. Because the moon is closer than the sun is to the earth, the moon exerts the greatest gravitational attraction. The moon's gravity is strong enough to pull the surface of the oceans into a huge bulge called a tidal bulge. We call the bulge a tide. Notice that there is also a tidal bulge on the opposite side of the planet, too. This is caused by the centrifuge1 force created as the moon revolves around the earth. Centrifuge1 force pulls water away from the side of the earth opposite the moon.

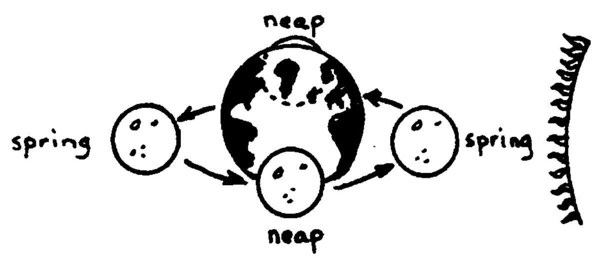
High tide occurs at the highest point of the tidal bulge. Low tide is occuring where the waters are not being affected by the moon's gravity. For example, when the Gulf of Maine is facing the moon, it will experience high tide. About six hours later, as the earth turns, the Gulf will experience low tide because it is now at right angles to the gravitational force of the moon. At about 12 hours, the Gulf is facing away from the moon. Centrifugal force is causing a tidal bulge on that side of the earth and there is a high tide again. At about 18 hours later, the Gulf is again at right angles to the moon and there is another low tide. In 24 hours and 43 minutes the earth has made one complete rotation and there have been two high tides and two low tides in one day in the Gulf of Maine.

Note that the rise and fall of the tide is a vertical motion; the water doesn't actually move horizontally into the shore, though it does seem to.

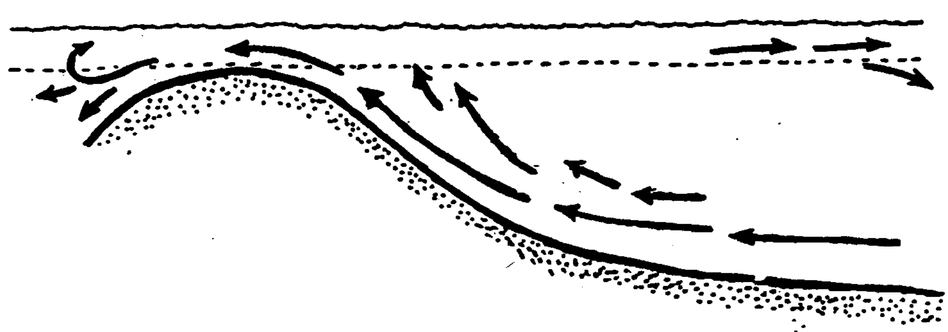


The **tidal range** between high and low tides is greater than average twice a month, and it is also smaller twice a month. Have you heard of **spring** and **neap** tides? The moon circles the earth once every 27.5 days. During this time, the earth, sun and moon are lined up with each other twice. This means that the moon and sun's gravity team up to pull together in a straight line on the waters of the earth. These **spring tides** occur at the new moon (when the moon can't be seen) and at the full moon.

Also, each month the moon and the sun are at right angles to each other when the moon is showing its first quarter or its third quarter. This means that the moon and sun are pulling somewhat against each other. This reduces the range between high and low tides. These tides are called **neap** tides.



Upwelling. Movements of water have some very beneficial effects on life in the Gulf of Maine. One important benefit is a result of the **upwelling** that occurs over the shallow spots in the Gulf. Cold water from the Atlantic is pushed up and over Georges Bank by winds and currents, bringing the nutrients into the photic zone where light can penetrate. Nutrients include the dissolved elements such as nitrogen, phosphorus, ammonia and carbon, which come partly from the remains of dead plants and animals. More nutrients are washed down into the bays and carried by the tides out to Georges Bank where they mix with the "upwelled" waters of the Atlantic. The Gulf of Maine is one of the richest fishing areas in the world, as a result.



Those same beneficial currents and tides also have some detrimental effects. They carry pollution from the cities all through the Gulf and into the North Atlantic. Boston Harbor is one of the most polluted harbors in the United States, and its waters move into the Gulf with every tide cycle.

The Gulf's Food Chain

Microscopic plants called phytoplankton thrive here, with plenty of nutrients and sunlight to help them grow. They are the basic building blocks of the Gulf's food chain. They use sunlight, carbon dioxide and nutrients in a process called **photosynthesis** to make their own food. A by-product of photosynthesis is oxygen, which is what animals need to breathe.

The general formula for photosynthesis is:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$$

Here is what the formula means:

Six molecules of carbon dioxide plus six molecules of water in the presence of light create sugar (food) and oxygen. (Plants use oxygen to break apart the sugar molecules for energy.)

Tiny animals called zooplankton graze on the fields of **phytoplankton,** the "grass of the sea" -- and sometimes they graze on each other! Some are then eaten by larger animals. Copepods are one of the most common kinds of zooplankton and are an important food for young fish.

Phytoplankton increase greatly or "bloom" in the spring and fall in some areas. These blooms are followed by population explosions of zooplankton. This cycle forms the base of the food chain that sustains fish, shellfish, birds, and marine mammals in the Gulf of Maine. Whale watchers are treated io the sight of migrating humpback, finback and minke whales within a few miles of the coast. The whales swim near the shore to feed on the small fish, shrimp-like krill and plankton that make up their diet. Sometimes schools of Atlantic white-sided dolphins are seen, too, snacking on "left-overs" from the whales' meals.

Humans also depend upon the sun and the phytoplankton that converts its energy into food. We eat fish and shellfish, many of which are dependent upon smaller animals that feed on zooplankton, which in turn feed on phytoplankton.

CLASSROOM ACTIVITIES-GULF OF MAINE

A. The Coriolis Effect on Running Water

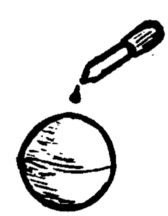
(Adapted from Salt Water News, Division of Marine Resources, State of Maine.)

Purpose: To discover how the Coriolis Effect influences the motion of water in the Northern Hemisphere.

Materials:

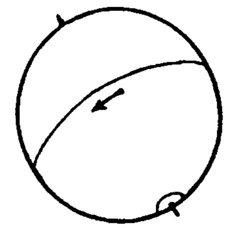
1. a round, earth-shaped object. An old globe is excellent but a volley-ball will work also. Mark the "north pole" and the "equator" on the "earth."
2. a medicine dropper or a large turkey baster.
3. a container of water, colored lightly with food coloring.
4. a large pan or sink to put under the "earth."

Background: The earth, as you know, rotates on its axis. Since the earth is a sphere, different areas of the earth are moving at different speeds depending upon their location. At the equator everything is rotating at 1040 miles per hour. At a point approximately 31 miles from the north or south pole, the speed is 16.8 miles per hour. The velocity increases as you move from each pole to the equator. The force that results from the change in velocity is caused by the Coriolis effect, named after the man who discovered it. This force acts on all objects moving over the surface of the earth, such as rivers, trains, ships, water, etc.

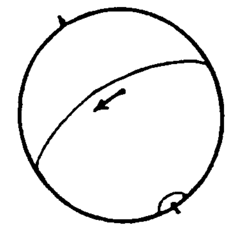


Procedure:

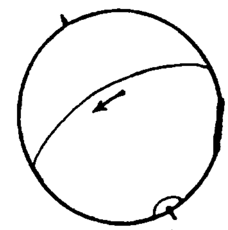
1. Predict how a stream of water will flow if it runs from the north pole toward the equator. Draw a line lightly on the ball from the "north pole" to the "equator" to show where you think the water will flow. Label this line "A."2.



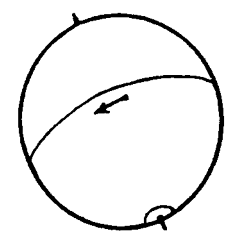
2. Fill the baster with water and pour a little on the "north pole." Draw the path it follows.



3. Look at the "earth" again. Suppose the "earth" were moving. Predict where the water will go. Draw a line and label it "B."



4. With the "earth" spinning from left to right, form a small stream on it from the "north pole" toward the "equator." Draw the path of the water. What happened?



<u>Questions to answer</u>

1. Which way did the water move when the earth was spinning?

2. From your observations, which way will a stream of water move as it enters the ocean from the land in the Northern Hemisphere?

3. Look at the map of the Gulf of Maine (p. 15) and draw in the directions the currents from the rivers will flow as they move into the Gulf of Maine. Do you see how the rivers and the Coriolis effect help to cause the Gulf of Maine Gyre, which moves basically counter-clockwise?

B. Tide Chart Reading. The tide chart below is for Portland, Maine. To adjust the tide times for the mouth of the Great Bay Estuary at Portsmouth, N.H., add 16 minutes. It takes two hours and 30 minutes for the tide to move into Great Bay. Add the times together to answer the following questions accurately.

1. What are the dates and times of the spring tides the neap tides?

2. Which days have the greatest tidal range?

3. Which days would be best to go to the clamflats in an estuary to dig for clams?

4. Is it important to have the tidal range in centimeters as well as in feet? Why?

SEPTEMBER 1991

Day	Time h m	Height ft	Height cm
1 Su	0321	8.7	265
	0920	0.9	27
	1539	9.9	302
	2209	0.4	12
2 M	0422	8.4	256
	1021	1.1	34
	1640	9.8	299
	2316	0.4	12
3 Tu	0530	8.4	256
	1128	1.1	34
	1749	9.9	302
4 W	0024	0.3	9
	0641	8.5	259
	1239	0.9	27
	1859	10.1	308
5 Th	0133	-0.1	-3
	0749	9.0	274
	1346	0.5	15
	2005	10.5	320
6 F	0232	-0.5	-15
	0847	9.5	290
	1448	0.0	0
	2106	10.8	329
7 Sa	0327	-0.8	-24
	0943	10.1	308
	1545	-0.5	-15
	2202	11.0	335
8 Su	0417	-1.0	-30
	1031	10.5	320
	1638	-0.8	-24
	2253	11.0	335
9 M	0503	-1.0	-30
	1117	10.8	329
	1728	-1.0	-30
	2341	10.7	326
10 Tu	0549	-0.8	-24
	1203	10.8	329
	1817	-0.9	-27
11 W	0030	10.3	314
	0634	-0.4	-12
	1248	10.6	323
	1903	-0.6	-18
12 Th	0117	9.8	299
	0719	0.1	3
	1333	10.3	314
	1953	-0.2	-6
13 F	0207	9.2	280
	0806	0.7	21
	1420	9.8	299
	2044	0.3	9
14 Sa	0258	8.7	265
	0854	1.3	40
	1510	9.4	287
	2137	0.8	24
15 Su	0352	8.2	250
	0947	1.7	52
	1603	9.0	274
	2236	1.2	37
16 M	0451	7.8	238
	1045	2.0	61
	1703	8.7	265
	2336	1.4	43
17 Tu	0553	7.7	235
	1145	2.2	67
	1803	8.6	262
18 W	0036	1.4	43
	0653	7.7	235
	1245	2.1	64
	1901	8.7	265
19 Th	0130	1.3	40
	0741	8.0	244
	1339	1.8	55
	1954	8.9	271
20 F	0218	1.1	34
	0829	8.3	253
	1426	1.4	43
	2039	9.1	277
21 Sa	0250	0.8	24
	0908	8.7	265
	1508	1.0	30
	2122	9.3	283
22 Su	0333	0.6	18
	0946	9.1	277
	1548	0.6	18
	2200	9.5	290
23 M	0409	0.4	12
	1019	9.5	290
	1624	0.3	9
	2237	9.6	293
24 Tu	0441	0.3	9
	1052	9.8	299
	1702	-0.1	-3
	2314	9.7	296
25 W	0516	0.2	6
	1127	10.1	308
	1741	-0.3	-9
	2352	9.6	293
26 Th	0552	0.2	6
	1204	10.3	314
	1823	-0.4	-12
27 F	0034	9.5	290
	0633	0.3	9
	1248	10.4	317
	1906	-0.4	-12
28 Sa	0119	9.3	283
	0719	0.5	15
	1332	10.3	314
	1958	-0.2	-6
29 Su	0212	9.0	274
	0809	0.7	21
	1425	10.2	311
	2054	0.0	0
30 M	0310	8.7	265
	0906	1.0	30
	1525	10.0	305
	2157	0.2	6

INTRODUCING ...
THE GREAT BAY ESTUARY

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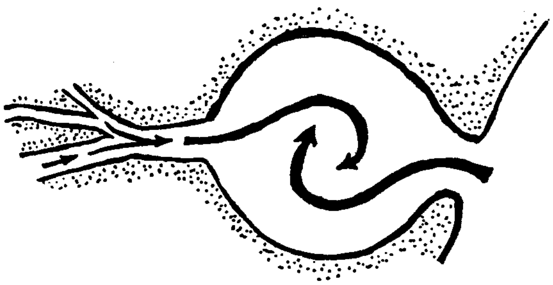
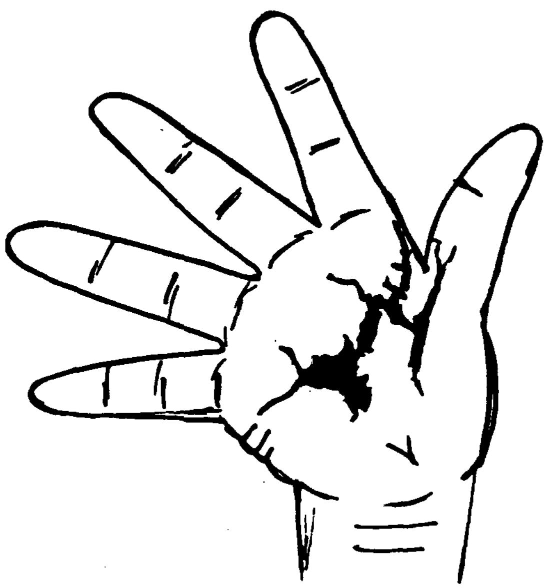
THE GREAT BAY ESTUARY

The Great Bay Estuary is a partially enclosed coastal body of water where fresh water is constantly mixing with tidal salt water from the ocean. Rivers are part of the estuarine system, bringing nutrients, pollutants and particles of soil from the land into bays. Salty, dense sea water moves in every 12 l/2 hours with the high tide. The twice-daily high and low tides move plankton, plants, animals, sediments, and pollutants throughout the estuary, into the coastal ocean and up the rivers as far as the dams.



Location and Size

The Great Bay Estuarine system located on the short New Hampshire coastline, consists of eight rivers, Little Bay and Great Bay. Pretend your arm is the Piscataqua River and your thumb the Cocheco and Salmon Falls rivers. Then, your forefinger would be the Bellamy River, the middle finger is the Oyster River, the fourth finger is the Lamprey and the fifth, the Squamscott. You would need an extra finger to represent the Winnicut River.



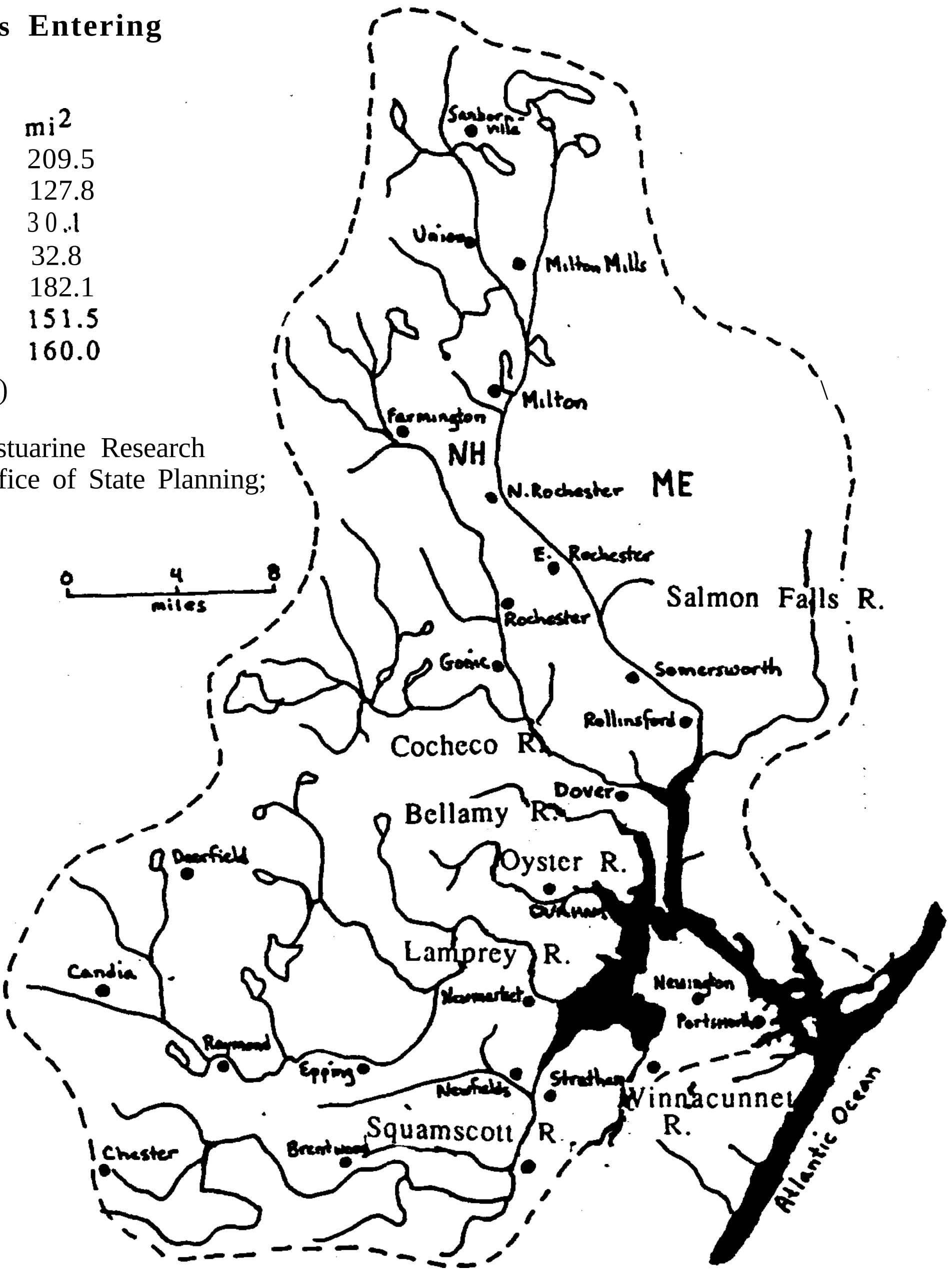
The estuary has a shoreline of about 100 miles, but it drains a much larger area called its watershed. All the water runs off the high ground into the eight rivers and the bays. The estuarine system covers about 930 square miles, l/3 of which is in the state of Maine. Look at the map below and find the eight rivers to see where the estuary gets its start. Can you see the. mouth of the estuary?

The Great Bay Estuarine System

Drainage Area of Rivers Entering the Great Bay Estuary

River Basin	km^2	mi^2
Lamprey	542.6	209.5
Squamscott	331.0	127.8
Oyster	78.0	30.1
Bellamy	85.0	32.8
Cocheco	471.6	182.1
Salmon Falls	392.4	151.5
Piscataqua	414.4	160.0
Winnacunnct	(unknown)	

The Great Bay National Estuarine Research Management Plan; N.H. Office of State Planning;



Formation of the Great Bay Estuary

Some estuaries around the world were formed in the deep gouges left by glaciers when they melted. The Bay of Fundy in the Gulf of Maine was formed in this way. In some cases, ocean currents may bring in sand and pile it up near the mouth of a river. Water from the river then spreads out behind this barrier. The sand builds into a long strip and protects the waters behind it, where salt marshes and mudflats soon develop. Sometimes the river pushes against the sand hard enough to form a channel to the sea. The Hampton-Seabrook Estuary on the New Hampshire coast was formed in this way.

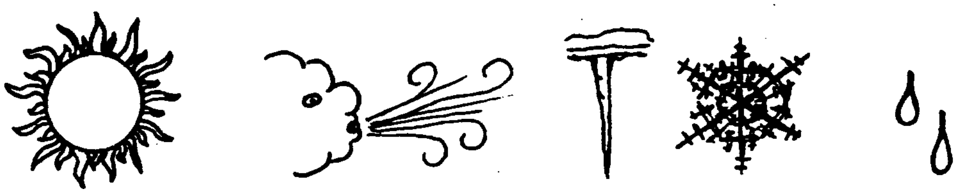
The Great Bay Estuary came about in a different way. When the last glaciers began to melt about 14,000 years ago, the oceans started to rise. They flowed over coastal lands and "drowned" the river valleys that help to make up the estuary. Salt water mixed with water from the rivers to fill the shallow basin that is the Great Bay and the deeper basin that is Little Bay. (Aerial photographs of Great Bay show the river channels clearly.) The Piscataqua River became the outlet to the ocean, running between what are now Portsmouth, N.H., and Kittery, Maine.

At the same time the sea level was rising, land that had been pushed down about 40 feet by the heavy weight of the glacier began to rise. It took thousands of years for the land to "rebound" until now it has reached the same level it was before the glacier covered it. But sea level continues to rise. One can see signs of this in some of the salt marshes, where grasses are covered with salty water for longer periods of time than they can tolerate. Some plants are even beginning to die.

Scientists believe that by the year 2100 sea level will be from .5 to 3.75 meters higher than it is now. What effect do you think this will have on the animals and plants living on the shores of the estuary?

CHANGES IN THE ESTUARY

If you were a plant or animal living in the waters of Great Bay or along the shores of some of the rivers, think what you would have to endure: daily and seasonal changes in water temperature, salinity and nutrient levels; exposure to hot sun, wind, ice, snow and rain; etc. The estuary is a place where everything is constantly changing.



Tides and currents cause many changes. Tides are the regular rising and lowering of the water caused in part by the moon's gravitational attraction on the earth. The tidal range, or the distance between the water level at high and low tide, is 8.2 feet in New Castle, N.H., at the mouth of the estuary, 6.6 feet at Dover Point, and about 5 feet up the Lamprey River in Newmarket. Many people mistakenly think that the estuary is completely flushed twice a day by the tides, but it takes 26 days for a mass of water entering the estuary to move through the system and out again to the ocean.

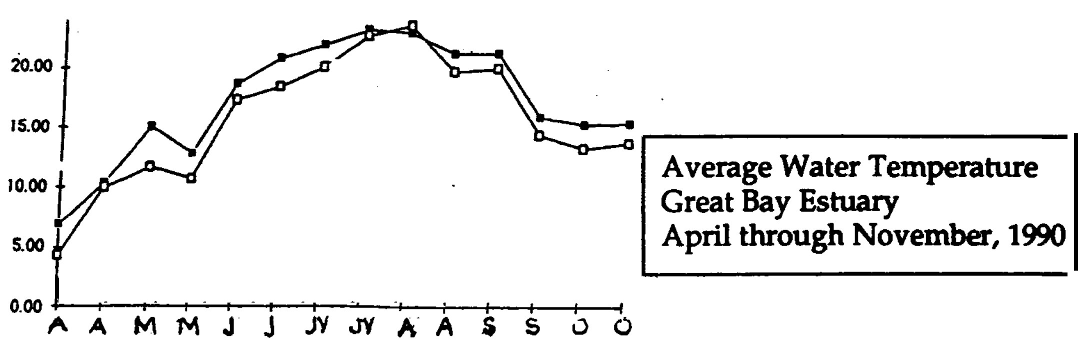
Twice each day the tide rises and falls. Cold, salty ocean water moves into the estuary at every high tide. This water mixes with the less dense fresh water from the rivers and streams. In some estuaries, this forms a sort of "wedge" with the denser, colder ocean water on the bottom and the lighter fresh water floating on top. But in Great Bay there is no noticeable wedge effect, because the salt and fresh waters are quite well-mixed due to the swift currents in the system. Water moves very rapidly in the deep rivers and narrow necks of the estuary. The currents through the Furber Straits, the "bottleneck" between Little Bay and Great Bay, average about three knots, but they can be as fast as five or six knots.

Seasons bring changes to the estuary as well. In the spring, when the ice melts, fresh water rushes into the bays and **salinity** can drop from the usual 22 or 23 **parts per thousand** to zero. (Scientists write "parts per thousand" with a symbol like this: **o/oo.)** Salinity is the total amount of dissolved elements in the water. Those elements appear as salts. In the ocean and in the estuary, the two most common elements are sodium and chloride (like the salt on your table), but there are others too, such as salts of magnesium, calcium, copper, lead, zinc, etc.

As one would expect, estuarine waters are saltier at the mouth of the estuary and get less salty the further up one goes into the bays and rivers. Most animals who live in the ocean and are used to an ocean salinity of between 32 o/oo and 35 o/oo cannot adapt to the estuary where salinity is so much lower and varies so much. On the other hand, plants and animals that have adapted to the big changes in salinity that occur as the tide comes in and out of the estuary twice daily have a difficult time staying alive out in the saltier open ocean.

But there are other changes. Water **temperatures** range from -1.9 degrees to 28-30 degrees Celsius (C) during the year, partly because of the shallow waters of the Great Bay proper. The water gets warm enough in the summer that tropical species of animals and plants that are washed in by early summer high tides can survive until the water begins to get cold in the fall. In the winter, temperature drops and sometimes all of Great Bay freezes.

Changes in temperature affect the body processes of animals and plants. If temperatures are low, changes such as those involved in digestion (metabolism) and photosynthesis are slower. If temperatures are high, these changes speed up. Plants and animals in the estuary must be able to endure both quick and gradual changes in temperature.



Animals living in estuarine waters take their **oxygen** from the water itself. Oxygen from the atmosphere diffuses into the water at the surface. When the wind blows, water and air molecules move rapidly and the water is aerated even more. Plants produce oxygen too, while they are photosynthesizing. They use oxygen to break apart sugars created during photosynthesis. This provides them with energy. The amount of **dissolved oxygen** (DO) is one of the most important indicators of water quality.

Nutrient levels indirectly affect the amount of dissolved oxygen in the water. If there are too many nutrients, too many plants may grow and begin to shade each other. The shaded plants stop photosynthesizing, starve and die. Bacteria then begin to decompose the dead plants, and in the process start to use up the remaining oxygen supplies. Animals in the water can't get enough oxygen, and they begin to die. More decomposition occurs, using up even more of the oxygen.

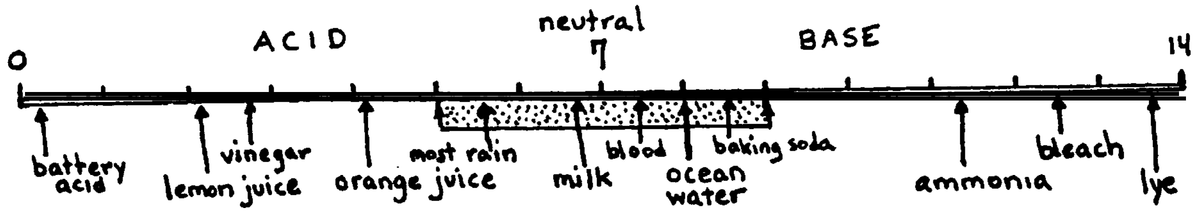
Temperature also helps to determine how much dissolved oxygen the water can hold. Colder water holds more dissolved oxygen than warmer water, because molecules are moving less rapidly at colder temperatures. Oxygen atoms, which can be easily "bumped" off the water molecules and escape into the atmosphere, are less likely to do so when there is less activity. Look at the table below to compare temperature with dissolved oxygen.

Dissolved Oxygen Content of Water

Temp. (° C)	DO (ppm)
0	14.6
5	12.8
IO	11.3
15	10.2
20	9.2
25	8.4
30	7.7

The pH level or acidity of the water is important. pH stands for hydrogen ion concentration ("p" is a chemistry notation for concentration; "H" is the chemical symbol for hydrogen). pH is measured on a scale of 0 to 14, with neutral (where the liquid is neither alkaline or acidic) being 7. Estuarine waters usually have a pH between 7.0 and 8.6, and the ocean is about 8.0. Both are considered to be slightly alkaline, which is a good environment for plants and animals to grow in. Rain is slightly acidic naturally, but some rain is highly acidic due to pollution and is almost like lemon juice. White Lake in New Hampshire has a pH of 4.3 and is called a "dead" lake because almost all the plant and animal life that normally occurs in lakes can only live within a pH range of 5.0 to 9.0. pH can change very rapidly when a storm or spring run off brings a large volume of fresh water into a body of water.

pH Scale



CLASSROOM ACTIVITIES
THE GREAT BAY ESTUARY

A. An Estuarine Aquarium

Purpose: To learn more about the behavior and interaction of several plants and animals of the estuary.

