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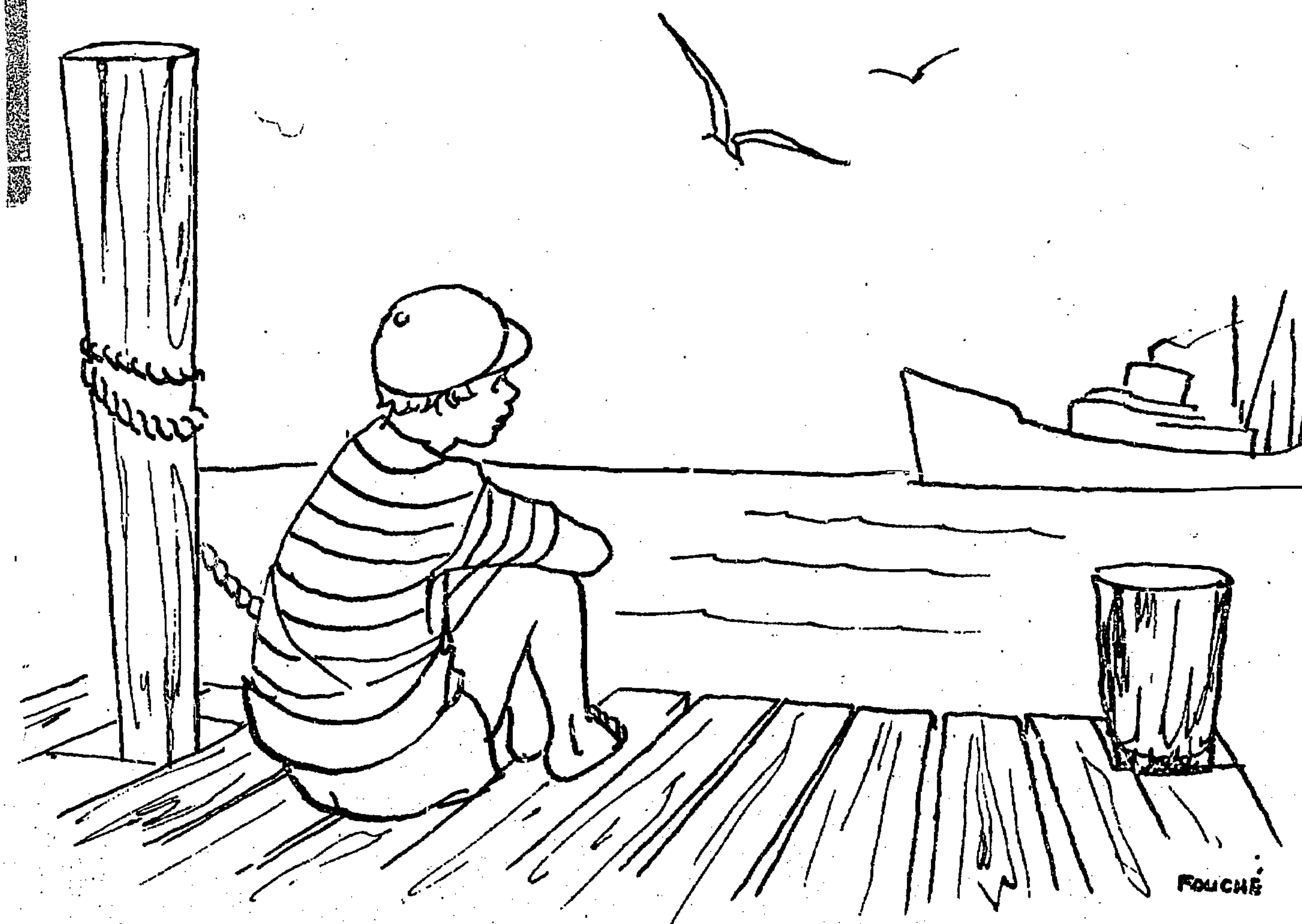
ABSTRACT

This publication is designed for use in standard science curricula to develop oceanologic manifestations of certain science topics. Included are teacher guides, student activities, and demonstrations designed to impart ocean understanding to high school students. When the student has completed this unit, he should be able to: (1) define an estuary; (2) describe environmental fluctuations of an estuary; (3) describe five types of estuaries; (4) list biological characteristics of estuaries; and (5) describe the most important function of a crab's shell. Two other units are included in this publication--Estu[illegible] Man, and Destruction and Restoration. The five major area[illegible] estuaries are important to man (harbors, sites of indus[illegible]ing grounds, sea farms, and recreational centers) are i[illegible]n this unit on marine biology. This work was prepared under [illegible] Title III contract. (Author/EB)

ESTUARIES



CHARLESTON COUNTY OCEAN SCIENCE PROJECT
ESEA TITLE III, P.L. 89-10

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FORFWORD

Prior to 1970, Charleston County possessed no formal program to develop an organized study of ocean science. A few teachers would cover selected topics on occasion, but there was no formal, district-wide effort to make ocean science curricula available to all students in the secondary schools of the district.

The increasing emphasis on the study of the oceans by federal, state, and local governments and the resultant increase in the importance of the ocean to all citizens has created a need for coherent ocean science programs for all students. Nowhere is the need for coherent study of the sea more immediately relevant than in Charleston County. The county is permeated with food and sport-fillad waterways and heavily dependent on naval and commercial shipping. Present and future problems in harbor maintenance and problems of estuarine multiple use indicate a need for a local citizenry literate in ocean science. The most effective means of developing large-scale literacy is the public school.

This publication is one of a series made possible through a Title III, ESEA grant entitled Oceanographic Science Conceptual Schemes Project. These publications are designed for use in standard science curricula to develop oceanologic manifestations of certain science topics. The publications include teacher guides, student activities, and demonstrations designed to impart ocean science understanding to Charleston County high school students.

The members of the ocean science staff include Dr. Gary Awkerman, Director of Natural Sciences, Mr. Michael Graves, Assistant Director of Natural Sciences, and Mr. Paul F. Teller, curriculum specialist in ocean science. They were assisted by the following writing staff: Sister Bernadette Kostbar, Ms. Beverly Lauderdale, Ms. Dorothy Bonnett, Ms. Caroline Pearson, Ms. Pat Hayes, Mr. Tommy Yon, Mr. Nat Bell, Mr. Steve Proctor, and Mr. Leonard Higgins. Principal typists were Ms. Anita Skinner, Ms. Roberta Brown, and Ms. Lynda Wallace. Without their cheerful, dedicated efforts and excellent typing, this project could not have been completed.

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Gary L. Awkerman
Director of Natural Sciences

What do we know about estuaries?

The nature of estuaries