Materials: Aquarium, filtration system, notebook, estuarine water, animals, plants, gravel.

Procedure:

1. Set up an estuarine aquarium prior to your Great Bay Living Lab Day. Arrange the filters, gravel, etc. --- BUT DO NOT FILL WITH WATER.

2. On the day of the field trip, bring clean milk jugs or covered buckets for estuarine water. Select a few "tough" animals such as a small green crab, periwinkles, mussels, and soft shell clams. Mummichogs are very hardy fish. Perhaps you can net a couple to put in your aquarium. An American eel will live in an aquarium. Look for one among the rocks along the shore. A cooler half-filled with estuarine water with a cold pack will keep the animals safe until you return to school.

4. Put the animals and plants into the aquarium soon after returning from the Great Bay Living Lab Day and arrange the habitat.

5. Have a volunteer aquarium committee who will tend the aquarium on a regular basis.

6. Check salinity with a hydrometer and thermometer each day. Use the graph of "Salinity Determination by Density" in the Appendices to make the conversion from temperature and density measurements to salinity.

7. Mark the water level with a grease pencil when you fill the aquarium. You can replace small amounts of water lost due to evaporation with ordinary tap water, as long as it has been set out overnight to partially rid it of chlorine.

8. Feed the animals tropical fish food. (Tetramine flakes will not foul the tank.) Pieces of squid or fresh fillets can be rubbed into very small bits and fed to the animals. Take out any food that is left uneaten after a day. **Do not overfeed.** Some of your animals are plant eaters. Be sure you have what they need to eat, also.

9. Set up an observation notebook like the form below to keep a daily check on the aquarium.

Aauarium Observations

date	time	temp	**densi** tv	salinity	**general** observations

Set a time limit on how long to keep the aquarium active. When you deactivate the aquarium, you can to return the live animals to the estuary, or preserve them for further study.

B **Plankton Observations**. (A good follow-up activity after the Great Bay Living Lab Day.)

Purpose: To become more aware of the diversity of microscopic life in the estuary by making and recording observations.

Materials: Compound and dissecting microscopes, well and plain slides, cover slips, plankton key, plankton, pencil.

Procedure:

1. Collect plankton samples. (You can use those you collected while aboard the boat or you can collect samples from a dock or bridge with a simple net made from a nylon stocking.)

2. Put a small amount of plankton on a slide.

3. Look at the plankton with both the dissecting and compound microscopes.

4. Fill out the data sheet for each sample that you observe. Be sure to make a sketch of the organism on the record sheet.

5. Use a plankton key to identify your samples. A Photographic Guide to Plankton of the Gulf of Maine, published by the Shoals Marine Lab* contains a good one. Can you identify the species that you have observed?

* The Shoals Marine Lab is an undergraduate teaching laboratory sponsored by Cornell University and the University of New Hampshire. It is located on Appledore island, one of the Isles of Shoals, about 8 miles off the New Hampshire coast.

Plankton Data Sheet

Name__________________________________**Date**___________________

Date Sample Collected______________Tide _________Place __________

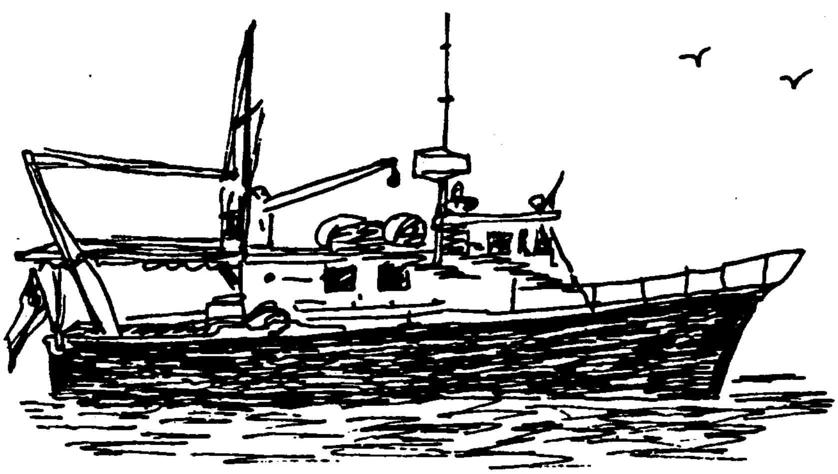
Shape	How does it move?	Color	Identification and sketch
1.			
2.			
3.			
4.			
5.			

GREAT BAY LIVING LAB DAY
ACTIVITIES -- ESTUARY

The activities described below will take place aboard the UNH's research vessel, the ***RV Jere Chase*** , in Great Bay. Students will move from station to station aboard the boat to do some estuarine sampling. These activities are described in detail in the pages that follow.

We will use various types of equipment to sample the water, sediments, plants and animals of the estuary. Data must be recorded on the record sheets provided. It is essential that teachers discuss the data together back in the classroom.

Samples of plankton and seaweeds can be collected during the cruise to use in the classroom, if coolers and plastic containers are brought along on the boat.



Great Bay Living Lab Data Sheet

Name______- Date______

Tide: Low_ Mid-___ High___ Weather____________________

Bird Checklist

-Great Blue Heron

_Cormorant

_-Tern

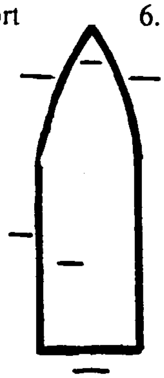
-Canada Goose

-Herring Gull

-Great Blackbacked Gull

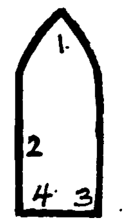
Boat Terminology

1. midships 4. starboard
2. stem 5. head
3. port 6. bow



Stations

1. water sampling
2. currents & photic zone
3. plankton sampling
4. sediment sampling



Plankton Station (Look at one species and use the form below to describe it.)

Shape	How does it move?	Color	Check one:
			Zooplankton Phytoplankton

Water Station

Depth (m)	Temp. (C.)	Density	Salinity o/oo	pH	DO (ppm)

Currents and Transparency (photic zone) Station

Photic zone: __________meters

Current Speed: Surface_______ knots.

Deeper: depth ______meters. Speed_______knots

Station 1 Plankton

Purpose: To examine various phytoplankton and zooplankton.

Equipment: Large and small plankton nets, slides, eyedroppers, wash bottles, magnifying glasses, microscope, petri dishes, etc.

Background: Plankton are plants and animals that float in the water and are moved by the currents. Most plankton are microscopic or at least very small, they are to be sampled by filtering sea water through a fine mesh net. There are both plant plankton (phytoplankton) and larger animal plankton (zooplankton). The zooplankton include animals that spend their whole life as a part of the plankton and those that are plankton only during their larval stages, such as mussels, barnacles, clams and oysters.

Procedure:

1. Before beginning, obtain the captain's permission. Tie the plankton nets securely to the rail and then throw them over the side of the boat.

2. After a few minutes, pull them in and wash down the sides of the net and then pour the plankton into a small container.

3. Look closely to see if you can detect movement in the sample. Use an eyedropper to pick up some plankton, put it on a slide and view it under the microscope.

4. Record the shape, movement technique and color of the plankton. You may take plankton back to school with you in a thermos or a container that you can keep cold.

NOTE: Between stations, you will assist in taking a core sample of the sediments. A hollow steel tube is plunged into the bottom of the estuary. When brought back on deck the resulting core of sediments is removed for study. Examine the core closely when it is brought aboard. Some of the estuary's history can be observed from core samples. Look for evidences of the sawmill and brick-making era of the 1700's, and the blue marine clay that indicates this part of the estuary was once ocean.

Station 2: Measurement of temperature, density, salinity, pH and dissolved oxygen.

Purpose: To use simple equipment to measure some of the physical and chemical parameters of, the water column.

Equipment: Van Dorn bottle, thermometer, hydrometer, dissolved oxygen and pH test kits.

Background: Salinity is a measure of the amount of dissolved salts in the water. It is usually expressed as the number of grams of salt in 1,000 grams of water or "parts per thousand" **(o/oo).** The salinity of the open ocean is about 35 parts per thousand, but estuaries can have a much lower level because of their freshwater input. We use the density and the temperature of the water to determine salinity. We will use a thermometer to measure temperature and a hydrometer to measure water density. Using the following table "Salinity Determination by Density" in the Appendices, we can determine the salinity of our sample.

Water temperature is important as well because chemical reactions occur faster in warm water and slower in cold water. For example, oysters grow much faster when the water is warmer because all their body processes, including digestion, are faster.

If time permits, a water sample will be analyzed using a LaMotte test kit to check the dissolved oxygen level. Perhaps the most important and abundant of the gasses in water, oxygen dissolves into the water as a byproduct of photosynthesis and direct absorption from the atmosphere. In a healthy estuary, the level of dissolved oxygen cannot fall below three or four parts per million (ppm) without placing a lot of stress on the plants and animals there.

The pH scale runs from zero to 14. A pH measurement of under 7.0 is acidic, over 7.0 it is alkaline or basic. A pH of 7.0 is neutral. Ocean water is slightly basic, with a pH about 8.0. Estuarine water usually varies between pH 7.0 and pH 8.6, but can be more acidic when lots of fresh water is pouring in from the rivers. Remember, most aquatic plants and animals require a pH between 5.0 and 9.3. We will use a LaMotte pH kit to test pH.

Station 3: Photic (Light) Zone and Current Speed

Purpose: To determine the depth that light penetrates into the water (the photic or light zone within which phytoplankton can grow) and to measure the speed of the surface and below-surface currents.

Equipment: Secchi disk attached to line marked with meters, current meter.

Background: Measuring the transparency of the water is a quick and easy process that brings together many important features of the estuarine system. Algae, microscopic animals, eroded soil and suspended sediments from the bottom all interfere with light penetration into the water. The distance sunlight penetrates into the water determines where photosynthesis is possible, and therefore how much food and oxygen are going to be present for animals that live there. Tidal, river, wind and currents keep the Great Bay Estuary well mixed and distribute food and nutrients throughout the system.

Procedure:

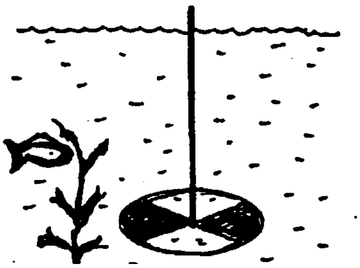
1. To determine the transparency of the water lower the secchi disk on the shady side of the boat until you can't see it.

2. Bring it up until it reappears. Lower it down a meter more and return it until it reappears again.

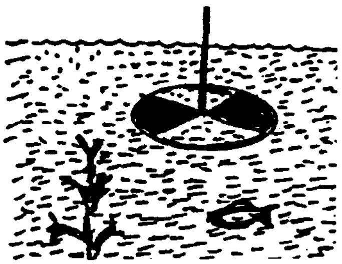
3. Keeping your eye on the point on the line at the surface bring the disk up and count the meters of line that were submerged.

4. Repeat again. Average your results.

Secchi Disk

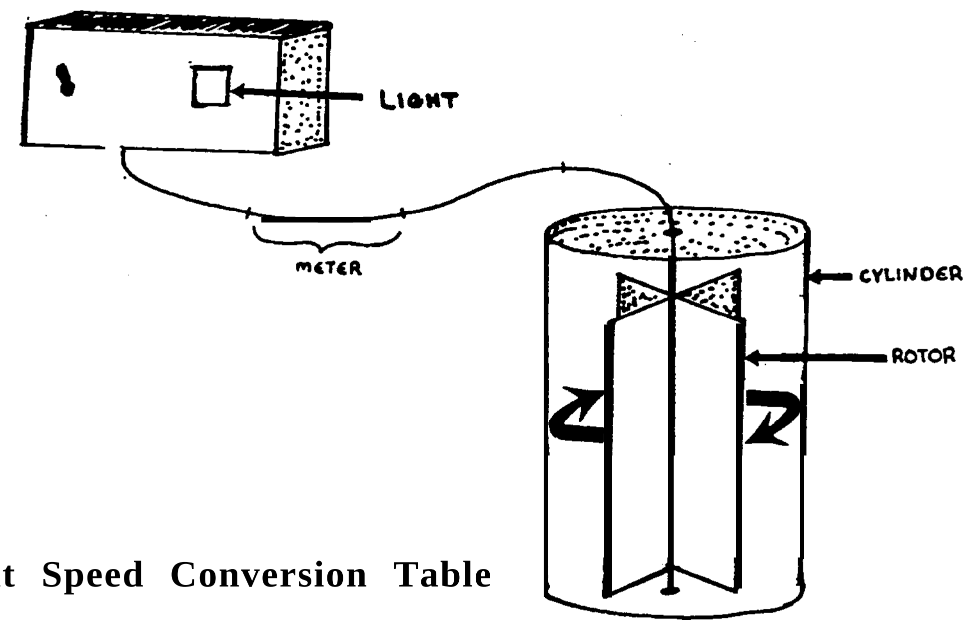


transparent water



turbid water

2. To measure current speed, lower the meter into the water until it is just below the surface. Count the number of times the red light on the water meter flashes in 15 seconds and multiply by four to get the number of flashes per minute. Use the conversion tables below to calculate the speed of the current in nautical miles (knots). Then measure the speed at a lower depth. Compare your measurements. Is the surface current faster than the current at a lower depth?



Current Speed Conversion Table

Number of Flashes/Minute	Knots*
0 - 99	1
100-199	2
200-299	3
300-400	4

*A knot is one nautical mile (6,076 feet -- a little longer than a land mile) per hour.

GREAT BAY ESTUARINE HABITATS: WATER

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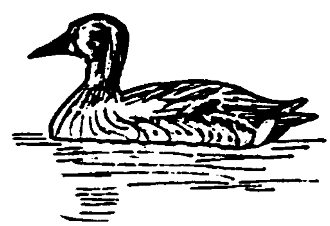
GREAT BAY ESTUARINE HABITATS: WATER

The animals that live in the protected waters of the Great Bay Estuarine System must adapt to many kinds of changes. Seasons bring changes in temperature, salinity, pH and water transparency to their habitat. Tides and currents cause other changes. Animals that live in the estuary must adapt to these changes.

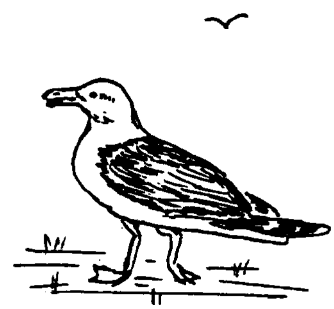
WATER BIRDS OF THE ESTUARY

The bays and river mouths of the estuary are like a quiet hotel with a good menu where you can eat as much as you want. Since the estuary is on the North Atlantic Flyway -- the path in the sky for birds who spend summers in the north and winters in the south -- it is a popular stopover.

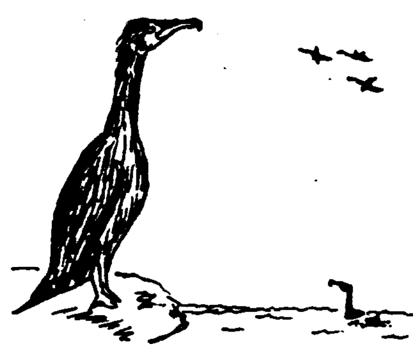
Black ducks, mallards, and blue and green-winged teal stop to rest and gain weight to sustain themselves for the rest of their journey.



From early spring to late fall, black, streamlined **double-crested cormorants** swim in the water, their un-oiled feathers allowing them to sink lower and lower until only their head and neck can be seen. They dive easily from this position, swimming underwater to capture small fish. Coming out of the water on some rocks, they stretch their long necks to swallow their food and spread their wings to dry. They digest their food fast and deposit droppings rich in nitrogen and phosphorus. These important nutrients are washed into the estuary by rain or tides. The cormorants nest on rocky islands all along the coast.



Grey-winged **herring gulls** and their larger cousins, the **great black-backed gulls**, fly overhead or swim in the bays, keeping a sharp eye out for fish and green crabs. Smaller terns “dive-bomb” into the water with a splash to snatch small fish in their sharp beaks. Terns nest on Nannie Island on the west side of Great Bay.



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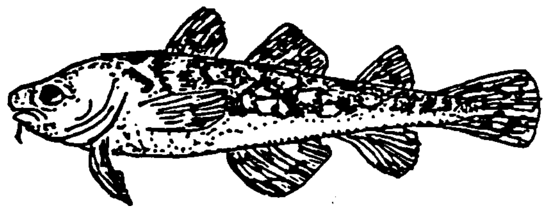
FISH OF THE ESTUARY

Of the more than 15,000 species of fish in the world's water systems, 52 have been identified as living here in the estuary. Some fish spend their whole lives in the estuary while others spend only a portion of their lives there.

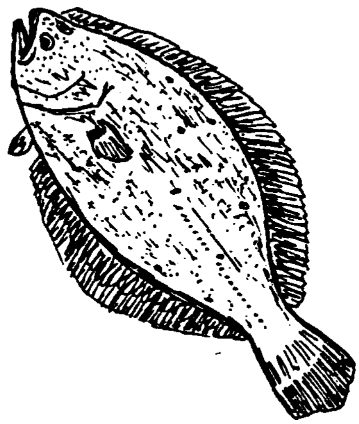
Permanent residents



The **tomcod** grows to about a foot long and looks just like a very small cod. They move along the bottom, eating shrimp, worms and other small animals. They seem to like cold water, because in the winter they move even further up into colder, fresher waters and spawn.

White perch look like small. striped bass and live in the mouths of rivers and streams. They travel in small schools and eat fish eggs and small animals on the bottom.

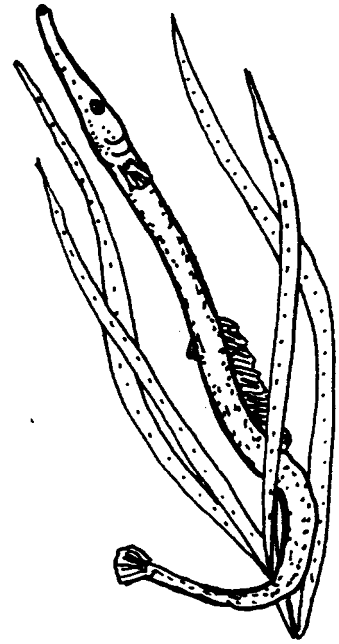
Flounders are flat fish that lie on the bottom, half buried in sediments, and wait until something good to eat swims by. Then they dart out and grab it. It helps that both of their eyes are on the same side of their head. There are several species of flounder in the estuary.



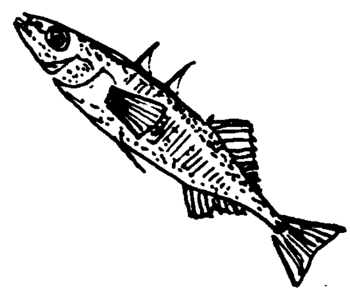
Summer flounder prefer less salty water and live near river mouths.

Winter flounder prefer constant temperatures, so they head for the deep ocean in the summer and winter when temperatures in the shallower estuary are more extreme. When **winter flounder** are young, they swim in the water like any other fish and their eyes are on opposite sides of their head. However, about six weeks after they hatch, the shape of their skull changes and one eye moves over to join the other eye on the same side of the head. They settle lower and lower in the water until they reach the bottom, where they will spend most of the rest of their lives.

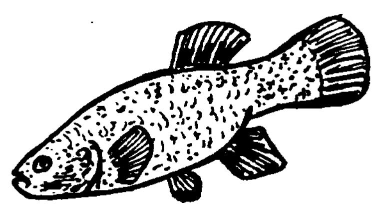
Hiding among the blades of eelgrass are long, very thin, silvery **pipefish.** They are 30 times as long as they are wide! Pipefish eat zooplankton and small crustaceans, and they don't seem to have many enemies. They breed in the spring and summer. Like her close relative the seahorse, the female pipefish puts her eggs into the brood pouch of the male and he takes care of the eggs until they hatch. The young pipefish mature in one year.



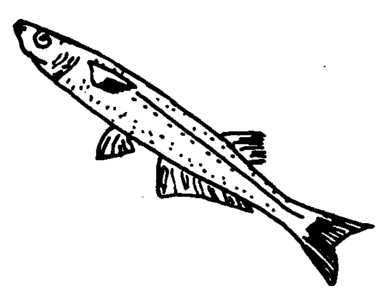
Sticklebacks live in creeks and streams in the marsh. We have several varieties in Great Bay, and they only grow to about three inches. They are omniverous, eating both small plants and animals. They breed in the spring. The male builds a nest out of mucus threads from his kidney. The female deposits her eggs and leaves the male to take care of them and to guard the small fish after they hatch.



Mummichogs are very tough little fish that can live in the most stressful areas of the estuary. In the wintertime, they bury themselves in the mud and sleep. The female lets her eggs float out into the water, where they are fertilized by the male. The eggs stick to the rocks and hatch about two weeks later. These fish are favorites of those who study embryology because their eggs are very easy to collect,



The **silversides** are small silvery fish who live throughout the estuary. They are often found in small creeks that cut through the salt marshes. They are the most numerous species in the estuary.



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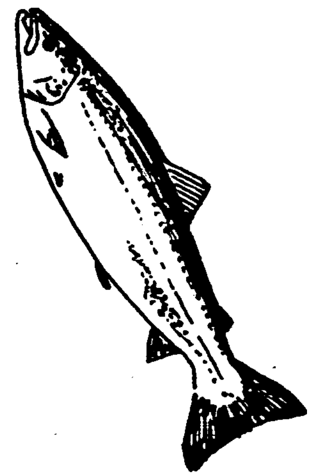
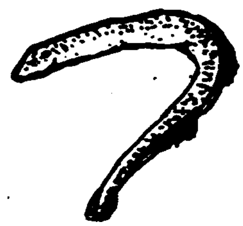
Part-time Residents

Some fish are only part-time dwellers in the estuary. The **Atlantic salmon, shad, rainbow smelt, sea sturgeon** and **alewifes** hatch in the freshwater rivers and streams of the estuary, then swim out to spend most of their lives in the ocean. When they become adults and are ready to spawn, they swim back to the same stream or river where they were born to lay their eggs. Some western salmon have also been introduced to the estuary and come back to spawn, but they die afterwards. About 10% of the Atlantic salmon survive and swim back to sea. Fish that hatch in fresh water, live most of their lives in salt water, and then return to freshwater to spawn are called **anadromous.**

Atlantic Salmon



The Lamprey River, which flows through Epping and Newmarket, was named after one of the most ancient fish in the ocean. **Lampreys,** another anadromous fish, lay eggs in horseshoe-shaped nests in the rivers and streams. They are long and thin and do not have jaws, but have a round mouth with five rows of teeth arranged in a circle. They attach themselves to any fish large enough to support them and then suck blood from the fish to feed themselves. They attach only to cold-blooded animals such as other fish. Humans and other warm-blooded animals need not fear them.



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Some fish live part of their lives in fresh water and part in salt water, but, unlike the anadromous fish, they hatch at sea and then swim back to the estuaries to grow up. The **American eel** is such a fish. You can find it swimming in Great and Little bays on its way to live in the mouths of rivers and streams.

Sometime between the age of five and 20 years, the American eel swims back out into the ocean. It stops feeding and its eyes grow larger. It swims for two or three months until it reaches the Sargasso Sea, a large area in the Atlantic Ocean off the coast of Florida. There, it breeds among the sargasso weeds. When the eggs hatch, the small “elvers” start swimming north, back to the rivers where their parents lived. It is a mystery how they find their way.

There is a another eel called the European eel that swims to the Sargasso Sea to breed, also. After the eggs hatch, the baby eels swim back to the rivers of their parents, in Europe.

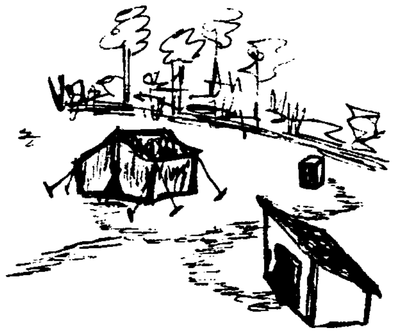
The American and European eels are very similar in anatomy, but there are enough differences to convince most scientists that they are two separate species.

Fish who spawn at sea but live most of their lives in rivers are called **catadromous.**

GOING FISHING

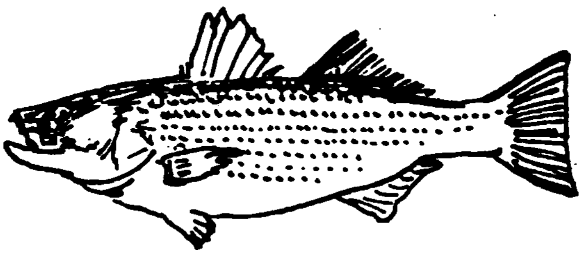
Many people catch fish in the estuary. Some go fishing just for fun. You can see people on the bridges over the rivers or in small boats, enjoying a day’s fishing. Others catch fish to sell.

In the winter, villages of small fishing shacks called “bob houses” appear on the ice in parts of the estuary. In Newmarket near the town dock there might be 40 to 50. People go into the shacks, cut holes in the ice and fish for the rainbow smelt that return to spawn in the rivers in January and February. On the Squamscott River, a family that has been fishing there for generations sets a net through holes in the ice and hauls in hundreds of smelt, which they sell. When the laws prohibiting this type of fishing were written this one family was allowed to continue to make their living in this way. They are also the only commercial smelt fishermen in the estuary. American eels and river herring are also caught commercially in the spring.



You need a license to catch some kinds of fish in the estuary. If you are going icefishing for smelt and white perch or plan to catch salmon, you need to get a license from the N.H. Fish and Game Department.

There are limits on the number of some fish that can be caught and how large each fish can be. For example striped bass, or "stripers" as people commonly call them must be thrown back unless they are 36 inches long. Why? Because once this popular fish had almost disappeared from the estuary because of overfishing. Now the N.H. Fish and Game Department wants to preserve enough adult fish to increase the number of stripers living there.

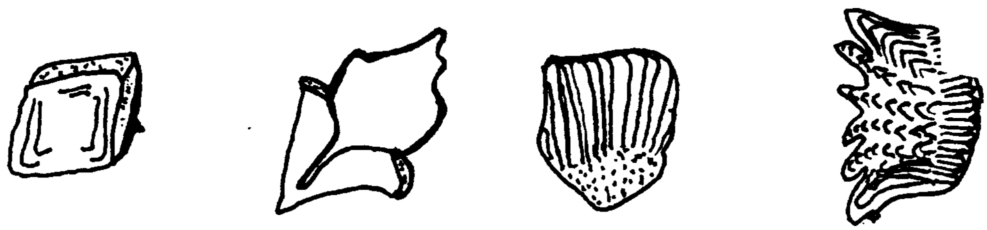


WHAT MAKES A FISH A FISH?

What makes a fish different from humans? Here are some differences. Can you think of others?

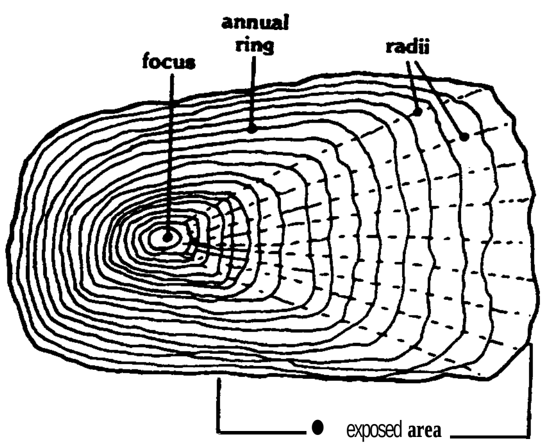
1. Fish live all their lives in water.

2. Fish have scales. Scales are outgrowths of skin and can be several shapes.



ganoid (sturgeon) | placoid (shark) | cycloid (mackerel) | ctenoid (flounder)

You can tell a fish's age by counting the rings on the scales, just like counting rings in a tree trunk.



Cycloid Scale

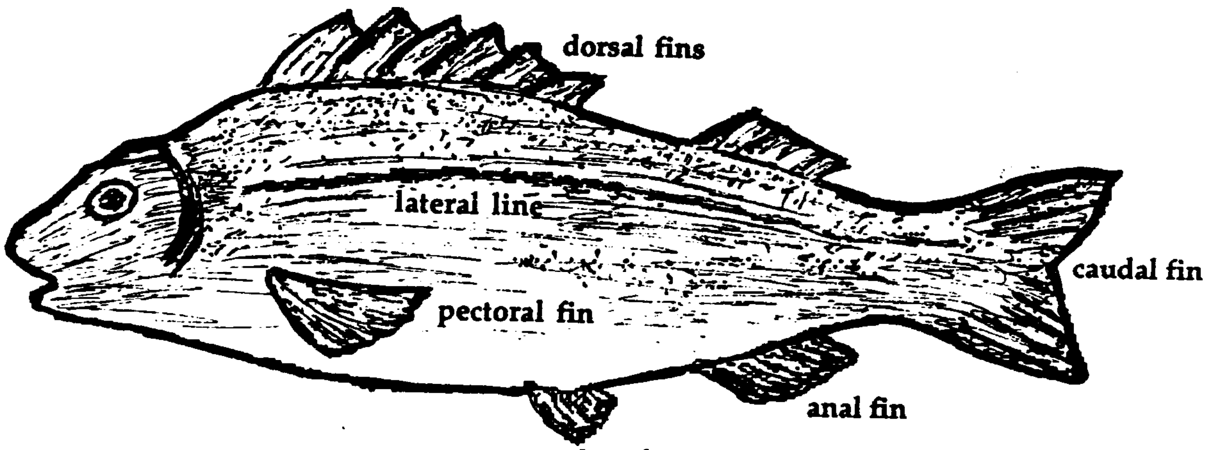
3. Fish have gills to take oxygen out of the water and to get rid of carbon dioxide.

4. Fish have fins especially designed for moving about in water.

More than 70% of the earth's surface is covered by water, so it is no wonder that there are so many fish species -- some 15,000 to 17,000 of them. By contrast, there are only about 4,500 species of mammals, the group to which we humans belong.

Fish were on the earth 400 million years before humans were. Perhaps that is why there are so many different kinds, shapes and sizes. Fish have had to adapt to a variety of conditions. They can live three miles above sea level in mountain streams or as deep as seven miles below the sea's surface. They can live in freezing water or hot springs. They can live in fresh or salt water. They range in length from a fraction of an inch to over 50 feet.

External Anatomy of a Bony Fish

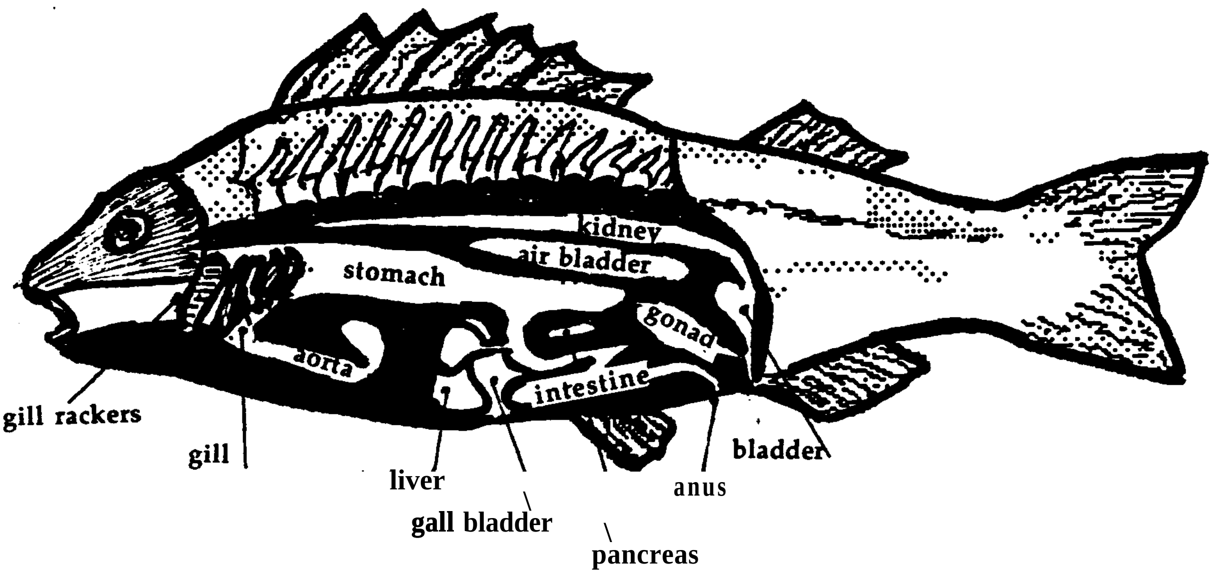


Fins help fish move in the water. The **tail** pushes the fish through the water, while the pelvic fins keep it upright. The **dorsal** and **anal** fins also help in keeping the fish from rolling. These fins are all single (not paired). There are two **pectoral** fins, one on each side of the body in exactly the same location. We say these are "paired fins." A fish can stop or turn by extending these fins. The pelvic fins are also paired, and they help the fish remain horizontal in the water. The spines or rays in the fins keep them upright when the fish needs them, and fold them neatly against its body when the fish needs to move fast.

Fish are covered with scales, which grow from pockets in their skin. Fish feel slick when you touch them because they are covered by a thin mucous that protects them from disease and helps them slip through the water more easily. It also makes them slippery and hard to catch, and sometimes the mucous tastes bad to other species.

A fish's color is due to a combination of cells that have pigment (color) and cells that reflect light. These cells can contract or expand to change the fish's color. Many fish are dark on top, which helps them appear to be the same color as the water when a predator flies overhead. They are also often light colored on the underside of their body so that they look like part of the sky to predators looking up.

Internal Anatomy of a Bony Fish



Do fish have to swim all the time to keep from sinking? No, most fish have a swim bladder, which is a gas-filled sack that they can inflate or deflate so that they can maintain **neutral buoyancy** in the water. This means that they can "hang" in the water without sinking or rising to the surface. Some fish such as the little sand sharks that sometimes venture into the mouth of the estuary do not have swim bladders, but have large livers that give them some buoyancy.

Fish breath by taking water into their mouths. When they close their mouth, the water is "squished out through the gills" where there are tiny blood vessels ready to absorb the dissolved oxygen in the water. (Remember that oxygen in the water comes from photosynthesis by plants and from the interface between water and the atmosphere.) About 80% of the oxygen in the water that passes over the gills is taken into the fish's bloodstream in this way.

Fish have different ways of reproducing. Most females lay thousands of eggs, which are fertilized by males releasing their sperm into the water around the eggs. The eggs usually have a yolk that the fish larva feed on until they are strong enough to burst out of the egg and start swimming. Both the eggs and the larvae are often food for other species -- even for other fish. Fish produce many eggs at one time to be sure that a few will survive to become adults.

CLASSROOM ACTIVITIES -- WATER HABITAT

A. Gyotaku (Japanese Fish Printing)

Purpose: To learn the process of fish printing and what it can reveal about external fish structure.

Materials: Fresh fish that are fairly flat (flounder are excellent), paper (newspaper, watercolor paper, newsprint or rice paper), ink tempera or water-base ink (linoleum block ink is best), and a stiff l/2-inch brush.

Background: This is an ancient art that is now used to record catches of sportsfish and to document information about fish biology. Fish prints often show details of the fish's external structure that are not apparant when looking at the fish itself. Before making the print, identify the fish, list its characteristics, research its natural history, and learn when, where and how it was caught.

Procedure:

1. Obtain a whole fresh fish. If the fish has been gutted, stuff it with paper to approximate the correct shape.

2. Wash the fish with soap and water. Dry it thoroughly.

3. Place the fish on newspaper on a piece of heavy cardboard on a wooden board. Arrange fins properly. You may want to pin them in a spread-out position.

4. Brush on a light, even coat of diluted tempera paint or water-base printer's ink.

5. Place paper over the fish and press lightly with your hands all over the body and fins, noticing scales, body structures, body shape, etc.

6. Lift the paper and study the print. (A small brush may be used to paint in the eye).

7. Notice the shape and location of the eyes, gills, scales, fins and lateral line.

8. Do a print of another fish and compare the two.

9. Label your print with both the popular and the scientific names of the species, and with your name and the date.

B. Design a Fish

Purpose: To have the students apply what they have learned about fish by inventing species that will meet certain qualifications.

Materials: Modeling clay, paper mache, wire, string, yarn, balloons, construction paper, and other scroungeable items.

Procedure:

1. Have the students invent a fish, picking one of the following descriptions as a guide. The student must detail the inner and outer anatomy of the fish, what it eats and how it gets its food, how it moves about, how it reproduces, and what predators it has.

*Invent a fish adapted for living on the bottom in sand or mud. It should be able to hide by burrowing under the sand or mud surface.

*Invent a fish whose appearance is so gruesome that other fish would be frightened to approach it. The fish must be grotesque, yet able to swim and live on the ocean bottom.

*Invent a fish that would live between rocks or on a reef. The fish would eat whatever it could catch and would need to be able to move around rock crevices.

*Invent a fish that lives in very deep water and must withstand great pressures. This fish would also eat other fish and would not have light enough to see by in its environment.

2. Have the students give their fish a scientific and common name, display their fish and describe its habits to the rest of the class.

3. Have students try to find examples of their fish using references. Then, they can do a comparison between their fish and the one that looks the most like it.

C. Fun With a Mummichog (Adapted from The Floating; Lab Resource Manual .)

Purpose: To investigate several adaptive features of mummichogs by designing experiments based on the following suggestions.

Materials: Aquarium with estuarine water and mummichogs, thermometer, DO kit, fish food, maze and hoop materials, etc.

Background: Mummichogs are found in nearly all salt marshes, tidal creeks and shallow pools. These hardy fish burrow six to eight inches under the mud to survive the drying out of shallow pools in summer and the cold of winter.

The dorsal (upper) surface of the males is dark green to steel blue with yellow and white spots. The ventral (lower) surface is white, pale yellow or orange. Females are olive green with a lighter ventral surface.

Mummichogs may be caught easily with a hand net in tidal pools of local salt marshes and placed in a saltwater aquarium filled with estuarine water. The pH should be between 7.0 and 7.4; the temperature between 18° and 20°C. Mummichogs are omniverous, and may be fed brine shrimp, boiled lettuce and regular fish food.

Procedure: (Make all changes gradually over a period of several days to avoid stressing the fish.)

1. Find the range of temperatures mummichogs can tolerate by placing them in tanks of different water temperatures. Is there a temperature at which the fish will not eat? What happens. when the temperature is lowered?

2. Can mummichogs adapt from living in salt water to fresh water? Record the speed at which the adaptation takes place.

3. Can mummichogs change colors to match their surroundings? Why are males different in coloration than the females?

4. What is the mummichog's range of tolerance to different levels of dissolved oxygen in the water?

5. Can a mummichog be conditioned to swim through hoops or a maze, or come to the side of the aquarium to be fed?

6. Do mummichogs school and, if so, do they have a special order?

C. Guppy Observation

Purpose: To observe fish behavior under various conditions that they might encounter in an estuary.

Background: Fish are cold-blooded animals with gills and fins. Guppies have been selected for this experiment because they are easily obtainable from pet stores, easy to keep alive in a classroom aquarium and very interesting.

Materials: Guppies, aquarium, tetramine fish flakes, microscope, slides, cover slips.

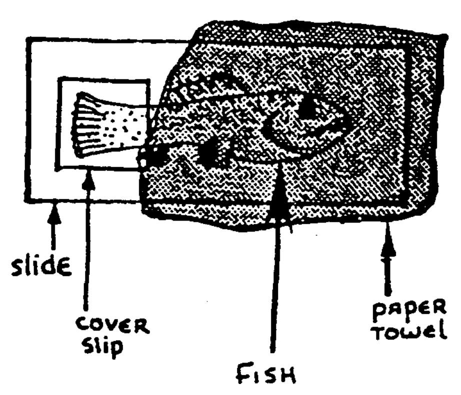
Procedure:

1. Observe the feeding behavior of a particular fish. Does it gulp its food or skim it? Is it a surface, bottom or mid-water column feeder? How long does it take to satisfy its appetite?

2. Put the fish in a smaller container of water and change various aspects of the environment: temperature, salinity, food amounts, light, addition of oil, etc. Observe the reaction of guppies to these changes and record them on the chart below. The gill structures are indicators of stress. Fast pumping indicates distress and high metabolic rate. **Be careful not to overstress the fish.**

3. Using a glass slide, lay a live guppy on the slide. Cover with a damp towel to keep it moist. Put a glass cover slip over its tail. Transfer the slide to a microscope and observe the movement of blood in the tail capillaries. Does it flow steadily or in spurts? (Return the fish to the aquarium as soon as possible.)

STIMULUS	RESPONSE
Temperature	
Salinity	
Food	
Oil	
Light	



GREAT BAY ESTUARINE HABITATS: MUDFLATS

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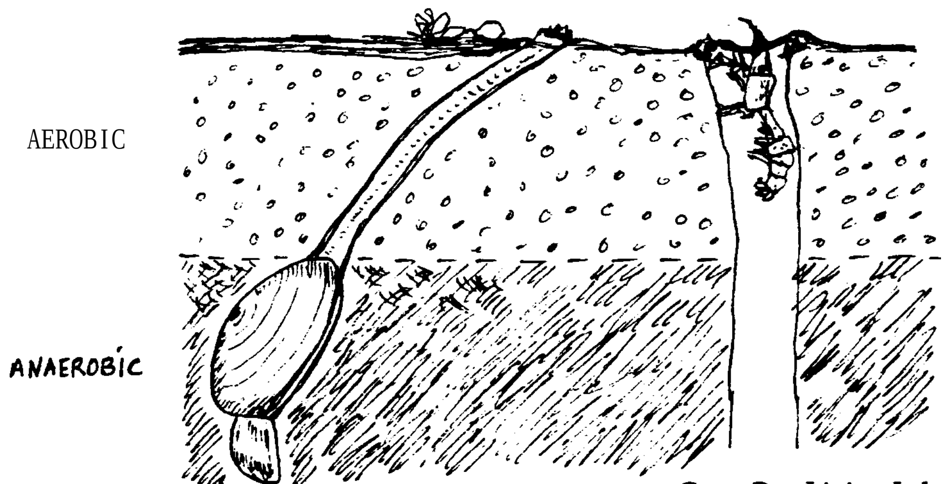
GREAT BAY ESTUARINE HABITATS: MUDFLATS

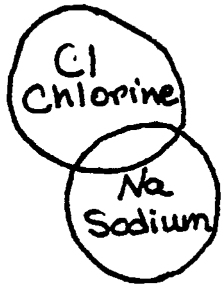
As the tide lowers, one-half of Great Bay becomes a mudflat. In Adams Cove, next to Jackson Estuarine Laboratory, **all** the water moves out, leaving a surface of thick mud covered with micro-organisms. Clumps of diatoms, tiny microscopic plants with hard glass-like bodies in many different shapes, turn the surface of the mud a glistening chocolatey gray. Green macro-algae, seaweeds that can be seen with the naked eye, add bright green color. The long pieces of **hollow weed** and the flat, green fronds of **sea lettuce** are easy to spot. There are small fuzzy-looking bits of **sea hair** here and there, also. These green algae show the presence of nitrogen, a chief nutrient for plants in the estuary. If there are lots of green algae, it may be a warning that there are too many nutrients in the system. There may be some untreated sewage coming into the estuary.

Mudflats occur in small coves and in the other protected waters of Great Bay, where fine particles of clay or mud (.07 mm. in diameter or less) are carried by swift moving water and dumped when the water slows down. Water rushes down the narrower rivers and then slows as it fans out into the calmer waters of Great Bay dropping its load of mud particles. Because these sediments are so tiny, they stick tightly together and the spaces between the particles become very small. Water, which carries oxygen, can't move easily through the sediments. Because of this oxygen is found mainly on the mudflat surface and penetrates only a few centimeters below. This is called the aerobic layer. Beneath it, where there is no oxygen, is the anaerobic portion of the mudflat. It is a dark, almost black color and smells like rotten eggs. Bacteria that use sulfur instead of oxygen are also present and they give off hydrogen sulfide which creates the bad smell.



Animals living on the surface take oxygen from the water using their gills. Those that burrow into the mud extend their gills into the water for oxygen or take oxygen with them into their burrows.

But there are other factors that make the mudflat a tough place to live. Imagine the hot sun beating down, heating up the mudflat and making surface water much hotter. Salinity gets higher and higher until it might reach 50 or 60 o/oo. The next day it might rain at low tide, flooding the mudflat with fresh water and lowering the salinity far below the usual 23-28 parts of salt per thousand parts of water



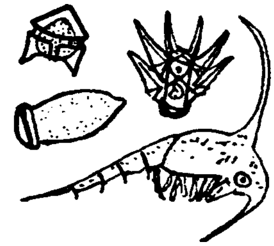
Temperatures change quickly during the day vary greatly and from season to season. During the winter in shallow areas of Great Bay temperatures may get down as low as -7.8°. When ice forms, it is broken by the rising and falling of the tide, scraping all the animals and plants off the surface of the flat. However, by the end of the summer more living things have colonized the flat.

Think about,

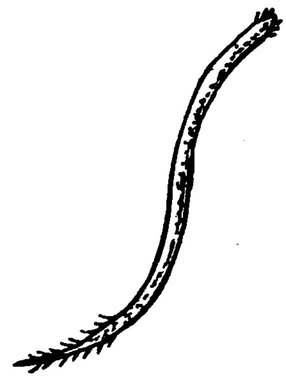
What kind of plants and animals can stand these stresses?
Do any animals live in the mudflats at all?
Do they all live on the surface where there is oxygen?
If so, how do they keep from drying out?
How do they stand big changes in temperature and salinity?
What happens when the ice moves out in the spring?
How can anything live in the anaerobic layer?

Even with all the stresses of low oxygen, ice, temperature and salinity changes, and exposure, the mudflat is a remarkably productive place. Although there aren't many different species of plants and animals, there are many of each species. We say that there isn't as much diversity as in other habitats, but that the abundance is great. Therefore, the biomass or the total amount of living things is comparable to that of the salt marsh.

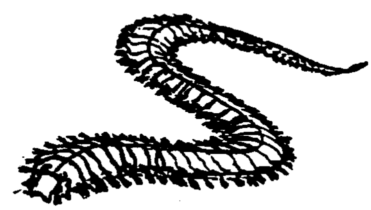
The shallow water that covers the mudflats at high tide allows enough light to support photosynthesis by the diatoms and microalgae that live there. Mudsnails, zooplankton and one-celled protozoa graze on these small plants, like cows in a grassy pasture.



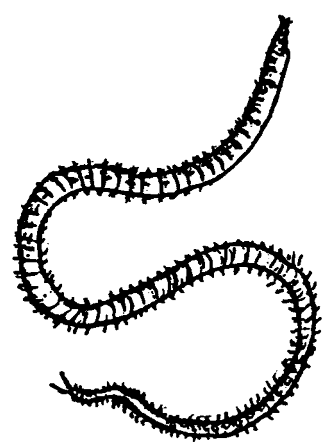
Animals that are a bit larger, but still less than two millimeters long, find it hard to live in the mudflat. But a small worm called a nematode finds it a wonderful place. There can be as many as 2,000 nematodes on one cubic inch of mudflat. These little worms are great hunters, pushing aside particles of mud as they go and quickly gobble up smaller animals.



Many animals burrow into the mud, including a variety of polychaete worms. The clam worm with its beautiful irridescent, jointed body burrows through the mud, looking for the chance to thrust out its sharp jaws to catch a small animal. Many people blame the clam worm for eating clams, but it really doesn't. It merely lives in the same habitat.

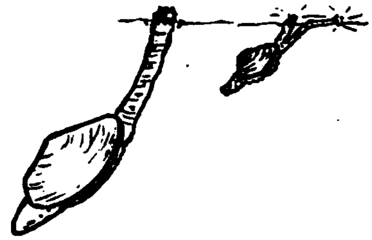


Other worms build tubes deep into the anaerobic mud and stay there, sticking out their gill structures into the water above to breathe. The bloodworm is one of these burrowers. It has a mouth with four jaws (a proboscis) that it can push out the head end of its body very quickly to catch its food. When the bloodworm needs to burrow into the mud, it pushes its proboscis into the mud and then rotates its body into the mud. It is called a blood worm because instead of having blood vessels, its skin is filled with red blood. It can grow to 12 inches in length, and it is harvested in the mudflats all along the Gulf of Maine and sold as bait.

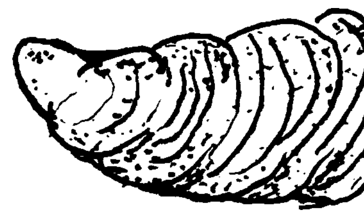


not to scale

Some animals that have hard shells can burrow into the mud. For example, soft-shell clams are successful mudflat dwellers. They stick their tubes out of the mud and suck, in water from which they filter out small organisms and bits of detritus. They are called “filter feeders.” There is also a very small clam found in the mudflats of Great and Little bays. It is about two centimeters long and makes a star-shaped set of lines around the tiny holes its filters make in the mud.



The American oyster grows in the mudflats and filters food from the water. It can live far up in the estuary in waters where the salinity is as low as 12 **o/oo.** There are several large oyster beds in Great and Little bays, and at the mouths of most of the rivers.



The blue mussel often grows in clumps over the lower parts of the mudflats, attaching itself to anything that is hard. They shoot out many small strings called “byssal threads” that glue them to rocks, other shells and even each other.

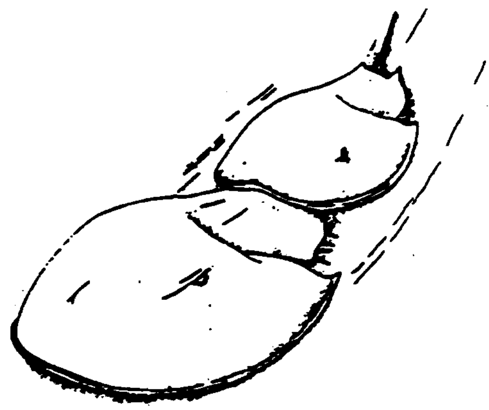
Striding along on its long legs, the great blue heron wriggles its toes in the mud to dislodge small animals that it then snags with its long sharp beak. Sometimes the heron wades in the nearby water, pausing occasionally to spear a fish, toss it in the air, and neatly catch and swallow it. Herons build nests that are about three feet wide. Sometimes they build as many as a dozen in a single tree. The droppings from these birds actually kill the tree after a few years. The colonies are always near water, where the herons get most of their food. They lay a clutch of four pale green eggs in the spring and by mid-summer the chicks are as big as their parents.

not to scale

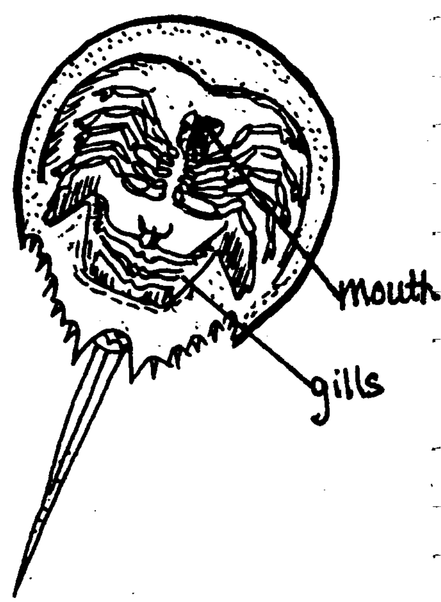
HORSESHOE CRAB -- A "BLUEBLOOD" FROM ANCIENT TIMES

The **horseshoe crab** is a survivor. It was on earth about 200 MILLION years ago, long before the dinosaurs and a very long time before human beings developed.

The horseshoe crab burrows deep into the mud in the winter and returns to the shore on the high spring tides in May and June. At that time, it lays its eggs among the rocks and mud at the highest tide mark.

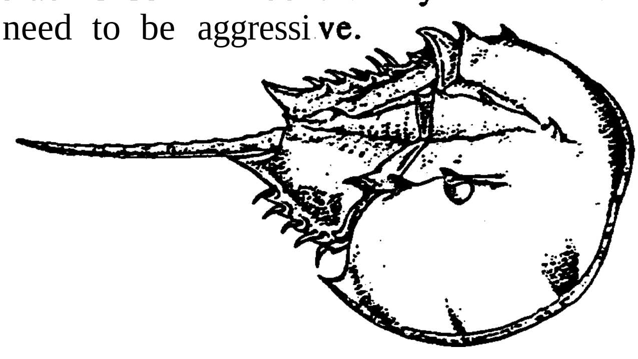


In June, you will often see a horseshoe crab "choo-choo" train, with a large crab dragging several other smaller crabs behind. The large crab is the female and she digs holes in the mud, depositing her eggs as she moves along. The male hangs onto the female with his "boxing glove" claspers and is dragged over the eggs as they are being laid. He releases a cloud of sperm and the eggs are fertilized.



The eggs are about the size of the head of a straight pin and slightly greenish in color. It takes them 28 days to develop into tiny, tail-less copies of their parents. They swim in the water column as a part of the plankton for a few days before they settle down to the mud, where they will live the rest of their lives. It is very interesting to collect the fertilized eggs, keep them in an aquarium filled with estuarine water, and to watch them develop.

The horseshoe crab is harmless, but people are often afraid they'll be attacked and speared by its sharp tail. Not true! The tail is used only to turn itself over if it gets flipped upside down. The **horseshoe crab is so well covered by its hard shell** it doesn't need to be aggressive.



The horseshoe crab has two compound eyes that see multiple images, like a kaleidoscop. It has several other pairs of eyes that see only light and shadow.

Its gills are located on the underside of the body and look like the pages of a book. They move back and forth to help the animal swim as it moves upside down through the water.

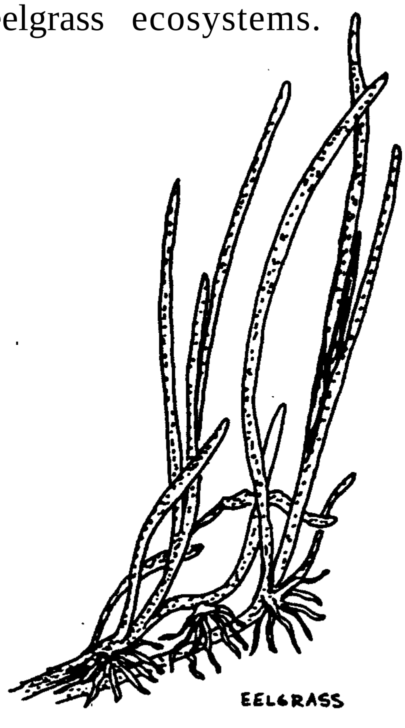
The horseshoe crab eats almost anything in path: dead or alive. It pushes food into its mouth with a pair of short, stubby legs. The other five pairs of legs are used for walking. The last pair have flaps that open up and help push the animal through the sand and sticky mud. The mouth is covered with flexible spines that rub together to break up the small crustaceans and scavenged materials that the crab eats.

People have always found uses for the horseshoe crab, grinding it up for fertilizer to using its shell for a scoop. Nowadays, scientists who study cells like to study the very large cells of this animal. Its blood is used to test drugs and fluids that must be injected into the human body to be sure they are free from contamination by bacteria or viruses. Lysate, an extract from their blood, is used in cancer research and as an indicator of spinal meningitis. There is a company in Falmouth, Massachusetts that collects horseshoe crab blood and sells it to the medical industry. A small quantity of blood is taken from the living horseshoe crab from time to time, while the crab is kept in the laboratory. Then local fishermen release the horseshoe crabs in the marshes.

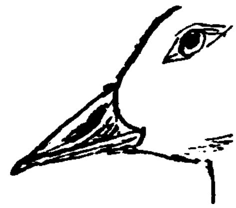
EELGRASS AND THE WASTING DISEASE

Eelgrass grows on the mudflats that are covered by water all or almost all of the time. It is not a seaweed or an algae, but a true grass that has migrated from the land over millions of years to live in salty water. Its roots are long and new plants can sprout from them. Eelgrass also has blossoms, and in July and August hundreds of seeds rain down upon the surrounding mudflats to produce new plants.

Picture a beautiful green underwater garden with leaves of grass that can be over a yard long floating and waving in the current. Algae and some animals live on the blades of grass, while others live among the roots. As sediment moves down the rivers into the the estuary, it is caught amongst the eelgrass, slowly building up the eelgrass beds and keeping the channels clear. Nutrients are washed in too, from rivers and the sea, and the eelgrass takes them up and uses them in photosynthesis. Then, as the eelgrass dies back, decays and becomes part of the detritus, the nutrients are returned to the estuarine system. If too many nutrients come in, algaes can grow to the point that they shade and destroy the eelgrass ecosystems.



Flounder, tomcod and pipefish use the thick eelgrass beds as a home and a nursery. Young crabs, lobsters and scallops also find a home in the eelgrass. It is a perfect place to hide from predators.



Canadian geese, brant (a kind of goose) and ducks eat the leaves and seeds of the eelgrass. Brant depend on it as a major part of their diet. In the 193Os, most of the eelgrass beds in the North Atlantic died from a disease known as the "wasting disease." Many ducks and geese died as a result, and the American brant nearly became extinct.

The eelgrass "die-off" had other negative effects that could be seen in Great Bay. Animals that used the eelgrass for a home suffered from its loss. Erosion increased because there was less grass to slow down the movement of the sediments. River channels in the bays silted up and the waters of the estuary became filled with sediment. Finally, though, the eelgrass began to recover from the "wasting disease" and by the 1960s many of the beds were back.

Today, there is a new outbreak of the "wasting" disease on both sides of the Atlantic. You can see large black stripes and patches on the leaves of the eelgrass, indicating that decay has set in. This new decline was first noticed in 1984 and it is spreading. Aerial photographs show great patches where the grass has already died.

Dr. Fred Short, a researcher at Jackson Estuarine Laboratory, has discovered that a slime mold is responsible for the present outbreak. He has found that the plants growing where the salinity is highest are the most likely to get the disease, while those growing further up in the estuaries seem to resist the infection more. Unfortunately, it is these high salinity areas at the mouths of the rivers that are also affected by pollution from fertilizing, septic systems and other human activities. So the eelgrass faces a double threat: pollution and disease. Dr. Short and his colleagues are trying to find an eelgrass variety that is resistant to the mold. Then he plans to reseed diseased areas. Imagine growing grass underwater! At least you wouldn't have to mow it!

CLASSROOM ACTIVITIES -- MUDFLAT

A. Make a Mucketarium (Some of this can be done on the Great Bay Living Lab Day, or you can obtain estuarine mud ahead of time.)

Purpose: To build a "microbial city" so that students can observe bacteria of different kinds at work under aerobic and anaerobic conditions.

Background: Micro-organisms such as bacteria and smaller viruses are the most important decay agents in the estuary. It is thought that micro-organisms can only be seen through a microscope. But the great microbiologist Sergei Winogradsky taught his students to build a microcosm of muds and sediments in a clear cylinder.

Materials:

4 large plastic soda bottles, with the tops cut off
Mudflat or salt marsh mud
estuarine water
sulfur source (hardboiled egg yolk -1 per container)
carbon dioxide source (shredded newspaper)
clear plastic wrap
rubber band
light source
bucket

Method:

1. Mix the mud with enough water to make it thick like whipped cream.

2. Pick out any sticks, rocks or leaves.

3. Add the eggs and shredded newspaper.

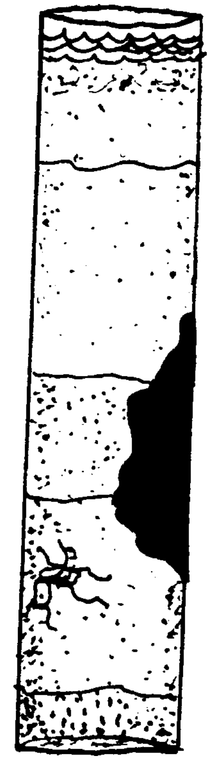
4. Pour the soil into the container slowly, hitting the base of the container against something hard every so often.

5. Cover the container with clear plastic wrap and put a rubber band around it.

6. Place it so that a lamp can shine directly on it

7. Make sure that a layer of estuarine water covers the soil at all times. Watch for layers of different colors to develop.

First, an oxygen gradient will develop. The lower levels of the mucketarium will have progressively less oxygen.



The green layer at the top is made up of algaes that produce oxygen. In the history of the earth's development, this layer occurred rather late in the process.

Notice the rotten egg smell. It is hydrogen sulfide being released by the bacteria in the reddish-purple band that is developing under the green band. A sulfur gradient is developing there. Its sulfur concentration is higher in the bottom and lower at the top.

As the oxygen and sulphur levels change, so do the colored bands. Watch them. You may also see some white bacteria start forming and growing, utilizing the methane given off by the sulfur-using bacteria.

Take a picture of the layers each week as they begin to reveal themselves. Date the pictures and post them near the mucketarium.

After several weeks have elapsed, you may want to look at some of the bacteria with a microscope. Wearing protective gloves and glasses, pierce the side of the mucketarium where the bacteria you wish to examine is located. (If you want to keep your mucketarium intact, you can put a probe inside to remove a sample.) Remove a small amount and make a slide.

To dispose of the mucketarium, dump the contents into a shallow pan and let them dry out in the sun for several days. This will kill most bacteria and viruses. Then place the remains in a paper bag along with the plastic container and put the bag in the garbage.

GREAT BAY LIVING LAB DAY ACTIVITIES - MUDFLATS

A. Mudflat Meander

Purpose: To examine the mudflat, an environment that is seldom seen

Equipment: thermometers, screens and pans, buckets of water, paper towels, a bucket of washing water, clipboards, mucketarium supplies.

Procedure:
After a walk along the rocky shore and a visit to the slate and basaltic rock formations from which the rocks on the shore come, students will be invited to look at the mudflat to:

1. Look for evidence of microbial action: glistening mud, bubbles.

2. Find the aerobic and anaerobic layers.

3. Determine what animals live in each layer, using several methods:

   Looking at a square meter of mudfIat and list what is seen: both the blue and ribbed mussels, periwinkles, mudsnails, green crabs, amphipods.

   Screening a trowel of mud from each of four quadrats to find snails, worms, etc.

   Looking at mini-pools in the mud for a set period of time waiting for worms to emerge. Use a magnifying glass to look at the proboscis (mouth parts) of the worms. You may see blood worms, clam worms, and many others. Ask why worms are important in the food web.

4. Come together as a whole group for five minutes to tell what was seen in the anaerobic and aerobic layers.

GREAT BAY ESTUARINE HABITATS: SALT MARSHES

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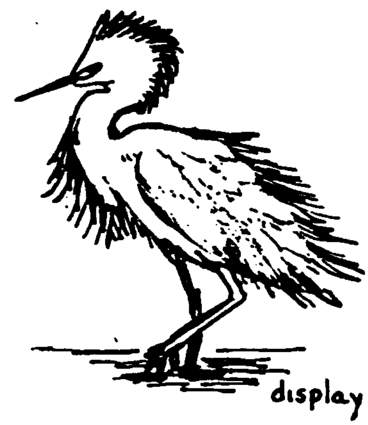
NURSERY OF THE SEA



A sea of salt marsh grasses sways along the shores of Great Bay. Hidden among those grasses are animals and other plants, including some of the seaweeds that grow on the rocky shores. A **snowy egret** wades at the edges of the marsh, darting around on its yellow feet chasing down small fish and crabs. Then, flapping broad white wings the egret flies into the air, tucking its neck against its body in an s-shaped curve just like the heron does.

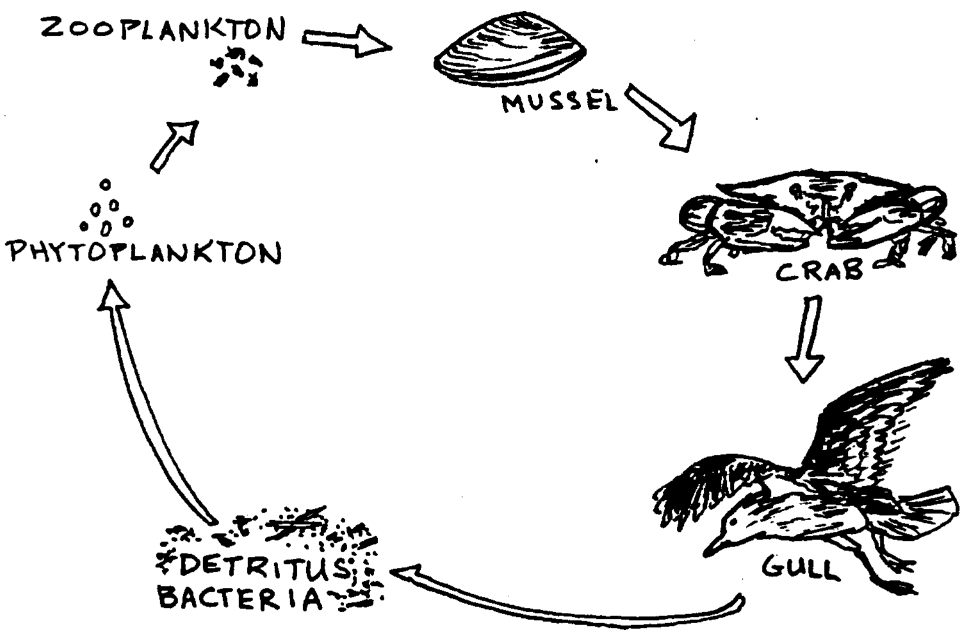
Formation Salt marshes formed after the glacial periods all along the shallow coastal plains on the East Coast in shallow, quiet waters behind barrier beaches or raised shorelines. Sediments piled up there until some sections were above the water level. Grass seeds borne by migrating birds took root in the mud. Over many years, the mud and roots became compressed into marsh **peat**, which can be 18-25 feet thick. The marsh grasses grew, combining nutrients from rivers and ocean with carbon dioxide and sunlight to provide energy for the estuarine system.

Detritus The grasses and other plants and animals that live in salty water form a community. The plants are the **producers** and the animals are the **consumers**. The viruses, bacteria and fungi form the third group in this **food web**. They are called **decomposers** because they break down the dead plants and animal remains into their original elements. These elements help provides a rich and nutritious “soup” of nutrients, such as carbon, phosphates and nitrates, called **detritus**.

Who eats detritus? **Detritovores**, of course! Many of the animals in the estuary depend upon detritus for their food: some zooplankton, filterfeeders such as oysters and clams, and some birds. The tides carry detritus throughout the estuary and into the sea, where coastal animals can feed on this wonderful soup.

<u>The salt marsh food web</u> The food web is made up of many different food chains. All of them depend on the sun's energy, which is used in photosynthesis by phytoplankton. These microscopic plants are the basic building blocks of the food chain. Phytoplankton are eaten by plant-eating animals, which are called **herbivores.** Some of the herbivores are eaten by the **carnivores** (meat-eating animals). There are also animals such as humans, that eat both plants and other animals. They are called **omnivores**.

Food chains often connect to each other, making the food web even more complicated. Some food chains are very long, with many plants and animals involved. An example of a salt marsh food chain is: Ribbed mussels filter both phytoplankton and zooplankton from estuarine waters that they draw through their bodies with their siphons. A green crab selects a small mussel, pries open its shell and eats the juicy meat. Flying overhead a gull spots the green crab and swoops down to grab it for dinner. The droppings from the gull fall into the estuary, are broken down by the decomposers. Plankton use the resulting nutrients as a part of their food, and the cycle begins again.



Factors that affect the marsh Tides wash across the marshes of the Great Bay Estuary twice a day, bringing in salty water and nutrients. The spring run-off and the fall rains dilute the water somewhat, and the plants and animals of the marsh must adjust to changes in salinity. The tall **cordgrass** that grows at the waters edge must have saline water covering its roots or it will die. Other grasses, such as **salt marsh hay,** can't have their roots in salt water for an extended period or they will perish. It is possible to look out over a marsh and determine exactly where the high tide reaches by identifying where these two grasses grow.

Climate is important. In Great Bay, the growing season is so short that only one crop of grasses can develop. In more southerly regions, summers are long enough for two or three crops to grow.

The type of soil in the marsh is also important. The soil in the marshes bordering the Squamscott River is of a type called **sulfihemist.** This soil holds water like a sponge and contains high amounts of organic materials that it releases slowly into the water, providing nutrients for the grasses and organisms in the water.

AN IMAGINARY WALK THROUGH THE MARSH

Marshes are very fragile and should not be walked through in the spring and summer. The grasses are still growing during those seasons and every footprint will mash dozens of grass stalks, ending their growth for the year. Then in the fall, after the frosts, there will be less grass for the decomposers to turn into food for the estuary. But we can take an imaginary walk at any season.

We will begin where a fringe of trees and plants such as **red cedar, bayberry, seaside goldenrod** and **seaside rose**, is growing. These plants receive salt spray and they must protect themselves from drying out. Seaside goldenrod has hairy leaves to prevent water loss. Bayberry leaves are waxy and sort of rubbery for the same reason.

White-tailed deer live in the woods, but they come out in the evenings to nibble at the salt marsh hay. **Rabbits** and **raccoons** are common marsh residents as are smaller animals like **mice** and **voles**, which live in the upland areas.

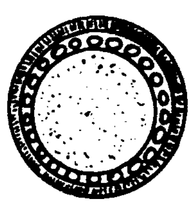
In the **high marsh**, where salt water reaches only during the highest spring tides and during storms, you can see a line of **black grass** and **bulrushes**.

Walk carefully into the marsh a bit and you will see **salt marsh hay** and **spike grass**. The salt marsh hay is the main plant in the **high marsh**. Its roots are covered by salt water at the highest tides each month, but only for a very short time. If you look at the marshes in Great Bay in September, you will notice that the hay is flattened into soft-looking swirls or “cowlicks.” Colonial farmers gathered this hay to feed their cattle.

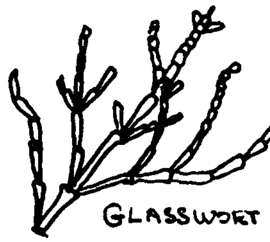
See the shallow pools of water among the grasses? They are called **salt pannes** and were scoured out by ice in the winter. They may only a few inches or several feet deep. Salinity in the pannes may be very high due to evaporation or quite low if there has been a recent rain.

Notice the floating mats of blue-green algae and purple sulfur bacteria. Bubbles often appear, indicating that hydrogen sulfide and other gasses are being released in the processes of photosynthesis and respiration. Look closely and sometimes you can see the whitish, cottony-looking bacteria that use methane for energy.

The next zone is the **low marsh,** and you will notice that the tall **cord grass** marks it very definitely. These grasses have roots that send out side shoots called rhizomes, which form a very strong root system. The rhizomes make the plant a perennial, as they go on living even after the part above the mud dies back in the fall. Look at the leaves of the cord grass. Some of them may be curling to decrease the loss of moisture to the. air. Do you see the little flecks of salt on the leaves? This plant uses salt from the water to maintain the internal pressure it needs to stand up in the wind and waves, but it can get rid of any excess salt through its leaves and roots. Cut across the stem of a piece of cordgrass and use a magnifying glass to see the ring of tubes surrounding a larger tube. These help to move oxygen from the small openings in the leaves, called **stomata,** to the roots below.

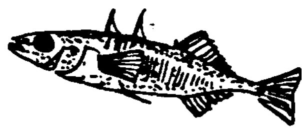


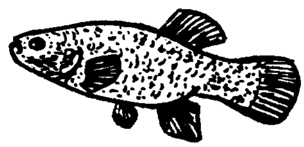
Many plants in the marsh are **succulent** and it can store lots of water within their stems and leaves. **Glasswort** and **seablite** are examples. Glasswort was made into pickles by the colonists and used as a part of their winter diet. It turns bright red in August. Taste it, if you like.

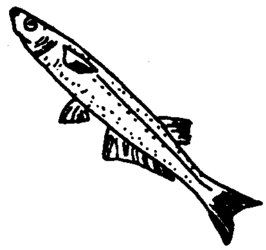


In the lower part of this zone you may see **rockweed** and **knotted wrack** attached to rocks or washed up on the edges of the marsh. Here, the periwinkles gather to scrape algae and diatoms off the fronds of the rockweeds and off the rocks.

Several other animals live in the lower marsh and mid-marsh. In the streams and ditches that are another feature of the marsh, you may see **Stickle-back** fish darting back and forth. The female lays her eggs in a nest that the male has prepared and leaves him to baby-sit until the eggs are hatched. **Mummichogs,** a slightly larger fish, and shiny little **Silversides** also live in these streams.





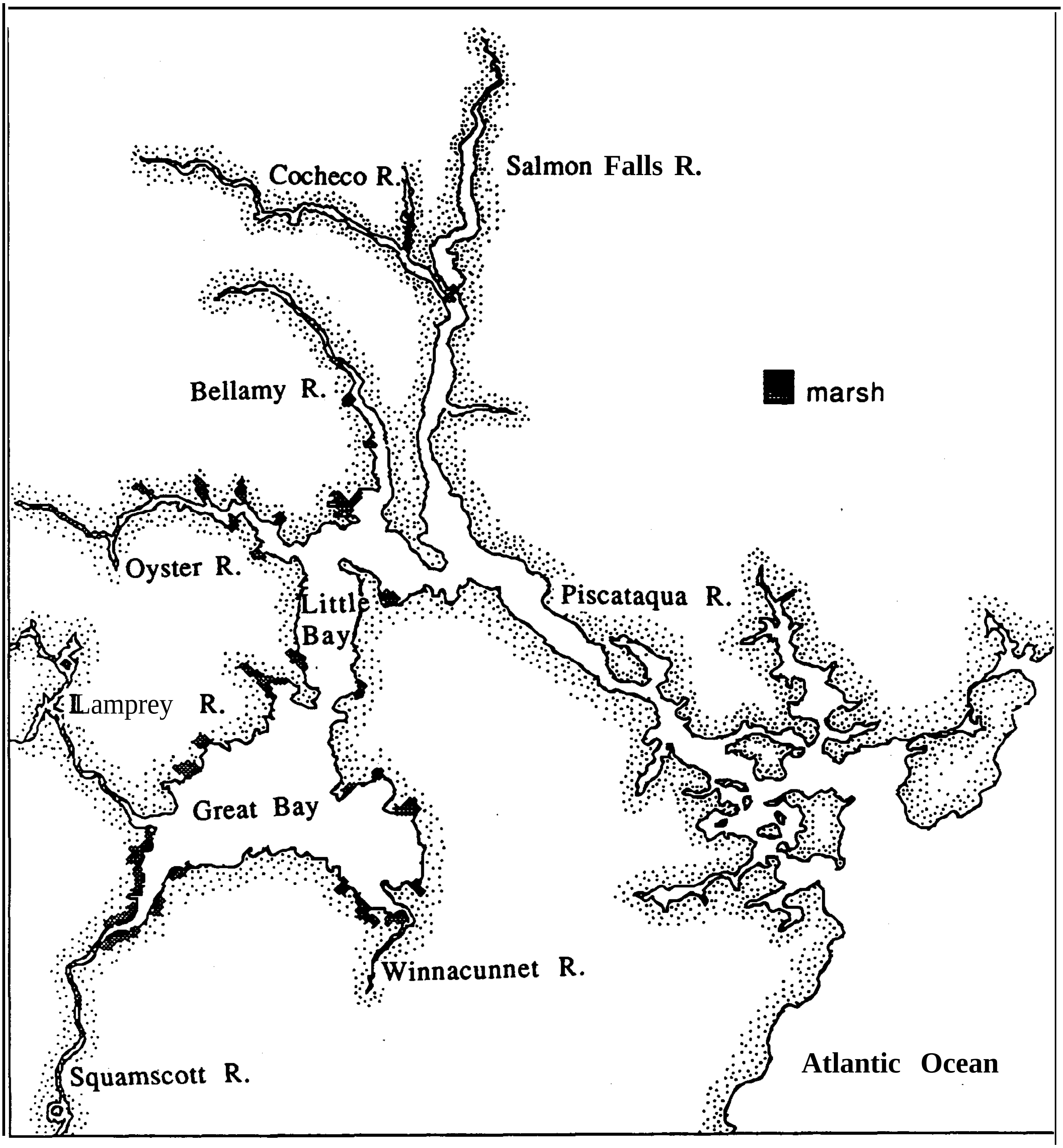


You may find the **coffeebean snails** climbing up the cordgrass blades as the tide advances. Climb they must, for they have primitive lungs and cannot breath underwater. The **ribbed mussel** and the **green crab** live in the lower marsh, as does the **mudsnail,** which moves its siphon back and forth to suck up detritus and diatoms.

Several other animals live there as well and all have to adapt to the many changes that take place in the marsh. Periwinkles, crabs, ghost shrimp and mussels have **shells** to prevent them from drying out at low tide and to protect them from other animals. The periwinkle can retreat into its shell and "close the door" with its operculum, trapping a bit of water inside to keep its body moist. The green crab carries its skeleton on the outside of its body in the form of a shell. This extra protection, its strong claws and its ability to move rapidly make it one of the most successful predators of the marsh.

Where are the marshes in the Great Bay estuary? Salt marshes are found all along the tidal portions of the rivers and especially around the Squamscott River and Great and Little bays. Since most of the marshes are quite narrow, it is easy for the tides and rivers to spread detritus, that nutritious soup made of decomposed plants, all over the estuary. The ice that forms in the winter freezes around the stems of grass and pulls up bits of salt marsh during the spring when it breaks up. These "salt marsh rafts" bump into the shore and put down roots, starting new little marshes. That is why we see so many "fringing" marshes all around the estuary.

Salt Marshes of the Great Bay Estuary



Why should we care about marshes? This is a good question, one that wouldn't have even been asked 20 years ago. Then, most people saw marshes as smelly, mucky wastelands that should be drained and filled in. Now we know that marshes should be preserved for many reasons.

Most importantly, the marshes take energy from the sun and **produce food** for animals and plants in the estuary and in the ocean. Salt marshes are among the most productive environments on earth, producing 10 tons of organic material per acre, two and one-half times as much as a good hayfield produces.

They provide a **permanent home for many animals**. In addition, the marshes serve as **nurseries** for others, It is estimated that 70% of the fish and shellfish in the ocean depend upon the marsh in some way. Some birds nest in the marsh, and many others use it as a **resting and feeding place** during their the spring and fall migrations. Some wade out on their long legs to gobble up small crustaceans and fish in the marsh creeks and adjacent mudflats. Others feed on the eelgrass.

Marshes are good **protectors**. They buffer storms that might destroy cities and towns behind the marsh. They also act as **sponges,** which helps decrease flooding after heavy rains.

Marshes act as **filters**. They filter out excessive nutrients and pollutants, to some degree. In some parts of the country, marshes are used as natural sewage treatment plants. Bacterial action and the tides help to get rid of the sewage, while nutrients from the sewage can be used by the plants and animals of the marsh. This must be carefully monitored, however.

Finally, marshes are places of **beauty**. They are fragile and must be protected from overuse, but they can be important places of recreation pursuits such as bird-watching. In some marshes, raised boardwalks give people access to the secrets of the marsh without destroying those mysteries. There is such a boardwalk through a marsh at Seabrook Station. It is open to the public and a trail map is available

People have responsibilities toward marshes. We have lost about two-thirds of the marshlands along the northeastern coast. Salt marshes in New Hampshire have been filled, dredged or cut off from the open ocean by the construction of roads, housing, marinas and industries. People hiking on marshes have trampled the soil down, compacting plant roots. For many years ditches have been dug throughout the marshes in an unsuccessful attempt to control mosquitos and green-head flies. Marshes have been sprayed with pesticides to control these pests, too. These pesticides run off into the water and affect the plankton and small creatures that live there.

We have laws that protect marshes. The N.H. Office of State Planning and its Coastal Program help to plan for marsh protection. In New Hampshire, people must apply for permits to fill wetlands such as salt marshes. They must have a very good reason to do so and even then the permit probably will not be granted. If someone damages a marsh, they can be fined by the state. They can also be forced to restore the marsh.

Laws are not enough, though. Everyone must learn to appreciate marshes and take responsibility for their well-being.

CLASSROOM ACTIVITIES -- SALT MARSH

Most can be done either before or after the Great Bay Living Lab Day.

A. Marsh Munchers (Adapted from Project Wild Aquatic.)

Purpose: To develop an understanding of the importance of detritus in the estuary.

Materials: Envelopes with the names of animals in the marsh, slide program on the marsh (see resource list in the appendices), food tokens

Procedure:

1. Use the slide program, ***N.H. Salt Marshes, Nurseries of the Sea.*** to introduce the students to the marsh.

2. Make a list of the animals in the salt marsh (bacteria, green crab, coffee bean snail, red-winged blackbird, great blue heron, Canada goose, snowy egret, mud snail, mummichog, silverside, raccoon, mosquito, spider, etc.). Explain that the identity of the animal must be kept secret. Some animals will be detritus eaters, and others will be predators who prey on them.

3. Then review the rules:
   *Each student represents a detritus eater or a predator,
   *Each detritus eater has five food tokens representing marsh animals of the same species.
   *The detritus eaters gives a token to a predator when tagged.
   *Each predator must get 10 food tokens to stay alive for one tidal cycle.

4. To play, detritus eaters show their feeding styles, squatting or standing, while the predators walk around, displaying their behaviors. A predator, displaying the correct eating behavior, may ask for and receive a food token, For a predator to live through a tidal cycle must collect at least six tokens, but it can collect only one token from each species. The detritus eaters keep on eating even after they have been "eaten" by their predators. They represent the remaining animals of that

species until they run out of food tokens. When they run out of tokens, they sit quietly in place “decomposing” in the marsh.

B. Marsh Metaphors (Adapted from Project Wild Aquatic.)

Purpose: To develop an appreciation and understanding of the salt marsh through the use of metaphor, linking the characteristics of salt marshes to everyday life.

Materials: A pillowcase or box to use as a Mystery Metaphor Container, sponge, soap, pillow, eggbeater, mixer, small doll cradle, sieve strainer, paper filter, antacid tablets, box of cereal, 3 x 5 cards that can show other metaphors such as a zoo (diversity) or a vacation resort (resting place for migrating birds).

Procedure:

1. Use material from this book and the resource list, and perhaps a tape recording of natural sounds from the marsh (available commercially). Ask the students to close their eyes and visualize a salt marsh -- examine sights, smells and textures; look closely at plants and animals, insects and small creatures; What does the air feel like? Compile a list of their impressions.

2. Reshow the slide program on marshes and make a list with the students about what the marsh does:

   *filters out toxins and excessive nutrients.
   *protects from wave action.
   •is a nursery for young animals.
   *provides food.
   •is a resting place for migrating animals.
   *provides a place for recreation.
   *is beautiful.

3. Then bring out the Mystery Metaphor Container and tell the students that everything in it has something to do with a salt marsh. Divide the students into groups of three and have a representative of each group take something out of the container. The group must decide how the object relates to a salt marsh. Then, sitting in a circle, have the groups present their "metaphor" after agreeing within the groups what function of the marsh the object represents. Finally, have the

students tell how these functions relate to human beings and end with a discussion of how marshes can be protected.

GREAT BAY LIVING LAB DAY ACTIVITIES

A. Salt Marsh Investigation.

Purpose: To observe the marsh using a variety of techniques.

Materials: a rope several meters long, salinometer, pH kit, thermometer, plastic bags, clipboard, record sheet, pencil, cup, posterboard, 3 x 5 inch cards.

Procedure:

1. First, have the students look over the marsh to see the cordgrass and salt marsh hay that mark the line between the lower marsh and upper marsh. Observe the succession of trees to bushes to grasses and discuss briefly.

2. Then have them take a "snail's eye view" of the marsh. They lie prone chin on the ground and jot down everything they see in 5 minutes on the cards. They should look for animal activity, erosion, pollution, new and last year's growth on grass stems, insects. etc. Have a brief sharing time afterward.

3. Next, have them stretch their rope in a section of the marsh and them record everything on both sides of the line. They can use their equipment and observational skills to find:

*water and soil temperature (they should test the soil at 0, 5, 10 centimeters depth)
•soil condition (dry, moist or wet)
•root structure of the salt marsh grasses
*evidence of bacterial action
• pH
•variety of plants and animals

Each group can collect one sample (no live animals!) from the high and low marsh to make a Living Marsh Collage using the poster board. Make this activity a focus for a wrap-up discussion. Take the collage back to the classroom for further study

GREAT BAY ESTUARINE HABITATS: ROCKY SHORES

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GREAT BAY ESTUARINE HABITATS - ROCKY SHORES

Slate covered beaches line the shores of Adams Point in the Great Bay Estuary. Little rectangular flat rocks have been chipped away off the rocky headlands by erosion. Waves pound away at the base of the headlands, while plants and freezing water break off pieces of slate. The rocks provide a good substrate (a place to attach to) for rockweeds to hold on tight with their holdfasts. Barnacles and mussels live there too, attached to the rocks.

The land along the shore between the high tide and low tide levels is called **intertidal** whether it is a rocky shore, a sandy beach, a mudflat or a salt marsh. Life here can be challenging. At high tide living is easy with the waves bring food and moisture to the animals living there. But when the tide is low, the hot sun may beat down, drying out animals that cannot move and making it much warmer, suddenly. Rain or snow may fall on the exposed intertidal area, covering plants and animals who are used to salty water, with a fresh water. bath. Sometimes during the spring tides, when more of the intertidal is covered than usual, plants that cannot tolerate high salinity suffer or even die.

Animals always have to be on the look-out for **predators.** They **could** end up as someone else's dinner! For example, as the tide gets lower, and more and more shore is exposed, seagulls swoop down to gather the green crabs that are scuttling about, trying to grab just about anything they can to eat.

Moving into the estuary nearer the rivers, there are even greater changes in temperature and salinity. This makes it harder for some rocky intertidal plants and animals to live there. We say that there is a **decline in diversity** of species, as stresses become greater. **Individual** species of animals and plants who adapt well to these changes may be found in great **abundance,** however.

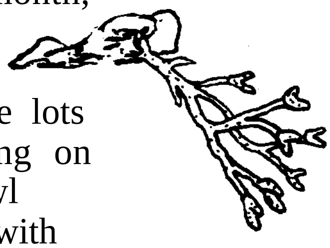
Zonation

How well animals and plants adapt to these **stressee** : tide and wave action, storms, predation, and changes in temperature and salinity, determines where they live. Plants and animals in the intertidal live in horizontal bands, called zones, because the rising and falling of the tides control exposure to most of these stresses and species vary in their ability to adapt to them. There is a lot of overlapping of these zones, but there are usually “indicator” species in each zone that help in identifying where the zones begins and ends. These zones follow a consistant order all around the world.

Beyond reach of the highest tides where there are still many land plants such as the **seaside rose,** there may be spray from the waves during a storm. This is called the **Spray Zone.** You will find spiders, beetles and flies here.

Just below the spray zone is the **Black Zone,** which gets its name from slippery black clumps of **blue-green algae** that cover the rocks. These algae are some of the most primitive plants on earth.

A line of broken grass stems, trash, decaying plants and animals marks the high tide level. You may see several of these **swash lines** . The highest one is the **spring tide line** where the tide comes twice a month, and the lower one marks the **neap tide line.**



As you walk toward the water you begin to see lots of little snails called **periwinkles** . Some are grazing on microscopic algae that covers the rocks. Others crawl along the fronds of **rock weed,** scraping diatoms off with their long file-like **radula**. They can trap a bit of water in their shells when the tide goes out, closing their “trap door” (**operculum**) to keep their bodies moist and cool. They also put out a sticky substance which helps them attach to rocks. If they should be knocked off a rock by waves or animals, their shell is shaped so that they just tumble along until they come to rest. There are no arms or legs sticking out that could be injured.

Imagine an animal like a tiny, fuzzy tennis ball, floating in the water. As it grows, it settles to the bottom where it glues its head to a rock and grows an 8-plated shell around its soft body. For the rest of its life it stands on its head and waves its legs in the water to bring in food The **barnacle** is one of the most common animals in this zone which is covered at high tides, so we call this the **Periwinkle/Barnacle zone.**

not to scale

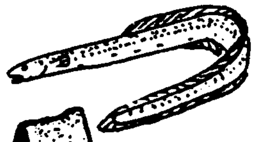
Green crabs hide under the seaweeds and among the rocks, trying to find a quick meal. Clench your fingers into a fist. Look at the back of your hand. It is shaped a lot like the back of a green crab. Look at a crab carefully and notice the five points along the shell on either side of its eyes. This crustacean has five pairs of legs. Two are claws used to rip apart its food so that it will fit into its small mouth.

The green crab is one of the most successful predators, partly because it is fairly new to our shores. Also the green crab can stand very low salinity. Most animals fill up with water and die rapidly when salinity gets very low, but the green crab can maintain its internal salinity balance. It has "green glands" that act somewhat like kidneys, filtering blood, and keeping the salt level high enough while eliminating the excess water. A large green crab can survive in the shade in the open air for about a week, and under damp seaweed for up to two months. Female crabs carry 100,000 eggs held up against their bodies by the broad tail. Most of these eggs are food for other animals once they are released, but some survive, floating among the plankton for several months.

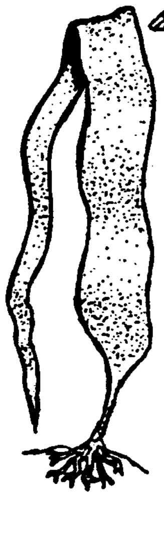
Further down toward the water is the **Rockweed Zone**. **Knotted wrack** and **rockweeds** attach to the rocks with their holdfasts, making good hiding places for the green crab. You can tell how old knotted wrack is by counting the number of spaces between air bladders on the main stem. Bright green **sea lettuce** is flattened against rocks and another leafy seaweed, **purple laver**, is found here also. Have you eaten some purple laver, wrapped around rice, in a Japanese restaurant? Clumps of **blue mussels** fasten themselves to rocks with their byssal threads. You may even see the **ribbed mussel** usually found in the salt marshes.

Below the rockweed zone there is a narrow **Irish Moss Zone** on some rocky shores in the estuary, but since irish moss usually requires higher salinity and more constantly cold temperatures, there isn't much of it. You may find some seaweeds in this zone that don't usually grow north of Cape Cod. Look for a red, sticky-looking mass. Pick it up and place it in some water and watch beautiful, feathery fronds unfold. This is **chenille weed** .

Many of the same animals that were in the Rockweed zone are here, too. Notice the **amphipods** -- little shrimp-like animals that are flattened, side to side. They hide under rocks, trying to escape the green crabs. Also there are true shrimp, like the glass shrimp that you can almost see through.



Sometimes in the mud between the rocks, you may find an **American eel** , resting on its way up the rivers where it will live until adulthood. They are about 8 inches long, and a silvery color with gold near the continuous fin on the top side of the their bodies. They grow to be about 3 feet long.



The **Kelp Zone** is always covered with water. However very little kelp grows in the estuary because not much sunlight can penetrate the cloudy water. Also, kelp can't tolerate high temperatures or low salinities. But sometimes we find kelp washed up on the shore.

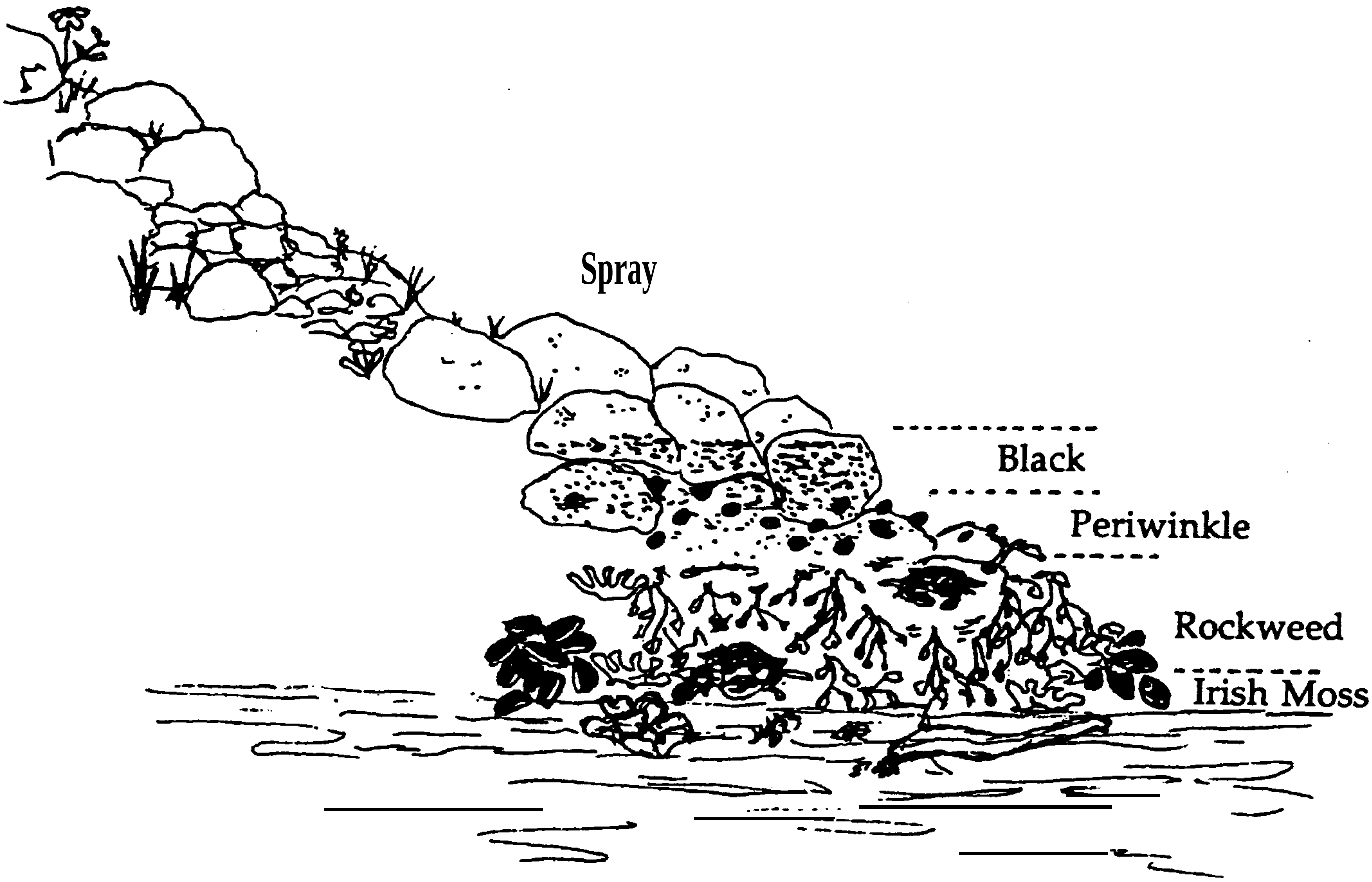
Estuarine intertidal zonation is a little different from coastal intertidal zonation. There is less seaweed, almost no irish moss zone, and no real kelp zone.

Turn the page to see what the zones look like on the rocky intertidal area in the estuary.

Zonation on an Estuarine Rocky Shore

What happens to the width of the zones when the shore is steeper?

What happens when shore is flatter?



CLASSROOM ACTIVITIES - ROCKY SHORE

1. Table-top Transect (This is a good exercise to do before the Great Bay Living Lab Day.)

Purpose: To become acquainted with the transect technique for study of the natural environment.

Equipment: flat cardboard at approximately 9 x 12 inches or larger, Elmers glue, a packet of dried soup vegetables (or several kinds of beans), a string marked in centimeters, a record sheet, a large paper clip

Procedure:

1. Assign each vegetable in the packet to be an indicator species of a particular zone:

    ___________ **Spray Zone: sea-side rose**

    ___________ **Black zone: blue-green algae**

    ___________ **Periwinkle/Barnacle Zone: periwinkle, barnacle, green crab**

    ___________ **Rockweed Zone: rockweed, knotted wrack, green crab**

    ________ **Irish Moss Zone: irish moss, chenille weed**

2. Then spread the thinned glue on the cardboard, one zone at a time and put the appropriate animals and plants in each one. Remember there can be some overlapping of zones.
3. After the glue has dried, and the vegetables are secure, give each card its transect number starting from with #l; have the students exchange cards. Then laying the large paper clip horizontally every 5 centimeters, have them count the different species within the paper clip, starting from the top zone. They should keep records on their record sheet.
4. After making the transect,
    - (a) Average all the transects to get an average number of indicator species for each zone or have each transect done individually.
    - (b) Make bar graphs of this information.
    - (c) Draw a zonation profile of the beach.

2. Seaweed Pressing

Purpose: To learn to use a simple key and to identify three major categories of seaweeds.

Materials: plastic bags, putty knife (or pocketknife), herbarium paper, large flat shallow pans, plant press (or flat boards and bricks or heavy books)

Procedure: Collect one or two plants of each species of seaweed in plastic bags. Try to get the holdfasts on at least two of the plants. Select an indicator species, and also try to get at least one each of red, brown, green and blue-green species. Put a little water in the bags to keep the seaweeds moist. Take them back to class and press them using the following technique:

1. In a flat, shallow pan put water to a depth of about 2 cm.

2. Rinse the seaweed to be pressed in clean water.

3. Place herbarium paper -- or other paper -- or a 6 x 8 index card in the pan. Position the seaweed over it. NOTE: You can also try placing the paper in the pan without water, laying the seaweed on the paper and then gently squirting water on the seaweed and tease it out with a probe as the water lifts it up.

4. As the seaweed spreads out, lift the paper, carefully draining the water off. Arrange the fronds further with a pin or probe.

5. Use the seaweed key in this section to help you identify the macro-algae. Write the scientific name, common name, you name, the place it was collected, and the date on a 3 x 5 card with a ball point pen. Include this with your specimen and tape it on it when the specimen is pressed and dried.

6. Place mounted specimens between sheets of wax paper, then blotter paper and finally, newspaper. Put into a press and place in a dry, airy place. When specimens are completely dry, mount on them on cardboard and cover with plastic wrap.

KEY FOR NEW HAMPSHIRE SEAWEEDS

1. Plant body (thallus) distinctly green 2
1. Plant body not distinctly green 5
2. Fronds long and threadlike 3
2. Fronds not threadlike 4
3. Fronds branched . . . . Cladophora
3. Fronds unbranched . . . . Chaetomorpha [Mermaid's Hair]
4. Fronds paper thin and flat . . . . . . .Ulva [Sea lettuce]
4. Fronds tubular and long . . . . .Enteromorpha [Entral grass, Link confettii]
5. Fronds yellowish brown to olive green or nearly black . . . 6
5. Fronds pink, red or reddish purple 21
6. Fronds irregularly round, hollow and gelatinous . Leathesia [Rat's brains]
6. Fronds not as above 7
7. Fronds forming a brown to black crust on rocks . . . Ralfsia [Tar spot]
7. Fronds not forming a crust 8
8. Fronds tubular 9
8. Fronds not tubular .13
9. Plant body branched throughout 10
9. Plant body little or not at all branched except perhaps at the base 11
10. Axes and branches 2-5 mm. in diameter . . . . . . Dumontia
10. Axes and branches usually 1 mm. or less in diameter (in part) . . . . Dictyosiphon
11. Plant body usually more than 1/2 meter long (1-5 meters). . . . . Chorda [Devil's shoelace]
11. Plant body usually less than 1/2 meter long 12
12. Plant body constricted;  without groups of sporangia (reproductive organs) and hairs appearing as dark flecks . . . . Scytosiphon
12. Plant body not constricted; covered with groups of sporangia (reproductive organs) and hairs appearing as dark flecks . . . . Asperococcus
13. Fronds filamentous (threadlike) 14
13. Fronds membranaceous (thin, pliable, sometimes transparent) and expanded 17
14. Fronds capillary (long and thin); formed of a single row of cells . . . . .Ectocarpus [Brown mermaid's tresses]
14. Fronds cylindrical .15
15. Branching of fronds pinnate (equal) and opposite  . . . . Desmarestia [Color changer]
15. Branching of fronds not pinnate and opposite 16
16. Fronds tough and dense . . . . Chordaria
16. Fronds soft and flaccid (limp) . . . . Dictyosiphon
17. Fronds simple (unbranched). 18
17. Fronds branching 20
18. Midrib absent . . . . Laminaria [Ribbon kelp]
18. Midrib present () 19

19. Fronds perforated with numerous holes; without lateral leaflets at base of blade .. . . Agarum [Sea collander; Devil's apron]

19. Fronds without holes; with lateral leaflets at base of blade . . Alaria [Wing kelp; Henware]

20. Fronds with a midrib; fruit terminal .Fucus [Rock Weed]

20. Fronds without a midrib; fruit born on short lateral branches Ascophyllum [Knotted wrack]

21. Fronds calcareous (made of calcium; hard) .... .22

21. Fronds not calcareous .... .23

22. Fronds erect, standing up, long and attached at joints, filiform and articulated ...... Corallina [Coralline]

22. Fronds thick, horizontally expanded but often rising at intervals in irregular protuberances (encrusting) .... Lithothamnion

23. Plant encrusting rocks, forming their pinkish to reddish-brown crusts near low water mark .. .Hildenbrandtia

23. Fronds erect; not crustaceous .... .24

24. Fronds tubular . ... Halosaccion

24. Fronds not tubular. .... -25

25. Fronds filamentous .... -26

25. Fronds membraneceous .... -28

26. Filaments branching ( [splits twice]) dichotomously, with transverse (across ) bands; lobster claw at end .... Ceramium

26. Filaments pinnately branching; without transverse bands (on one side like a comb) .... .27

27. Filaments pectinately branching (with opposite branches of unequal length) .... Plumaria [Plume moss]

27. Filaments branching irregularly .... Polysiphonia

28. Fronds thin and delicate like tissue paper; purplish-red .... Porphyra [Laver]

28. Fronds not tissue paper thin 29

29. Fronds large and leaflike; simple to dichotomously or palmately (like the palm of your hand and fingers) divided .... Rhodymenia [Dulse]

29. Fronds dichotomously (branching two times each) branched with narrow divisions 30

30. Fronds covered with small papillae (bumps) . . . .Gigartina [Grape-stone]

30. Fronds without papillae ...... .Chondrus [Irish moss]

3. Various Periwinkle Behaviors

Purpose: To observe aspects of periwinkle behavior.

Materials: periwinkles, aquarium or large jar, estuary water, rockweed.

Procedure: Collect periwinkles which are found in great numbers in the rocky shore intertidal. They are easily kept alive in an aquarium or in an open jar filled with salt water in a refrigerator. Collect them the day of the field trip.

A. Periwinkle behavior: put the snails in an aquarium or a large jar with estuarine water. Answer these questions:

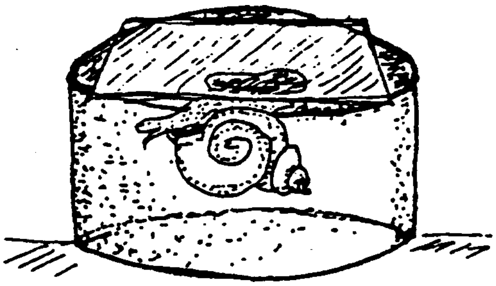
1) Where do the periwinkles congregate?

2) Where are they in the morning? In the afternoon?

3) Do they move around the container? How do you know? Remove a snail, dry it, and put your initials on the shell with permanent magic marker. Return the snail When it returns to the side of the container, circle its position, each day for several days.

B. Feeding Behavior Observations

1) Place the periwinkle in a washbowl with a glass plate on the bottom.



2) After the snail has attached itself, take the plate out. Put some seaweed in the dish and invert the plate with the snail attached. What happens? Does the snail begin to eat the seaweed?

C. Radula Dissection

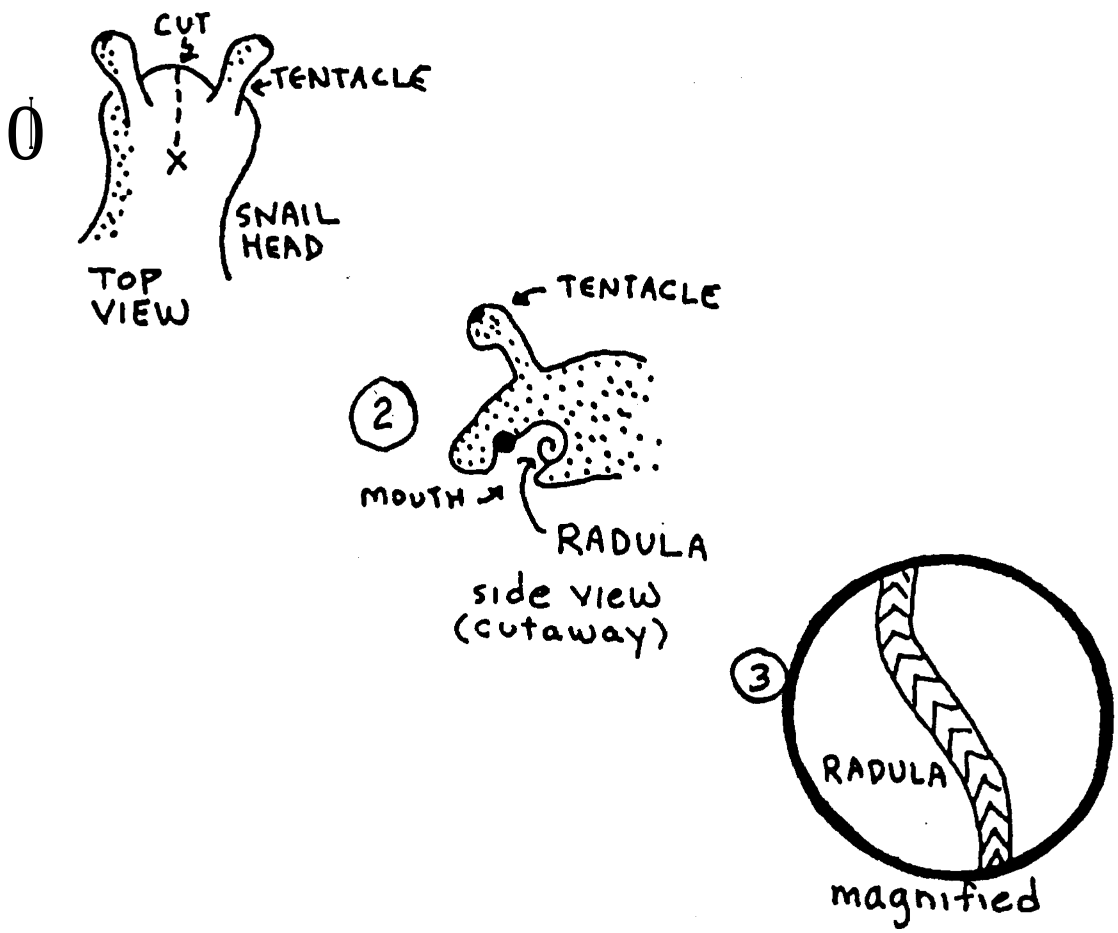
1) Place the snail in boiling water.

2) After a few minutes remove the snail from its shell. (You can crush the shell gently with a rock.)

3) Carefully cut along the top of the head between the tentacles

4) Locate a long, coiled thread-like structure attached to a small red tissue. This structure is the radula. Remove it with tweezers.

5) Mount the radula on a slide. Stain it with methyl blue if possible. Observe it at low power. Draw, what you see. Describe how the periwinkle eats.



GREAT BAY LIVING LAB DAY ACTIVITIES-ROCKY SHORE

We will take you to the nearest rocky shore after your tour of Jackson Estuarine Lab and give you a chance to do one or more of the following activities. Have your clipboard and pencils ready. One of you may carry the cooler. Three others should be in charge of collecting a limited number (not more than two or three) of specimens if you have plans to use them for classroom study. Live animals should NOT be collected unless you plan to dissect them or to put them in an aquarium. (An estuarine aquarium is easy to set up and you can collect water on your Lab Day for it.) You will be working in groups of 3 or 4, for most activities.

Activities :

1. **Transect Study. (This may be modified by the instructors according to tide height, weather, or time available)** A transect is study made along a line at certain regular intervals to study an area. We will be trying to find out the following things:

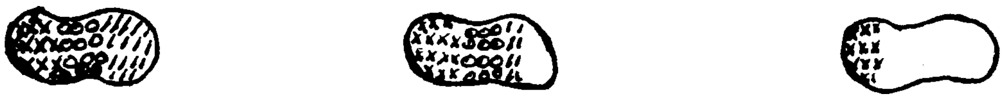
   -how wide are the zones?
   -what is the per cent cover and how does it change as we approach the water?
   -how does the diversity of life change as we approach the water?

Equipment: Marked rope or string, a quadrat (a square l/4 meter on a side), string, a carpenter's level, lab sheet

Procedure:

(1) Secure the end of the rope at the high tide level and stretch the string in a straight line to the water's edge.

(2) Lay the quadrat at the first meter mark and estimate the percent cover:



100% 75% 25%

(3) Then count and record the indicator species plants and animals in the quadrat on your record sheet. Repeat.

Rocky Shore Transect at Great Bay Field Data Sheet

Name ______________________________ Date ______________________________

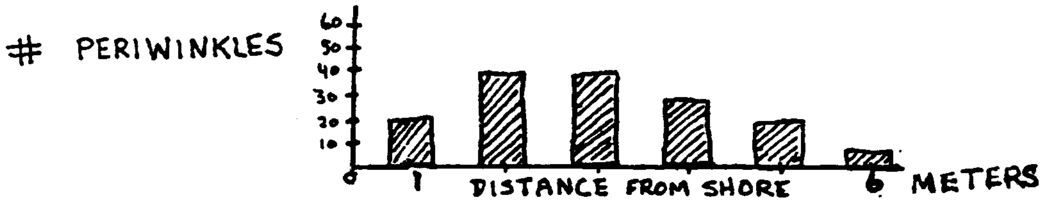
meter	rockweed	barnacles	periwinkles	sea lettuce	other

How wide is the periwinkle zone? ____________ meters. Did you find any red seaweeds? ____________. What determines how wide the zone will be? ____

____

(4) If time permits, you can also record the elevation of each sample as you move along. Just hold put the meter stick upright at the first meter. Put the carpenter's level on the string and stretch the string tightly between the "0" and the meter stick. Move the string up or down the meter stick until the bubble in the level indicates that the string is level. Look at the meter stick and read the elevation in centimeters. Record it on your record sheet.

(5) When you get back to school, make bar graphs to show what you found. You can do graphs just for your group, or you can average the whole class findings for each indicator species and do the graphs that way.



(6) Look at the data you collected in each transect and discuss the questions we asked at the first of the exercise. Did you get any other information from your transect? Was light or shadow a factor? Do you think a transect could be used to study anything else?

2. Periwinkle Population Base-line

Purpose: to establish a base-line for periwinkle population on the rocky shores of the estuary.

Equipment: l/2 meter hoops, clipboard, pencil, etc. (large sheet of paper and a magic marker for the teacher.

Procedure: Divide the students into groups of three and have them stand randomly over a pre-measured area of the beach. (You can assume the area of the beach is 500 square meters if you don't have time to measure.) The students will gently throw their hoops into the intertidal, count all the periwinkles within the hoop, and multiply by 2 to get the number per square meter. Each group should record their average on the large sheet of paper. Then someone can find the grand average of periwinkles per square meter on the beach. Multiply that by the area of the beach and it will be an estimate of the number of snails there are.

Questions:

1. Does this technique give us valuable information?

2. Would information of this type be more valuable if it were taken over a period of ten years?

3. Do you think the periwinkle is a good "indicator" species? Why or why not?

GREAT BAY ESTUARINE HABITATS: UPLANDS

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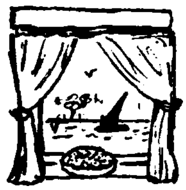
GREAT BAY ESTUARINE HABITATS - UPLANDS

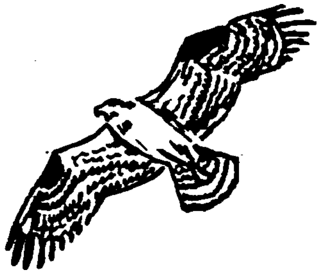
If we walked all along the shores of the rivers and bays that make up the Great Bay Estuarine System, we would need to wear waterproof boots at any time of the year. But if we walk through the hilly areas and open meadow on Adams Point in the fall, sneakers or hiking boots should be adequate.

We'll meet in the parking lot at Jackson Estuarine Laboratory. Look to the west, over the meadow, and you will see Great Bay in the distance. The Adams family had a big white house that stood right here. Imagine Mrs. Fannie Adams glancing out the kitchen window when she heard her husband, Edward ring the ship's bell on the gundalow as he sailed across Great Bay to Newmarket. He rang the bell so she could put the apple pie in the oven to be ready for him when he returned. (Could it really take only about an hour to go to Newmarket, unload the gundalow, take on a new cargo and return to Adams Cove, right outside the house? Probably not , but it makes an interesting story!)



Captain and Mrs. Adams invited visitors to stay in their house's many rooms to vacation during the summer. People came to fish, gather oysters, and swim and go boating. They were some of the estuary's first tourists. The Adams built a small iron seat on rocks overlooking Furber Straits to sit in while hunting ducks. It is still there and is called the "shooting chair." Go ahead -- try sitting in it. Do you suppose many people came here just to look out over the Bay to the Newington side? Maybe they waved at a gundalow loaded with hay from the nearby marshes fringing Crommet's Creek.

Perhaps they watched for the eagles that still stop over in the fall and winter. There, we can see one now. Flying high above us, it looks like an adult. Eagles have a wing span of up to 80 inches and make their nests in the tops of dead trees. This one is flying toward the undisturbed shoreline of the former Pease Air Force Base, where we hope there will be a wildlife refuge for endangered species such as this.



Other large birds like to roost in bare dead trees. The osprey or fishhawk is a large brown speckled bird with a strong curving beak. Look there's one now, hovering over the water. Watch it dive, feet first, and with a huge spash it grabs a fish in its strong claws and retires to its nest to eat it. Baby ospreys learn to dive like that in their first year. What a lot of skill it must take to catch dinner that way.

As we follow the path around, we see a beautiful **birch** tree lying on the rocks below, a victim of erosion. Its trunk is almost two feet in diameter! Soon it will be broken down still further by waves, animals and plants to become a part of the nutrients that nourish Great Bay.

Looking to the right just after we pass the birch tree, we can see some low bushes with almost all their leaves gone, but with little cup-like remains of flowers. **New Jersey tea** made from the leaves of this shrub sustained the colonists throughout the 13 colonies right after the Boston Tea Party. (England was trying to make them pay a tax on imported tea, and some of the Bostonians dumped the tea in the harbor as a protest.) It became very patriotic to drink "New Jersey tea" in those days, and it still makes a good hot drink.

Keep walking through the drying grasses and watch for small holes in the ground that might be homes for **mice** and **moles.** Do you see any tracks? Other animals such as the **red fox,** the **white-tailed deer** and **rabbits** like to visit the meadow,

but they wait until evening when humans and dogs are not there.

As you come to the end of the meadow, turn to follow the edge of the trees. You will soon come to a small pond, fringed with **cattails** that continue on along the creek and down to Adams Cove. Overlooking the pond you will notice the Adams family tomb. Many members of the family are buried here in this beautiful place. The Adams' imported marble from Carrera, Italy, to put on the face of the tomb, but lately earth has been heaped up in front of it to protect it.

Returning to the parking lot, walk up the hill just a bit and you will notice a path near the stone posts where a gate once was. Follow it to see the large rock that was used as a pulpit for family church services held there during good weather. The tall **pines** and **hemlocks,** mixed with some **birch, oak** and **alder** trees make it a cool and lovely spot. You can walk far enough to look out at Little Bay, but be careful not to get too near the edge of the cliff.

If you have more time, walk carefully, single file, down the hill along the one-lane road. Watch out for that **poison ivy!** Even though its three green shiny leaves are turning red and yellow, don't touch them. Don't pick the white berries that look so inviting. Both the leaves and the berries give off the oils that cause an allergic reaction.

As you move down the hill, notice that the air seems more moist. **Sweet fern** line the road and an endangered species, the **marsh elder,** is hidden among the tall trees. See the red seed cones on the fuzzy-barked **elkhorn sumac** trees? Their leaves are bright red, too. You can see the salt marsh off to the left, blazing with the dark greens and browns of the grasses, sparked by red **glasswort** growing close to the ground.

Now you must choose again. If you walk on down the road to the public boat landing you may want to go along the shingle beach. Notice how the **red cedar** have grown into the rocks, splitting off pieces that are spread across the shore by the tides. See those low bushes with the long dark green leaves and small waxy-looking grey berries? Pick a leaf and smell it. Does it remind you of the Christmas holidays? These are **bayberry** bushes. The berries are boiled and as the wax melts, it floats to the top where it is skimmed off for candle-making. It takes a bushel basket full of berries to get four pounds of the wax used to make those wonderful-smelling bayberry candles.

Coming up toward the road again, you may see the purplish-blue flowers of the **chicory**. Only a few flowers are on each of the tall stems, and each flower opens only for one day. The chicory root can be dried and ground up and used as a substitute for coffee. There is an old story which says that a young girl, sadly waiting for her sailor boyfriend to return, was changed into the chicory plant. The blue flowers represent the blue of his uniform.

How confusing! Here are more blue flowers! They look a little different, though. There are many more flowers on each stem, and each flower has many more petals than does the chicory. Yes, and there is yellow center to this flower. It is an **aster**. Look around and you will see lots of them. You might even see a very rare, endangered aster, the **large salt marsh aster** with its very pale blossoms and long, slender leaves. In New Hampshire, it is found only here in the Great Bay Estuary. This aster is just one of the endangered species to be found in the estuary. New Hampshire has laws that protect plants and animals that are so rare they might disappear.

Yellow looks very nice with blue, and there are lots of tall, spikey **goldenrod** around here, too. The goldenrod growing up near the trees has thin leaves, and there is the **marsh goldenrod** with its thicker, hairy leaves further down near the marsh. Can you tell the difference by feeling them?

Do you still have some time to explore? Take the map and start back up the hill. Notice the path that leads to your right. Take it and walk along the edge of the marsh and out to the lookout point. The rest of the path is wet, slippery, and dangerous when it goes up again onto the headlands, so return to the parking lot via the paved road.

Getting to know the names of some of the plants, noticing where animals are living, and enjoying the brilliant colors of leaves, grasses, berries and fall flowers help you realize what a beautiful and complex world we live in. Each one of these plants and animals has a unique function, a niche, in the estuary ecosystem.

Some things to think about: A change to any part of the ecosystem, no matter how small it may seem to us, affects the whole thing. Think about this parking lot we're standing on. Just paving it was a radical change. Pavement is a desert; it grows no food, you can't eat it, and you can't burrow in it. It doesn't absorb water, so rain runs off, making somewhere else wetter. Does the increased runoff wash nutrients away from this area? If so, where to? Can the other place handle it? The paved ground is hotter in the summer and colder in the winter. Grasses around the pavement had to change to species that could tolerate this variation. What would you do if you were a mouse? A fox? Can you think of other things that would affect the ecosystem? Can something as small as a footprint in the marsh change it? What do you think?

CLASSROOM ACTIVITIES -- UPLANDS

A. The Osprey Dive-Bomber (Adapted from ORCA, Washington Sea Grant Program, Seattle, Wash.)

Purpose: To understand how the osprey catches its prey.

Materials: pencil, glass of water, newspaper, masking tape, large plastic shoe box, chair

Procedure: Read the short paragraph in this chapter about the osprey for background. How does an osprey see well enough, dive fast enough and be accurate enough to catch a fish on the very first try (as they often do)?

1. Place a page from the newspaper on the wall. Stand back 30 meters and try to read it from that point. Who has the better eyesight, you or an osprey? (The osprey can see eight times better than humans can.)

2. Place a pencil in a glass and start filling the glass with water. *Record observations on your data sheet.

   *Look at the object from the side through the glass. What do you notice?

   - Look at the pencil from the top. What do you see?

   •Keep filling the glass and repeating the first two observations. Does the change in water level affect the image of the pencil in any way?

3. Put a thin strip of tape in the shape of a fish on the bottom of the shoebox near one end. Look over the edge at the tape. Move your head until the tape **disappears from sight.** Have a friend slowly fill the box with water as you continue to look over the edge. IMPORTANT: DO NOT MOVE YOUR HEAD.

4. What happens to the image of the tape as more water is added? Why?

5. Now let's see how successful you'd be as an osprey. Use a sharp pencil as your talons. Stand on a chair and overlook the target (the tape on the bottom of the shoe box). You have one chance to hit the target. Throw the pencil like an arrow into the water. Did you hit the target? If so, you will survive. (For more of a challenge, use a larger container with more water and use a longer, narrower object for talons.) Try it again. How many tries did it take before you hit the target? What strategy did you use? Be ready to discuss it with the rest of your group.

6. What behavior of light are you investigating in these experiments?

B. Create-A-Tour Give the students a copy of the text and the map and ask them to create a hypothetical "walk" of things they would like to see when they come to visit Adams Point. They can include any of the habitats previously mentioned, along with at least five places in the Uplands section. They can choose several plants from among those mentioned on the map and look them up in references such as the following:

Newcomb's Wildflower Guide by Lawrence Newcomb.

Edible Wild Plants by Dr. Garrett Crowe and Richard Fralick. Available from the Marine Education Resource Center (MERC), Sea Grant Extension Office, UNH, Durham, NH.

Wildflowers of Eastern America. by John E. Klimas and James A. Cunningham.

Students should create a guide for themselves so that they can identify four plants in the wild. A piece of paper folded in quarters with a picture and important facts about each plant on each quarter makes a handy pocket-sized reference.

a. Describe the soil (type and condition) the plant grows in.
b. List at least one type of plant that grows with or near it.
c. List any animal signs associated with it.
d. Sketch it, paying attention to leaf shape, arrangement on the stem, whether there are fruits or seeds, etc.

C. Rare Species and Their Protection Try to show how rare plants and animals are protected by local, state and federal laws. Consult the Great Bay National Estuarine Research Reserve Management Plan (available from the MERC and the Great Bay National Estuarine Research Reserve office) for a list of endangered species in the Great Bay Estuary. Create a bulletin board display and/or poster and give a session for the class or for some younger students. Collect newspaper articles describing the progress in designating part of Pease Air Force Base a national wildlife refuge.

D. Food Chains in the Uplands Develop some food chains for estuarine animals and plants that include some of the plants mentioned on the map. Do a poster showing the food chains and display it for your class.

4. **Recipes with Wild Plants** Do research to find some of the recipes associated with glasswort, cattails, New Jersey tea and sumac. Then gather one of the plants needed on the Great Bay Living Lab Day and make the recipe afterwards.

GREAT BAY LIVING LAB DAY ACTIVITIES -- UPLANDS

A. Be an Expert.

Purpose: To give students a chance to use the guides they made up in class.

Procedure:

1. Each student should select one flower, tree or shrub to focus on during the walking tour of the uplands.

2. Using the guide that they made for themselves in the classroom exercise, they should find their plant and check the information they researched against their own on-site observations. Make notes on:

   - the soil (type and condition) that you see the plant growing in.
   - the type of plants that you see growing with or near it.
   - any animal signs you see associated with the plant.
   - its features and then sketch it, paying attention to leaf shape, arrangement on the stem, whether there are fruits or seeds, etc.

3. After the walk, or back in the classroom after a general discussion of what was observed on the trail, make up a game show in which each student participates by utilizing their descriptions.

B. Identify Herbs, Grasses and Trees

Purpose: To categorize meadow plants into three major classes using a random sample technique.

Materials: l/2-meter hoops (you can make them of stiff wire), pencils, clipboards.

Procedure:

1 Walk around the meadow (it is a rectangle about 50 meters by 90 meters), using the material in this chapter and noticing all the plants.

2. Divide students into groups of two or three and give each group a l/2-meter hoop

3. Have the students spread out across the meadow.

4. Have them throw the hoop three times, each time counting and recording the percent cover within the hoop of three general species groups:

grasses (hollow, jointed stems) ----

herbs (non-woody stems) ----

trees and shrubs (woody stems) ----

a) Multiply by two to find the percent cover per meter.
b) Enter on a large chart and average.
c) Multiply the area of the meadow by the average number of each type of plants per meter.
d) Look over the meadow to see if the class thinks this is an accurate way of making an estimate of percent of the three species groups in the meadow. Why or why not? What could make it more accurate?

Throws	% of cover Grasses	% of cover Herbs	% of cover Trees/Shrubs
Average			

C. A Sensory Index for the Uplands of Adams Point

Purpose: To use all the senses in studying the uplands.

Procedure: During the walk, have students do some sensory activities so that they develop a sensory index, including smells, shapes, textures, colors, etc. They will then use them to describe their experience back in the classroom through a variety of mediums: poetry, art, etc. They can use the chart below to guide and record sensory perceptions they experience. They should be encouraged to smell, touch, look closely, and listen carefully. It is helpful if the teacher can take the uplands walk ahead of time.

Sensory Index for Adams Point

Name ______________________

Date ______________________

Textures:

rough: (Example: bark of the shagbark hickory)

smooth: ______________________

waxy: ______________________

stickery: ______________________

fuzzy: ______________________

Colors:

bright red: poison ivy, glasswort, sumac leaves and fruit

____

yellow: poison ivy leaves

____

blue: sky ______________________________

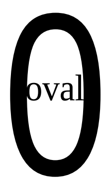
____

Smells: Example: salt air, rotten egg smell

____

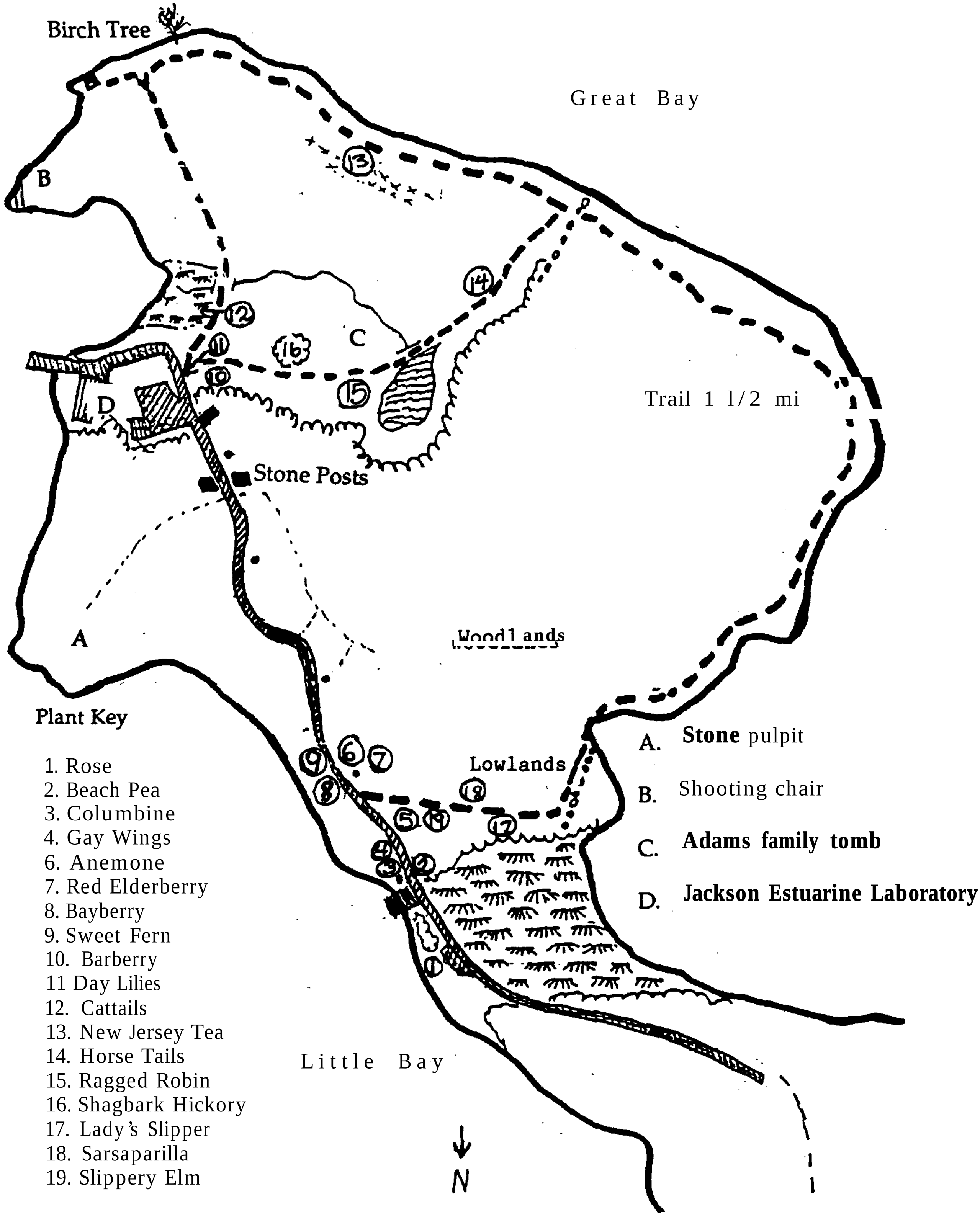
____

Shapes: Look around and see what shapes you see: oval, round, square, rectangle, triangle, trapezoid, etc. Draw the shape, and then look to see how many other things are same shape and list them. For example:



- birch tree
- leaves of the bayberry bush

Walking Map for Adams Point



THE GREAT BAY ESTUARY: THEN AND NOW

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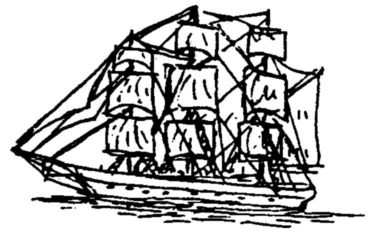
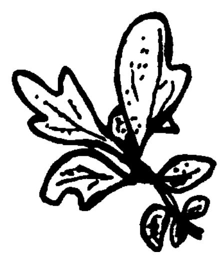
EARLY DAYS ON THE ESTUARY



YOU ARE THERE, aboard Captain Martin Pring's ship, the Speedwell. The date is June, 1603. The ship anchors among the islands at the mouth of the Piscataqua River, and you board one of the longboats to move upstream to look for sassafras (a plant used for medicine in those days), and for fresh water.

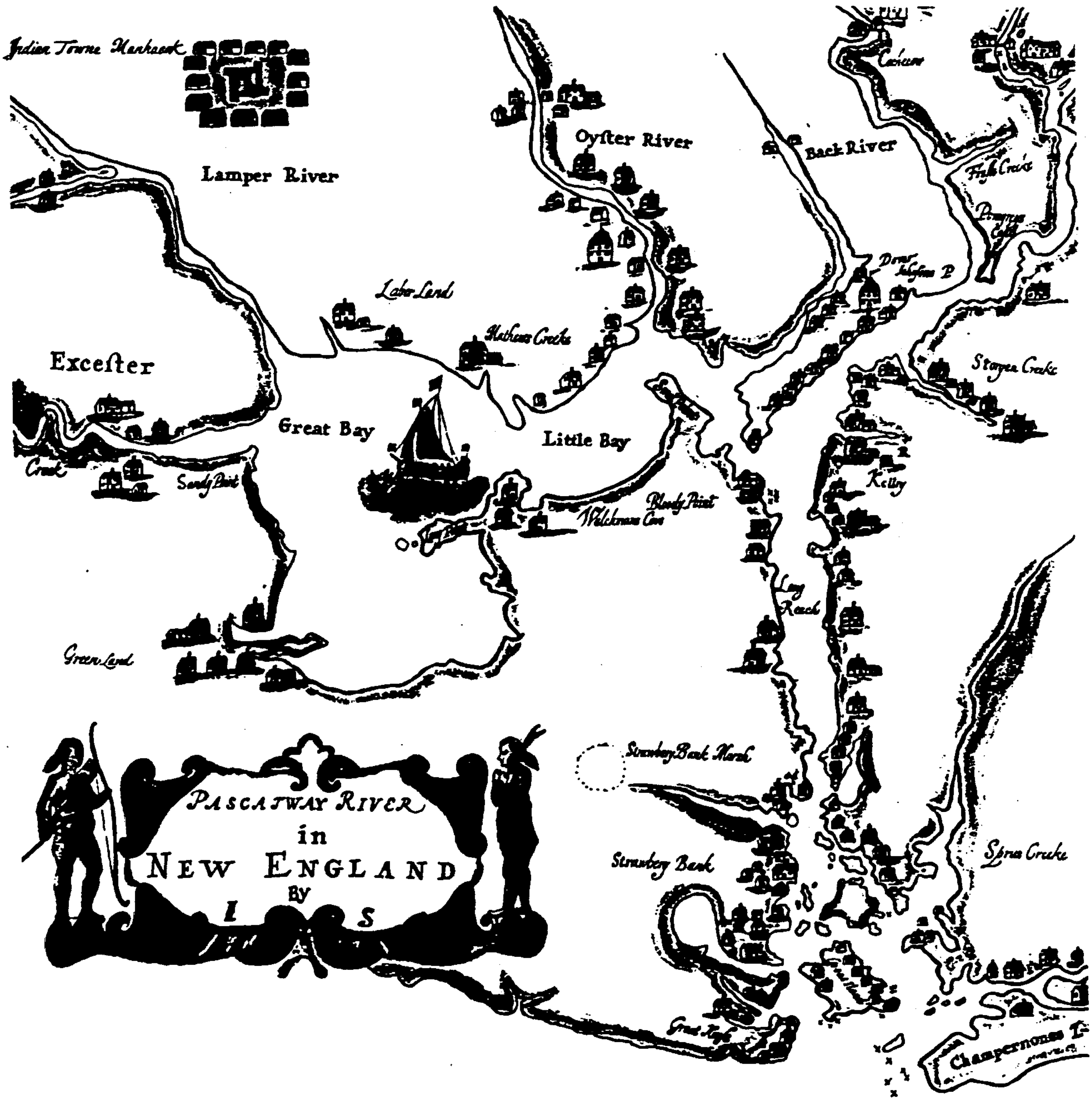
You pull at the oars, but it is an easy task because you are being pushed by the incoming tide. Seven miles upriver, you head west, riding the swift currents into a small bay. Rowing past the mouth of a small river you watch a tall blue heron spear fish with his sharp beak, as he stands near the fringing salt marsh. You pass another river mouth and, then, your small boat shoots forward, through some narrow straits into a large bay. Looking into the murky waters, you notice eelgrass growing just below the surface, and you guide the boat along the channels through the grass toward shore. Landing, you look around at the bay and at the tall pines that grow almost to the waters' edge. Captain Pring records in his diary that you see "sundry sorts of Beasts, as Stags, Deere, Bear, Wolves, Foxes . . . and Dogges with sharpe noses".



Finding no sassafras, you collect some fresh water for the voyage back to England and leave Great Bay, rowing back up the river to the ship. Tomorrow you will sail away on the rising tide.

Soon other Europeans will learn of your discovery, and begin to cross over from Europe to start settlements, such as Strawbery Banke (now Portsmouth). Some say that the Great Bay Estuarine System was the birthplace of New Hampshire.

Look at the map below, drawn in the early 1700's, and trace your imagined journey with Master Pring. Perhaps you will want to learn more about the discovery of Great Bay and the native Americans, the Abenaki, who lived there for many years before the coming of Europeans.



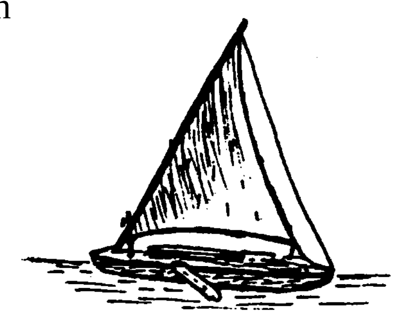
based on ancient maps (notably Americanus 1670)

People came from Europe to settle the Great Bay area because its natural resources made it possible for them to make a good living easily. They came to fish and to hunt animals for their hides from which leather could be made.

Some came to harvest the tall, straight spruce trees that lined the Bays and the rivers. They would be shipped to England to use for ships' masts. The huge trees were trailed by teams of oxen from the forests to the "mast schooners" waiting to take them across the Atlantic. Trees were marked with the King's broad arrow, and no one could cut them without the king's permission. Some of those trees still stand today.

Sawmills sprang up along every river, milling wood to build houses and shops. Shipyards along the Bay and in the new towns of Portsmouth, Newmarket, and Dover bought timber from mills nearby to build ships. Sometimes ships would actually be built inland, then taken apart, pieces carefully numbered, and put together again on the shores of the Bay.

In the winter, farmers built gundalows which were, flat-bottomed barges with single triangular sails. They cut wood, loaded it onto the gundalows and floated it down in the spring to the brickyards that lined the mouths of the rivers. There was plenty of blue clay to be found along the riverbanks. Bricks made from this clay were used to build many buildings in Boston, including those on Beacon Hill.



The gundalow was used for almost 300 years to transport goods and supplies between the coast and the inner parts of the state. An exact replica of a gundalow, the "Edward F. Adams" was recently built. It is named after one of the last gundalow captains. Mr. Adams lived at Adams Point, in a house that was built on the site of what is now the parking lot for Jackson Laboratory. The gundalow is moored in York, Maine each winter, and every summer it sails to various ports in the estuary, to introduce people to this important part of the region's history. It is often featured in public celebrations.

HERE AND NOW IN THE ESTUARY

How do people use the estuary today?

Recreation

Looking across Great Bay on a sunny Saturday, and you see sails bending before the wind, small motor boats darting to and fro, and even an occasional skier skimming over the water. At the mouth of the Bellamy River, windsurfers whiz across the broad embayment. People trudge along the bridges, carrying fishing poles, and you may see someone just sitting in a lawn chair near the car, enjoying the sun and fresh air. At Adams Point, some hardy oystermen wade in the water waist-high, dredging for oysters with a special rake. In the winter, small "bob houses" dot the frozen parts of the estuary. Inside people are fishing for rainbow smelt and white perch. Almost any time of the year, people drive to scenic spots along the estuary to eat their lunch, to hike, and just to enjoy the views.

Bird-watching is popular and salt marshes are favorite places to observe herons, egrets, and other wading birds. Since the estuary is on the New England flyway, land birds appear during their migrations. In winter, members of the Audubon Society record the return of the American Bald Eagle to the shoreline on both sides of Great Bay.

Fishing

Recreation is not the only way the estuary is used by people. Some people make a living from it. Commerical fishing is a good example. There are lobstermen who set hundreds of traps both in Little Bay and on the Piscataqua River. The Great Bay Lobster Company buys fish and shellfish from commercial fishermen, services their boats and loads them up with ice and fuel for the next cruise out into the Gulf of Maine. Further down, toward the mouth of the river in Portsmouth is the Portsmouth Fishermen's Co-op. Here more than 20 fishermen have joined together to buy ice, fuel, and supplies and sell their fish. The Co-op takes their fish and sells it to local restaurants and seafood stores. Some of the fish are taken to Boston where it is auctioned off for the best possible price.

The fishing industry is dependent on fairly clean, undisturbed environments for fish, shellfish, and clams. More than 70% of the fish and shellfish along the coast depend upon the estuary for food, shelter and as a nursery for their young.

Research

The Great Bay Estuary is also a "living laboratory" where research is conducted by the New Hampshire Fish and Game Department and by scientists from the University of New Hampshire (UNH) and other universities. Some of these projects include: studies of eelgrass beds and life cycles of animals and plants that live in the estuary; studies on the micro-organisms that cause disease in humans; seaweed research which has been a major study topic for many years; a complete bathymetric map of the estuary that is being complied; and a complete profile of the estuary being completed by UNH's Jackson Estuarine Laboratory and will be used as a base from which to measure all future changes.

The University of New Hampshire's Coastal Laboratory at Fort Constitution near the mouth of the estuary in New Castle can provide "almost ocean" conditions in its flow-through sea tables. Graduate students as well as university scientists carry out research there.

Education

Educators use the estuary as an outdoor classroom. The University of New Hampshire's Sea Grant Extension Program runs several programs there. Marine Docent volunteers take people on tours of Jackson Estuarine Lab, explaining the ongoing research and how it relates to the estuary. They also help to staff the Great Bay Living Lab program for educators and students from grades 7 through 12. Ninth graders from New Hampshire and Maine come to study the estuary through the popular M & M (Math and Marine Science) program in the summer.

Industry

All along the New Hampshire side of the Piscataqua River, there are "tank farms" for the storage of oil products that are shipped all over New England. There is a small oil "eco-separator" refinery, a concrete storage tank, and a cable-laying company. Three electrical plants dominate the skyline and there are several marinas. Most of the rivers have harbors with docks and moorings for recreational boats. The Main side of the estuary has fewer commercial and industrial sites, but it does have the Portsmouth Naval Shipyard where nuclear submarines are repaired.

A Place to Live

Land use is changing in the estuarine watershed. In the 1950's, forests and farms covered most of the land. By the 1980's developed lands where people lived and industries were situated had increased by about 25%. The area still has forests and wetlands, however.

More and more people are moving into the watershed area of the estuary, building homes and condominiums near the shore. In New Hampshire, much of the use of the land is regulated at the local level. For example, towns decide what the width of the "set back" from the shore of a river or lake shall be. Buildings cannot be built within 100 feet of a river in Lee. In Dover, there is no set back ruling.

In Portsmouth there is a new hotel, only a few feet away from the harbor. There in the picturesque waterfront area, restuarants and boutiques compete with tugboats and the salt pile for space.

In Newington, Pease Air Force Base is closed and the State of New Hampshire is taking over the land. A commercial airport is planned for the area. People from towns along the estuary are concerned about noise and air pollution from frequent passenger and cargo flights. There is no provision to deal with the increased automobile and truck traffic on the already crowded highways that will be used by airport customers. Some portion of the land will most likely be saved for a wildlife refuge since some endangered American eagles stop there in the winter. But how compatible is a wildlife refuge with heavily used runways?

The tiny New Hampshire coastal area is getting more and more crowded. What does this mean for the Great Bay Estuary?

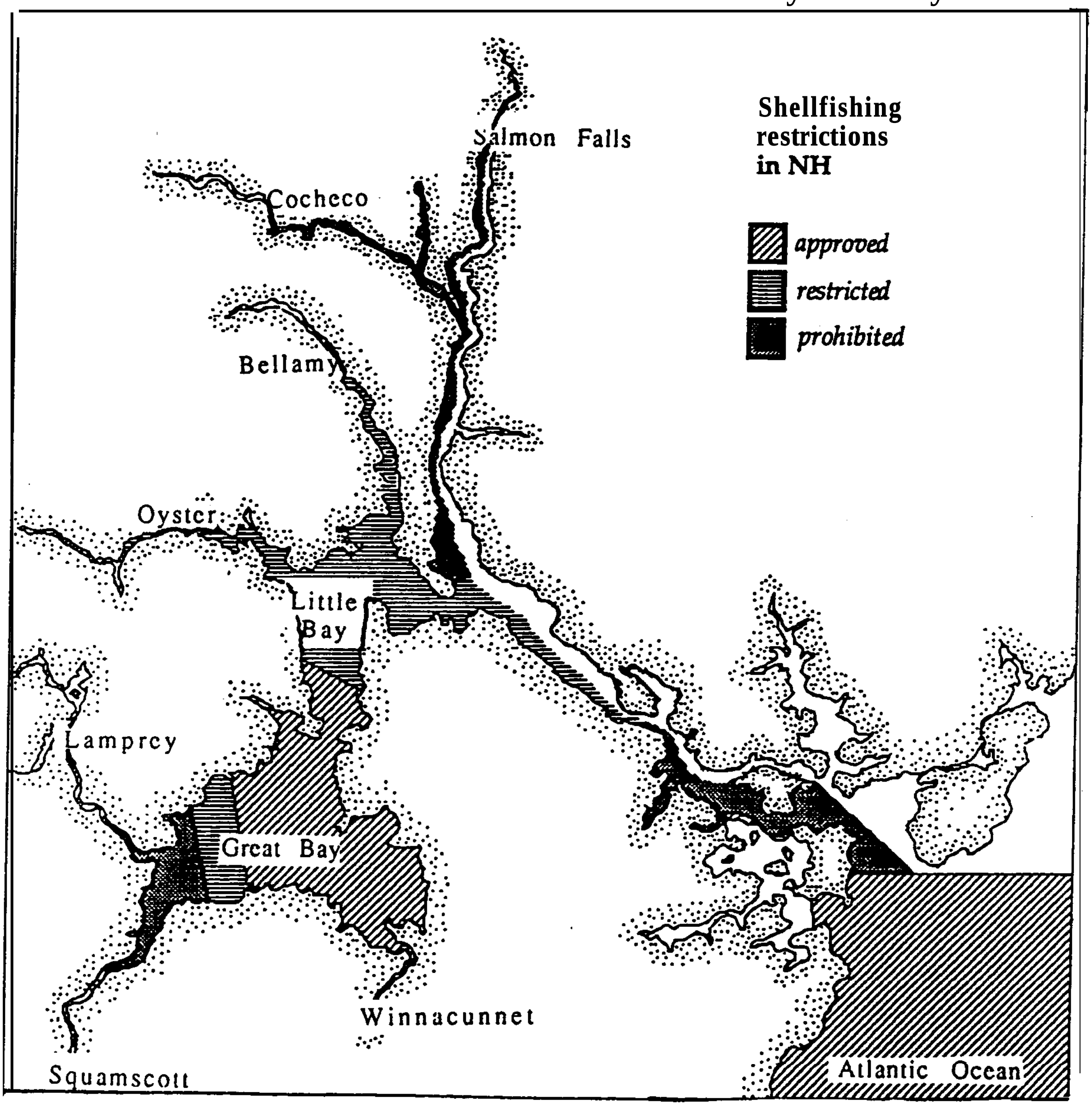
THE GREAT BAY ESTUARY: HEALTHY OR NOT???

People have long thought of the estuary as a clean, safe place. They use the estuary for recreation, education, research, industry and live on its shores. But just how clean is it?

Shellfish Bed Closings.

For the past several years, many of the shellfish beds in the Great Bay Estuary have been closed.

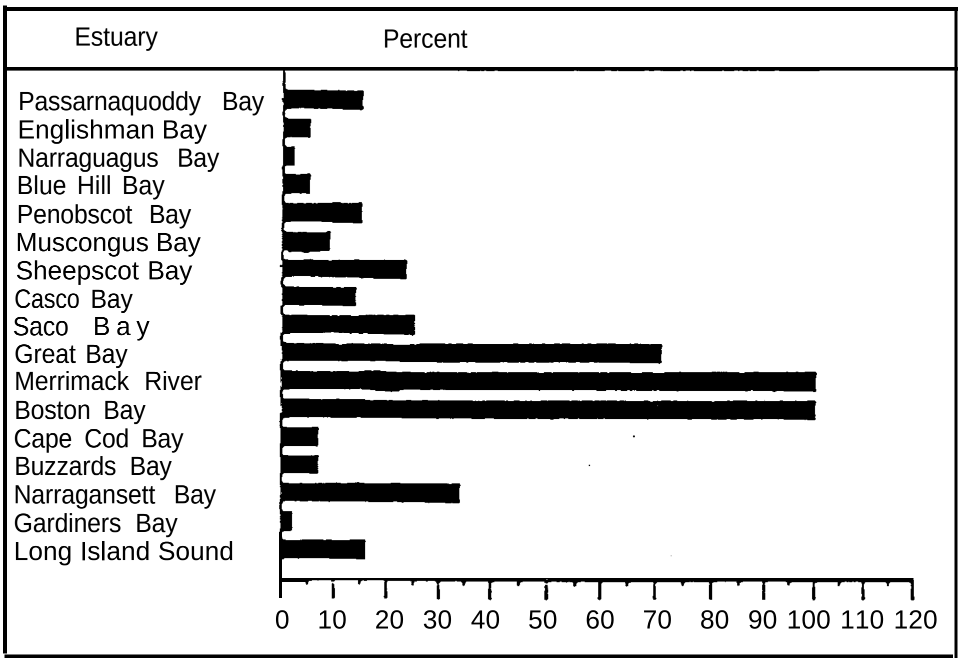
Shellfish Bed Closures in the Great Bay Estuary



The New Hampshire Department of Health takes water samples all over the estuary and counts the coliform bacteria present in the samples several times a year. Coliform bacteria from both animals and humans are called "indicators". Wherever coliform bacteria are present you also find the more dangerous viruses and bacteria that cause human diseases such as gastro-enteritis, polio hepatitis, meningitis, etc. If the coliform count is more than 70 per 100 milliliters of water, then filter feeders like clams, mussels, and oysters living in that water cannot be safely eaten because they concentrate these disease-causing organisms in their bodies. Although the animal doesn't get sick, humans who eat them, may.

Great Bay proper had the third highest percentage of shellfish bed closings in New England in 1989. All other estuaries listed are in Maine or Massachusetts.

Harvest -Limited Shellfish-Growing waters by Estuary in New England. (Great Bay Estuarine Trust Newsletter, Fall, 1989).



Sewage

Why are the shellfish beds closing all around New England and in the Great Bay Estuary? Mainly because of pollution coming from sewage-treatment plants and septic systems that drain directly into the water. As more people move to the area, there is more and more sewage coming into the treatment plants. Some of them just aren't adequate enough to take care of the added waste.

Combined Sewer Outflows

Many towns have **combined sewer outflows** (CSO's) where sewage and debris from the town streets and parking lots flow through the same pipes to the sewage treatment plant. When a storm occurs, all the storm water plus sewage is brought to the sewage treatment plants and they simply over-flow, with some untreated sewage running into the rivers and out into the bays.

Sewage Treatment Plants

Sewage treatment plants are very important, but they are also expensive. Sometimes towns don't have enough resources to upgrade their plants from **primary treatment** which settles out the solid portions and drains off the liquids. Everything is treated with chlorine to keep bacteria and viruses at a safe level. Then the liquid is drained into rivers.

Secondary treatment plants like the one in Durham are better. They aerate the sewage and mix it with bacteria that actually "eat" it. The liquid is drained off, treated with chlorine to kill, harmful micro-organisms, and drained into the Oyster River. The sludge or solid portions are composted with sawdust. Bacterial action causes the mixture to heat to high temperatures, eventually killing the bacteria and making the compost safe to use on non-edible plants. Of course, they always keep a good supply of bacteria for the next batch of sewage.

Now, however, scientists are finding that chlorine has a very harmful effect on zooplankton, and are beginning to question its use. Much more expensive processes may be needed to replace chlorine treatment. Ultra-violet light as a disinfectant may be one solution. However, most people agree that more research is needed to solve this problem.

Something is being done about the problem of sewage. Some towns along the rivers of the estuary are trying to upgrade and enlarge their sewage treatment plants. This is very expensive, but absolutely necessary. In the years between 1990 and 2000, the population in those towns around Great Bay proper will increase 22 percent. More people means more sewage. Dover and Exeter are building new secondary treatment plants. Newmarket has just completed theirs. But some cities are still dumping raw sewage into the rivers, even though it is against the law and they have to pay fines. Since the estuary is one system, what happens in **one** area affects the **whole** estuary.

Other Sources of Pollution

Runoff, oil, exhausts. Other sources of pollution are not as easy to track. When we aren't sure of the exact source, we call it **"non-point"** pollution. Run-off from parking lots and highways bring toxics from oil and car exhaust fumes containing nitrous oxide. Fumes from cars and trucks are a cause of acid rain since nitrous oxide is one of its principal ingredients.

Farms, lawns, golf courses. There are still some farms along the estuary's shores. Homes are built and lawns and gardens fertilized. New golf courses are planned for the area, and they, too, will be fertilized extensively. Fertilizers and manure contain nitrogen and phosphorus, the basic nutrients needed for plant growth. They are washed out of the soil by rain and run into the estuary. Plants need some nutrients in order to grow, but if there are **too many** nutrients, there will be too many plants in the water. They will shade each other from the sun and many will die. As they die, oxygen will be used up and **eutrophication** will take place. While there. don't seem to be high levels of nitrogen and phosphorus in the estuary now, we don't know at what point levels could become too high.

Toxic wastes and heavy metals. We know that there are **toxic substances** in parts of the bottom of the estuary. Dover once had very active factories for tanning leather. Chromium, a heavy metal, is used in the tanning process. All chemical waste used from the processes were dumped right into the Cocheco River where heavy metals such as chromium are held by the sediments. It is suspected that toxic wastes seep into the estuary from places like Pease Air Base and the Portsmouth Naval Shipyard Both Maine and New Hampshire and the federal Environmental Protection Agency (EPA) are now investigating the land and water near the shipyard to check for toxic wastes.

What are toxic wastes? Sometimes they are chemicals in gas or liquid form. Sometimes they are metals that settle out of substances used in factories. Heavy metals such as cadmium, lead, nickel, zinc, and chromium bond tightly to particles of sediment and then settle to the bottom where they are covered with new sediments. If the sediment is disturbed, sometimes the heavy metals break loose from the particles to which they are bonded, and re-circulate into the water. There they can be swallowed by fish or filter feeders and eventually make their way up the food chain. Many toxic wastes cause disease in humans and other animals.

Bilges and oil spills. Ships and boats that pump oily water from their bilges into the water pollute the oceans and estuaries. A major oil spill in the Piscataqua River is difficult to clean up before the swift currents push it all through the estuary.

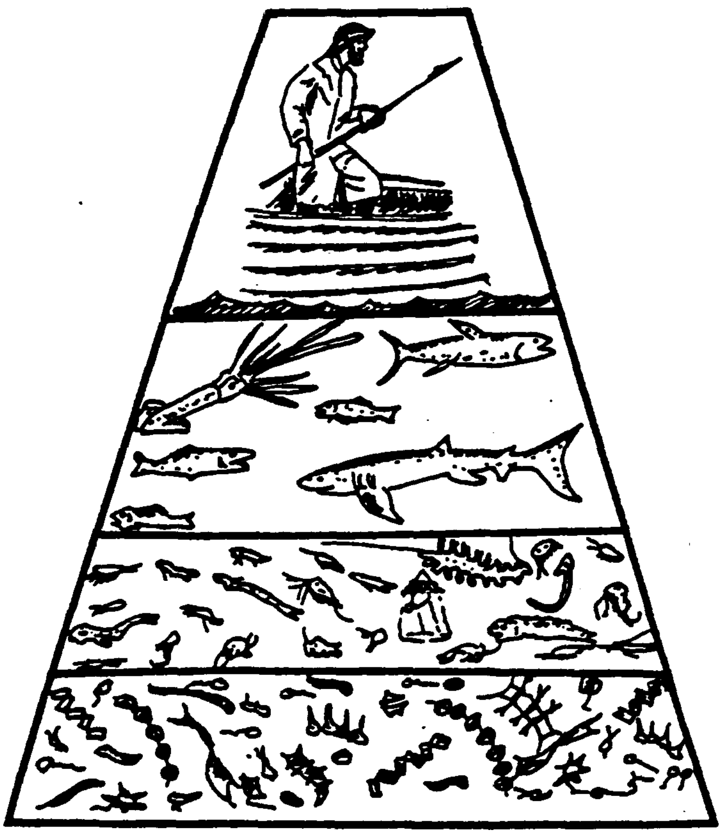
Heated water. Two fossil fuel power plants on the Piscataqua River use water to cool their generators. It is flushed back into the estuary at temperatures as much as 25 degrees Farenheit higher than the water as it is entering. When heat stresses an organism so much that it may die, it is considered a pollutant. However, some animals can grow readily in warmer water. Flounder were being grown experimentally in the heated water that the Newington power plant releases. The experiment was abandoned when it was impossible to synthesize the correct food for the fish at a certain stage of their life. But they did grow faster in the heated water than they would have in other parts of the estuary.

Effects of Pollution

Some pollutants may collect in the food chain by a process called bio-accumulation. The process begins as phytoplankton (producers) each accumulate small amounts of a pollutant. The zooplankton (primary consumers) then feed on the phytoplankton and concentrate higher amounts of the pollutants in their bodies. Small fish feed on the zooplankton, and the process snowballs. For example, if:

1 million phytoplankton each accumuIate one part DDT, and
They are eaten by 100,000 zooplankton, and
100 smaII fish eat the zooplankton, and
1 mackerel eats the 100 small fish.

Then DDT is passed along in higher and higher concentrations until it reaches the highest members of the food chain. Humans are at the top of some food chains and receive a much higher concentration of pollution than is present in the surrounding waters.



Red Tide

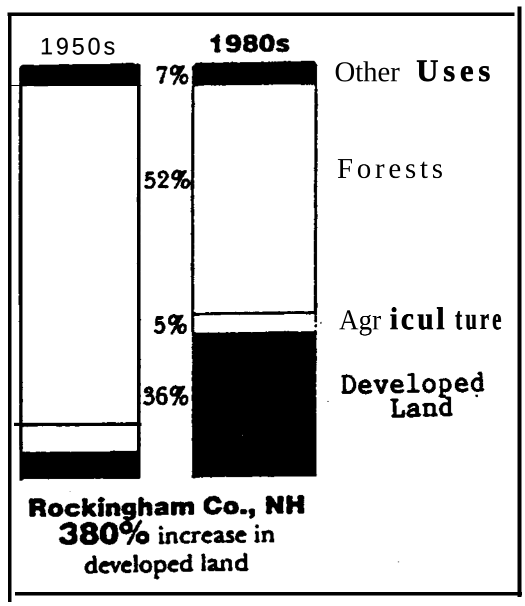
Pollution may be one of the reasons that "red tide" is spreading. During the summer and fall people are warned, not to collect mussels or dig clams and oysters from areas where the water contains too high a level of a particular dino-flagellate. This organism is called Alexandria tamerensis. Filter feeders like clams, mussels, and oysters concentrate red tide organisms in their bodies at many times the level they exist in the surrounding water.

Red tide does not hurt the filter-feeder. But when humans eat the shellfish, they are getting a huge dose of the saxitoxin which Alexandria contains. They develop paralytic shellfish poisoning (PSP), for which there is no known cure. The first symptom is numbness of the lips and fingertips, soon the person can no longer breathe. Clam flats and oyster beds in the estuary have been closed each summer because of red tide, even though it is much more prevalent on the coast.

Pollution is a big problem, one that increases as more and more people and industries move towards the coasts all over the world.

Predicted Population

	1960	2000
Dover	19131	30534
Greenland	1196	3884
Madbury	556	1658
Newfields	737	1330
Newington	1045	7983
Stratham	1033	5992



Information for both charts from the Great Bay National Estuarine Research Reserve Management Plan, N.H. Office of State Planning, 1988.

CONSERVING THE RESOURCE FOR THE FUTURE

What can be done to improve and protect the Great Bay Estuarine System now and in the future? Wise management and regulation of the resource are required, and steps are being taken in that direction by several means.

The National Estuarine Research Reserve System

Recognizing that estuaries are "nurseries of the sea", and concerned with their rapid deterioration, the National Estuarine Research Reserve System was established by the U.S. Congress as a part of the Coastal Zone Management Act of 1972. It is administered by the National Oceanic and Atmospheric Administration through its Santuaries and Reserve Division.

To date, 19 different types of estuaries have been selected across the United States for reserve status. They include some fresh water estuaries such as Old Woman Creek in Ohio. Several are located on islands. The Waimanu Valley in Hawaii is one, and Jobos Bay in Puerto Rico is another.

Noting that many estuaries in the Northeast are heavily impacted by pollution, four reserves are located there: in Wells, Maine, at Waquoit Bay on Cape Cod, Narragansett Bay in Rhode Island and recently, Great Bay in New Hampshire.

In October, 1989, Great Bay proper was officially designated the **Great Bay National Estuarine Research Reserve.** The **New Hampshire Fish and Game Department** is responsible for management of the Great Bay Reserve. A reserve manager is coordinating both research and education for the Reserve. An education facility is planned for property belonging to the Reserve in Stratham. A system of trails, and an improved boat ramp, the latter being funded by the Fish and Game Department will complement educational program.

NATIONAL ESTUARINE
RESERVE RESEARCH
SYSTEM

Preservation,

The main purpose of the Reserve is to manage the Great Bay waters and its shoreline so that natural resources are protected and the existing and traditional uses are preserved. One of the ways to ensure this is to acquire land to form the Reserve. Land is being protected through the purchase of conservation easements from landholders and outright buying of land. Easements encourage conservation uses of the land. Lands that are acquired in this way are combined with public lands already owned by the local, state and federal governments to form the Reserve.

Educating the public and involving them in aspects of preservation are also important goals of the Reserve. Property at Depot Road in Stratham, N.H. was purchased for the reserve and it is here, overlooking Great Bay, that a small education facility will be built. Programs for schools and the general public will be developed and people visiting the Center will be encouraged to use the outdoors like a classroom to learn more about the Bay. A boardwalk through the salt marsh will be built and several hiking trails created, as well as a boat landing area.

Additional State Support ,

State Coastal Programs in both Maine and New Hampshire work with management of the entire estuary. For example, in New Hampshire, plans for how best to manage the "hidden harbors" of the Lamprey River in Newmarket and the Cocheco River in Dover have been done. Maine has issued a permit to harvest oysters near the shoreline of the Piscataqua at Eliot, provided the harvester “cleans” the oysters of harmful micro-organisms before selling them. The company uses ultra-violet light to kill bacteria and viruses in estuarine water. Clams and oysters are placed in this sterilized water, and they siphon it through their tissues, washing the bacteria and viruses away.

Education and Public Support.

Public education about the estuary is occurring in various ways. One of the newest educational programs about Great Bay is **The Great Bay Watch.** Teams of adult and student volunteers monitor the temperature, salinity, dissolved oxygen content, and turbidity of the estuary at ten sites. They take their samples twice a month and provide data for researchers and private and public agencies.

People from the surrounding communities have formed a group called the **Great Bay Estuarine System Conservation Trust.** These dedicated citizens have provided input about the estuary to local, state and federal planners for the past several years and provided many public programs. They work closely with the Great Bay National Estuarine Research Reserve. Recently they have been granted funds to do a shoreline bird study along the Great Bay proper.

The **Piscataqua Gundalow Project** is interested in tying together the past history of the estuary with the present. The "Edward F. Adams" is an exact replica of the last gundalow to ply the waters of Great Bay. It serves as a floating museum, moving from town to town to present programs on the estuary. There are materials for educators and a large exhibit at the John Hancock Warehouse in York, Maine.

The **Isles of Shoals Steamship Line** brings its large boats, "The Thomas Laighton," and the "Oceanic" up the Piscataqua River into the bays, packed with visitors, inspired by the sort of "eco-tourism" opportunities the cruise presents. **Portsmouth Harbor** Cruises also has an inland river cruise which noses its way into the Cocheco and Lamprey Rivers.

Other citizens' groups such as the **Lamprey River Association** and the **Strafford Rivers Conservancy** sponsor programs that are designed to encourage the public to appreciate the rivers of the estuary.

Research.

The Great Bay National Estuarine Research Reserve Management Plan lists the following items as targets for research. Researchers at Jackson Estuarine Lab and elsewhere have already begun to make some a reality:

1. Establish priorities for research.

2. Support baseline monitoring and develop a scientific profile of the Great Bay.

3. Enhance contact and collaboration among groups with estuarine research interests.

4. Recruit researchers to the Reserve.

5. Incorporate research results into the Reserve's education and interpretive programs.

6. Be a source of reference materials on Great Bay.

7. Make data and results of research available to the public.

8. Work on coordinated programs with other Reserves.

It is hoped that through the efforts of educational programs, research, and wise management practices, that the fragile balance of the productive Great Bay Estuarine environments may survive the onslaught of increasing human population demands. Appreciation and concern must come first. When scientists, ordinary citizens, government agencies, and students and teachers become concerned about a resource like the estuary, they will find ways to ensure protection of that resource.

CLASSROOM ACTIVITIES - THE GREAT BAY ESTUARY THEN AND NOW

The Great and Little Bays (Adapted from Project Wild Aquatic)

Note: This might be a good ending to a unit on the estuary.

Purposes:

1. To have students be able to evaluate the effects of different kinds of land use on estuarine habitats

2. To discuss and evaluate lifestyle changes to minimize damaging effects on the estuary.

Method: Students create a collage of human land-use activities around an image of Great and Little Bays

Background: Every human use of land affects wildlife habitat, positively or negatively. What humans do with the estuary is a reflection of their priorities and lifestyles. The conveniences that we all feel we can't live without produce mixed results for the natural environment.

There is conflict, too, between people who believe that the natural environment is there for humans to use and exploit in any way they want, and those who think it must be preserved. Some want a balance between the economic growth that gives us those conveniences and a healthy environment. At the middle of the conflict is the concept of growth.

In most systems control of growth is a part of the self-regulatory process which takes into consideration all needs of all parts of the system. The vitality of any eco-system is shown by its ability to be self-regulating. By not considering themselves a part of the natural environment, but somehow above and apart from it, people often damage its natural dynamic balance. Often we upset this balance through the ability to import energy sources that allow a system to exceed its natural limits. Sometimes we rob a system of energy that it must have in order for it to stay in balance. An example of this occurs when people build dams to create power or to capture water for irrigation. These activities affect wildlife habitat.

The question now is how to develop the awareness, knowledge, skills and commitment that are necessary in order to take responsible actions to restore the balance that will allow systems like the estuary to continue. The Great Bay estuarine system is already out of balance. Its shellfish beds have been closed for three years almost throughout the estuary. Oil slicks lurk under the water, damaging lobster habitat and fishing equipment. Oil spills on the river are fairly frequent, and many go unreported.

Materials: For every three students: scissors, masking tape, paste or glue, posterboard 18 x 24, one set of land use cutouts, and a large piece of paper with an outline map of Great and Little Bay (11 x 17 inches) upon which to fasten the cutouts. (Use the map from the appendices, adjusting it until you have a map that shows only Great and Little Bays as large as possible on the 11 x 17 inch paper. Most copiers have magnification abilities.)

Procedure:

1. Prepare copies of the Great and Little Bay outline map and the land use cutouts ahead of time. Tell the students they will be responsible for arranging the pattern of use of the estuary in such a way as to do the best they can to preserve the health of the Bays.

2. Divide the class into groups of three or four students, with each group representing one of the interest groups. You can generate the list of interest groups from the students, or you can just pre-assign the groups. Some interest group examples are:

   *residents who want to live in the area
   *farmers who want to have farms down to the water's edge
   *airport developers
   *harbor developers
   • gas station owners
   •steel mill owner who wants to relocate the mill to this area
   •parks department employees
   *teachers
   *leather tannery representatives who want to preserve jobs
   *blue-collar worker
   *university professor
   •others that the students may name

3. Pass out the estuarine system use materials and the large paper that will serve as a base for the group's bays and associated activities

   Tell the students that **all** cut-outs must be used, they can be cut smaller than they are but all the parts must be used. They may touch, but they cannot overlap. The students may create additional land uses on the blank forms. Use tape loops to fasten the land uses to the paper so that they can be moved around.

4. Before the students can use the land use cutouts, they must create a list of pros and cons for each land use. These can be recorded on the chalk board.

   Here's an example:

   Farms

Pro	Con
-produce food	-pesticides are used
- economic value	-cause of soil erosion
-provide jobs	-sometimes wetlands drained to make farmlands

5. Have the students work in their teams for 45 minutes or more.

6. Each group will display and describe their work in progress. Encourage discussion of choices. In discussions emphasize that:

   •no land use can be excluded.
   •the estuary must be preserved and wildlife habitat conserved.
   *everyone must agree.

7. Through discussion, and brainstorming when problems are faced, create a land use plan for the bays that will accommodate all uses with the proper precautions.

8. Ask the students to create a list of things they can personally do to begin to reduce the potentially damaging effects of their own lifestyles.

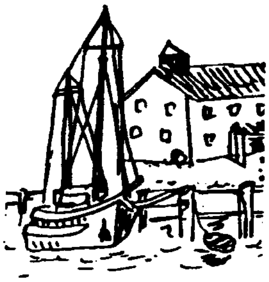
9. Create an **action team** to keep watch on the estuary through the media, to research protective laws and regulations, and to identify organizations that are working to protect the estuary. Devise ways to keep everyone informed such as:

- an action board with news clips, slogans, etc.
- weekly radio broadcast over the school's loudspeaker
- investigate the possibilities for becoming part of the Great Bay Watch, a citizen water monitoring group for the estuary.

The team may also want to write a resolution pertaining to conservation of the estuary's natural resources that could be introduced in the state legislature or through local town meetings.

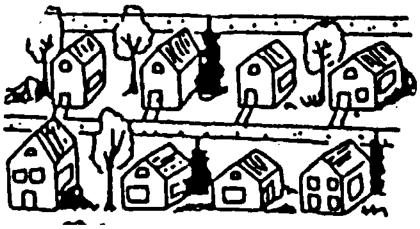
Field trips to various points of interest along the Bay for the purpose of making a video or still photographic record of the estuary might be another activity for the team.

Land Use Form Sets. (Duplicate as many as needed so that each group can have a complete set. Students may want to suggest some other uses for some of the blank forms.)

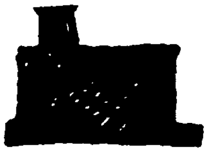


MARINA

POWER PLANT



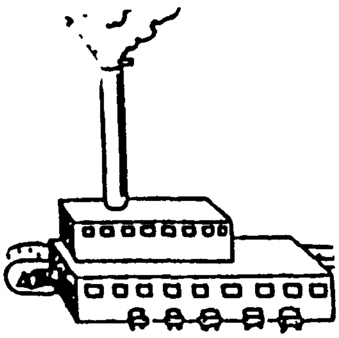
HOUSES



SEWAGE

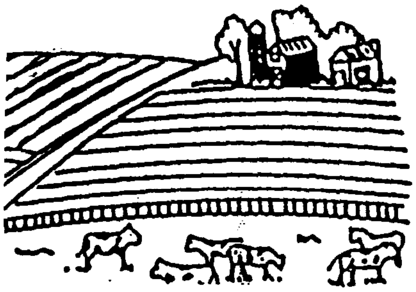
TREATMENT

PLANT

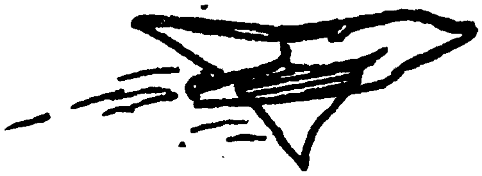


FACTORY

WILDLIFE SANCTUARY



FARM



AIRPORT

APPENDICES

TABLE OF CONTENTS

RESOURCES

Most video tapes, slide programs and publications listed below can be found in the Marine Education Resource Center (MERC) at the Sea Grant Offices, Kingman Farm, University of New Hampshire. They are loaned free of charge to participants in the Great Bay Living Lab Program. The locations of resources to be found elsewhere are noted at the end of that entry.

Video Tapes

Ammon Rock, A Mountain In The Sea, This program covers a special environment which is located about 150 miles offshore in the northern Gulf of Maine. It includes scenes of divers and various types of underwater equipment (20 minutes).

Estuary. Explore the biologically important wetlands where the rivers meet the sea. Excellent underwater microphotography allows for a close-up view of this delicately balanced ecosystem (12 minutes) N.H. Fish and Game Dept., 2 Hazen Drive, Concord, N.H. 03301.

The Intertidal Zone. This program explores the zone between high and low tidal areas. Incredible underwater photography brings you eye to eye with animals and plants that have adapted to living in this harsh environment (17 minutes). N.H. Fish and Game Dept., 2 Hazen Drive, Concord, N.H. 03301.

Not Just Another Fish Story. The fishing industry in the Gulf of Maine is described, from the seafloor to the dinner table (30 minutes).

Options for the Future. This program covers the need to balance harbor and coastal development with natural resource protection (23 minutes).

Pointless Pollution: America's Water Crisis. Walter Cronkite narrates this examination of America's water pollution and what is being done to combat it (28 minutes). N.H. Fish and Game Dept., 2 Hazen Drive, Concord, N.H. 03301.

A Sea Beside the Sea. This is an overview of the Gulf of Maine covering everything from its origins, to the many pressures it is experiencing today (30 minutes).

Slide Programs

The Great Bay. This provides a general overview of the estuary. (A slide-tape presentation, 12 minutes).

New Hampshire's Treasure. The Great Bay Estuary, Describes the estuary in detail (with script, 25 minutes).

The Great Bay Estuarine Research Reserve. Explains the purpose of the research reserve and provides some information about the estuary (with script, 30 minutes).

The Salt Marshes: Nurseries of the Sea. Provides a detailed description of the salt marshes in the estuary (with script, 30 minutes).

The Wetlands. Explores America's swamps and marshes describes how they are being threatened and explains what is being done to protect them (60 minutes). N.H. Fish and Game Dept., 2 Hazen Drive, Concord, N.H., 03301.

Wings Across New Hampshire Covers the state's coastal birds (live presentation, 45 minutes). New Hampshire Audubon Society. Call (603) 224-9909.

Books, References and Curricula

Adams, John P. ***Drowned Valley: The Piscataqua River Basin.***

Apollonio, Spencer, ***The Gulf of Maine***, Division of Marine Resources, State Offices, Augusta, Maine.

Anderson, Franz 0. "Estuaries," ***Encyclopedia Britannica,***

Berrill, Michael and Deborah, ***Sierra Club to the North Atlantic Coast, Cape Cod*** to ***Newfoundland.***

Brighton, Raymond A. *They Came to Fish.*

Brody, Michael and B. Sharon Meeker. *The Floating Lab Teachers Resource Manual.*

Charting Our Course: An Activity Guide for Grades 6 - 12 on Water Quality in the Gulf of Maine. Available from the Maine State Planning Office, State Offices, Augusta, Maine.

Clark, R. B. *Marine Pollution.*

Coastlinks. a Resource Guide to Maine's Marine-Related Organizations. Maine Coastal Program, State House, Augusta, Maine

Coulombe, Deborah A. *The Seaside Naturalist.*

Current. The Journal of Marine Education. National Marine Educators Association, Volume 10, Number 1, 1990.

"Estuaries," *Sanctuary: Bulletin of the Massachusetts Audubon Society.* July/August, 1984.

"Estuaries", *Current Journal of Marine Education.* National Marine Educators Association, Spring, 1991.

Estuarine Studies: An Activities Text for Maine Schools. Fisheries Education Unit #16, Education Division, Department of Marine Resources, Augusta, Maine. Highly recommended for use with high school students.

"Fragile Nurseries of the Sea: Can We Save Our Marshes?" *National Geographic.* Vol. 141, No. 6, 1972.

Gates. David A. *Seasons of the Salt Marsh.*

Great Bay National Estuarine Research Reserve Management Plan. New Hampshire Office of State Planning: Concord, N.H., November, 1989.

Gulf of Maine Conference Proceedings. From an International conference held in December, 1989. Contains many reports on the Gulf of Maine. Lots of valuable information here. Available from the Maine State Planning Office, Augusta, and the Canadian-American Center of the University of Maine, Orono, Maine.

Kingsbury, John M. ***The Rocky Shore,***

Lee, Thomas F. ***The Seaweed Handbook,***

Nybakken, James W. ***Marine Biology: An Ecological Approach,***

"Wetlands and Marshes," ***Ocean Related Curriculum Activities*** Pacific Science Center/Washington Sea Grant. Curricula on marshes, estuaries and wetlands, waterbirds, tools of oceanography and much more.

Pease Air Force Base Comprehensive Development Plan, Pease Development Authority, Pease Air Force Base, Newington, N.H.

Petry, Loren C. ***A Beachcomber's Botany,***

A Photographic Guide to Plankton of the North Atlantic. Shoals Marine Laboratory.

Snow, John 0. ***Secrets of a Salt Marsh,***

Teal, John and Mildred. ***Life and Death of a Salt Marsh***

Through the Looking Glass Teachers Guide, Popular teacher's manual for programs at the Seacoast Science Center at Odiorne Point State Park, Rye, N.H.

Centers, Reserves, and Other Resources

Bellamy River Bird Sanctuary, Dover, N.H. Contact the Audubon Society of N.H. in Concord at (603) 224-9909.

4-H Aquaculture Marine Facility. Seabrook, N.H. (603) 679-5616. Call Robin Wojtusik for information about aquaculture in the classroom.

Great Bay Estuarine Research Reserve. Manager, Peter Wellenberger. (603) 868-1095.

Jackson Estuarine Laboratory. Visits to the Lab can be arranged. Call (603) 749-1565, Sharon Meeker.

Kittery Historical and Naval Museum, Kittery, Maine. Tours, group rates. By appointment. Call (207) 439-3080.

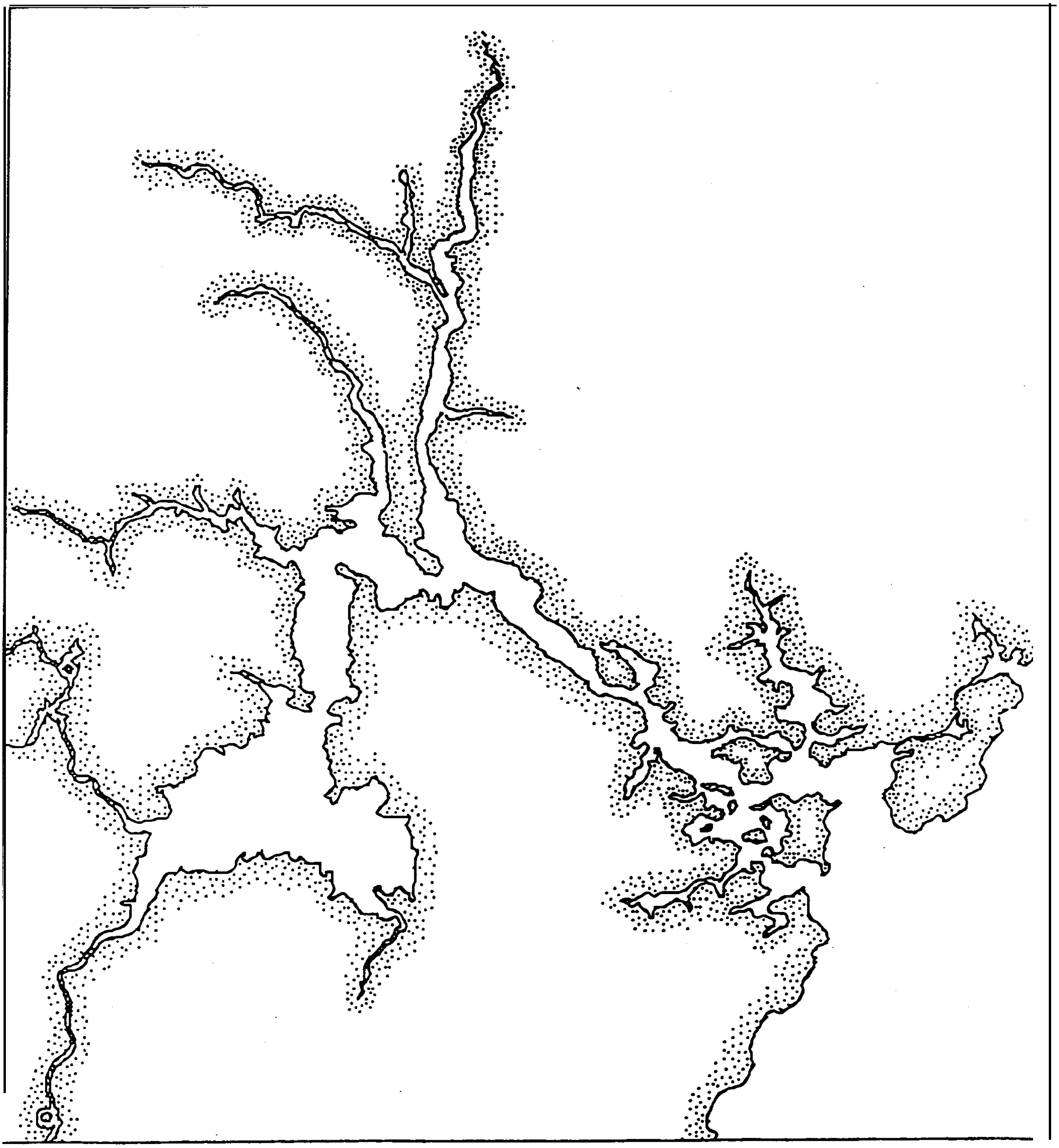
Piscataqua Gundalow Project. Contact Michael Gowell. (207) 439-0886. The gundalow visits various sites in the Great Bay Estuary during the summer. It is moored at the York County Historical Society's John Hancock Warehouse dock for the remainder of the year.

Seabrook Station Education Center. Educational program includes a self-guided tour of the nearby salt marsh. You won't have to get your feet wet. Call (603) 474-9521.

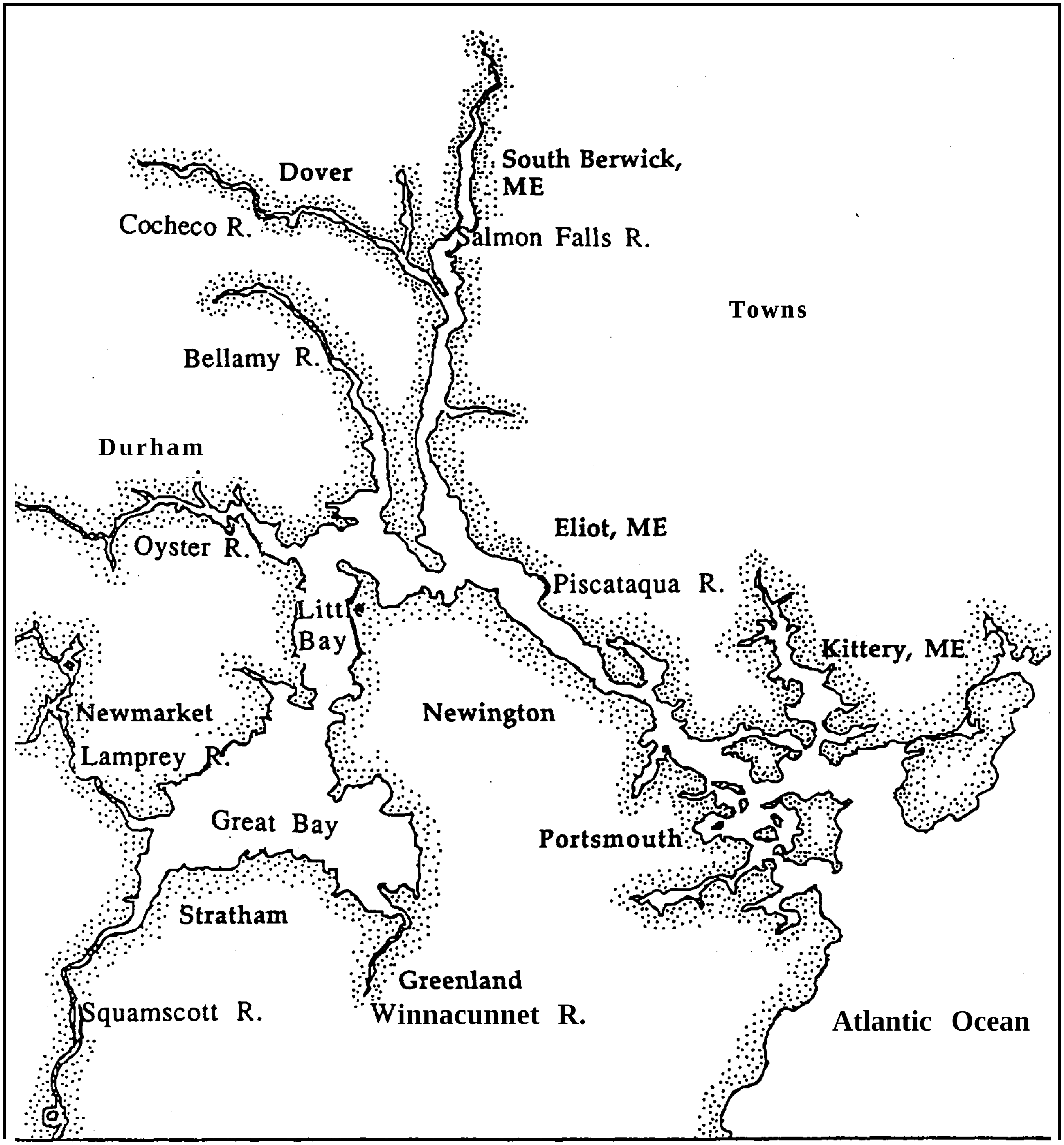
SEATREK. Talks on estuarine subjects by UNH Marine Docent volunteers. Call Sharon Meeker (603) 749-1565.

Wells Estuarine Research Reserve. Wells, Maine. (207) 646-1555. Tours of the salt water farm, marsh, etc.

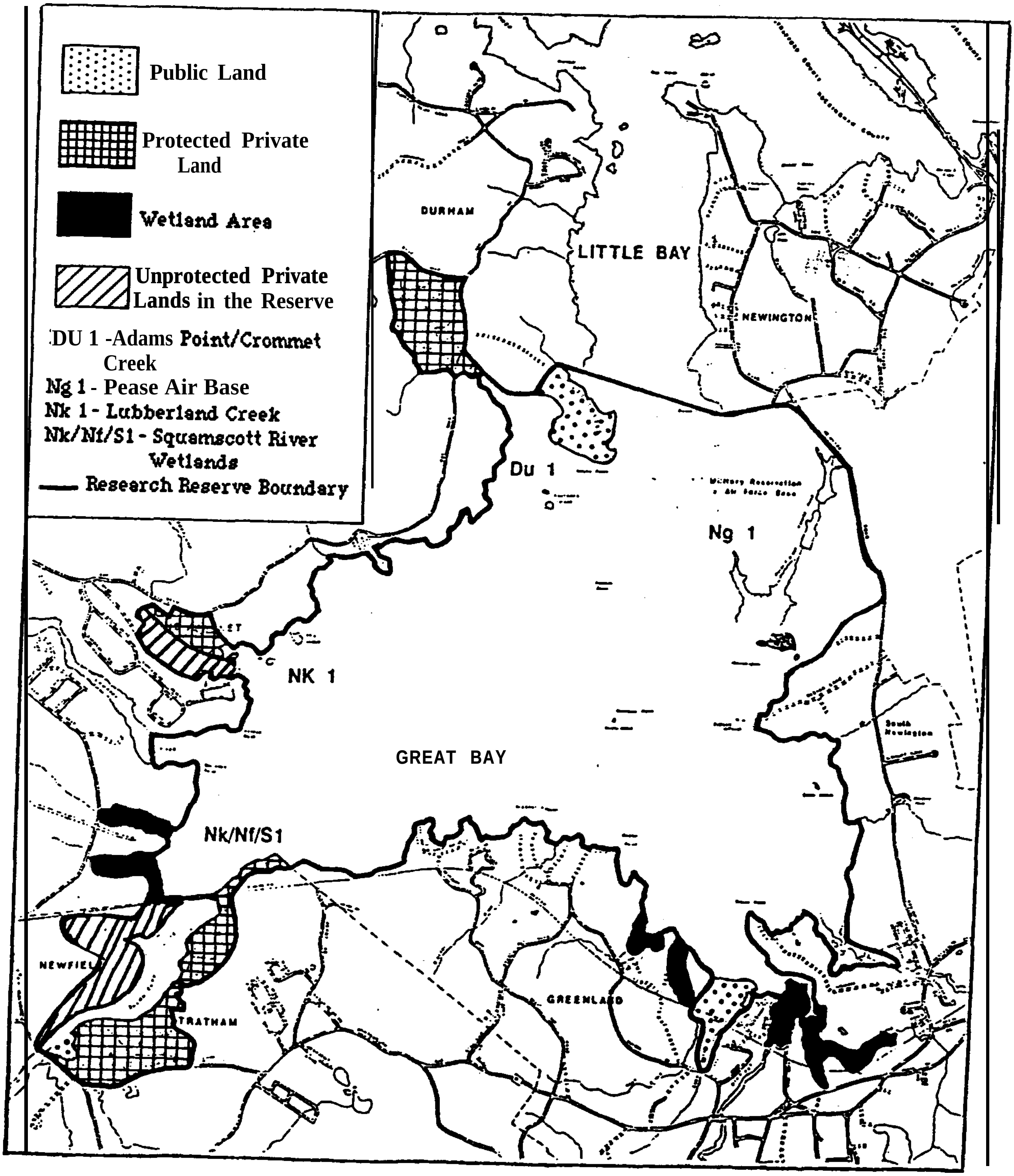
THE GREAT BAY ESTUARINE SYSTEM



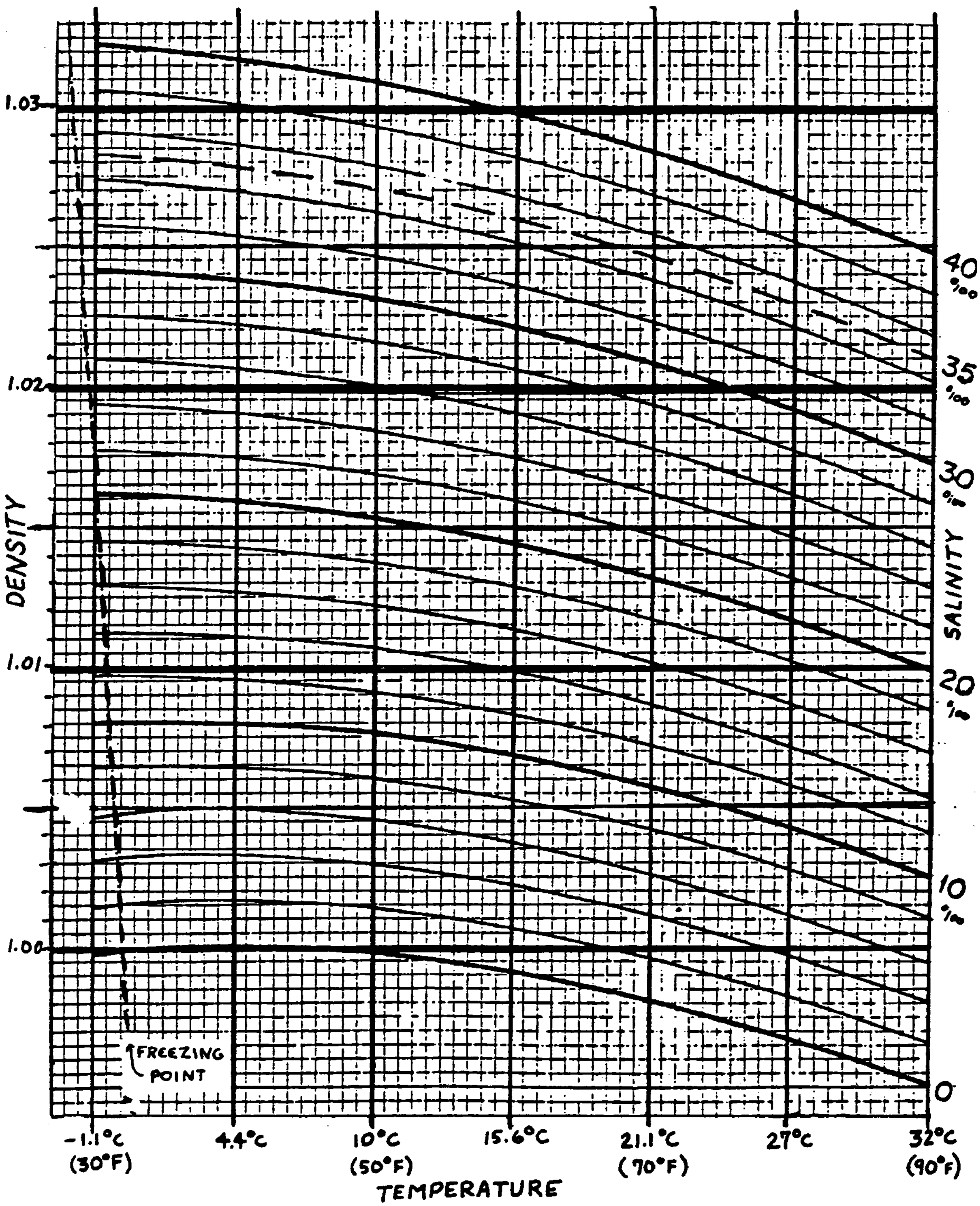
THE GREAT BAY ESTUARINE SYSTEM'S TOWNS,
RIVERS AND BAYS



GREAT BAY NATIONAL ESTUARINE RESEARCH RESERVE, 1991



SALINITY DETERMINATION BY DENSITY

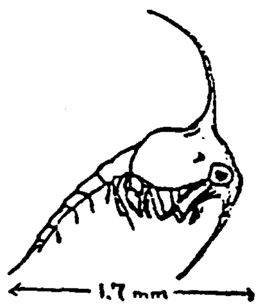


Salinity is in parts per thousand (‰).

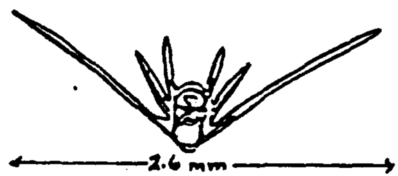
Density is in grams per cubic centimeter (CC).

Temperature is in degrees Celsius (°C).

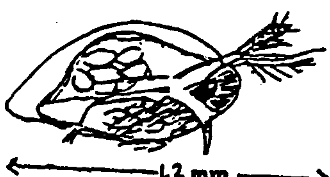
PICTURE KEY FOR NEW HAMPSHIRE PLANKTON



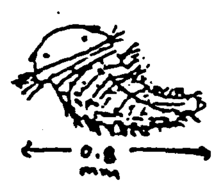
ZOEA LARVA of CRAB
(Decapoda : Crustacea)
Zooplankton



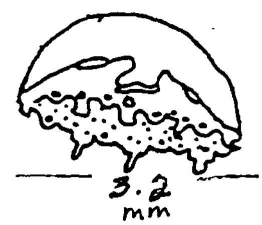
OPHIOPLUTEUS LARVA of BRITTLE STAR (Ophiuroidea: Echinodermata)
ZOOPLANKTON



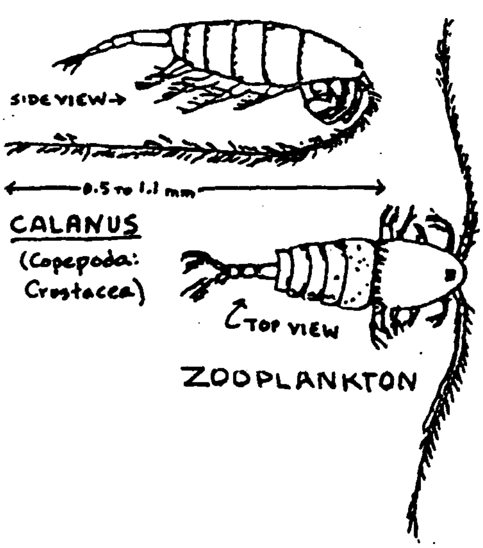
EVADNE (Cladocera: Crustacea)
ZOOPLANKTON



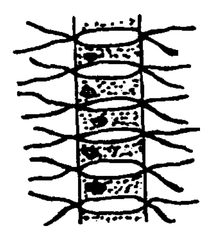
PRE-SETTING LARVA of POLYCHAETE WORM (Polychaeta: Annelida)
ZOOPLANKTON



LEPTOMEDUSA
(Coelenterata)
ZOOPLANKTON



CALANUS
(Copepoda: Crustacea)
ZOOPLANKTON



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GREAT BAY LIVING LAB DAY STUDENT RELEASE FORM

Date: ____________________

________________________ ____ has my permission to accompany his
(Student's name)

class on the Great Bay Living Lab Day, sponsored by the Sea Grant Extension

program at the University of New Hampshire.

In case of emergency. please call ____________________________________
(Name of person to be notified)

at ________________________.
(phone number)

If my child should require a doctor's care the lab instructors as well as the

teacher have my permission to secure that care.

Signed, ________________________________
(signature of parent or guardian)

____
(phone number)

(School name)________________________________

(School phone number)________________________________

GREAT BAY LIVING LAB DAY
EDUCATOR/CHAPERONE RELEASE FORM

Date: _________________

I, ______________________________ plan to accompany a class attending
(print your name please)

the Great Bay Living Lab Day, sponsored by the Sea Grant Extension

program at the University of New Hampshire, on ____________________.
(date)

In case of emergency. please call ________________________________
(Name of person to be notified)

at _______________________
(phone number)

If I should require a doctor's care the Living Lab instructors have my

permission to secure that care.

Signed, ________________________________
(signature)

(School **name)**________________________________

(School phone number)______________________________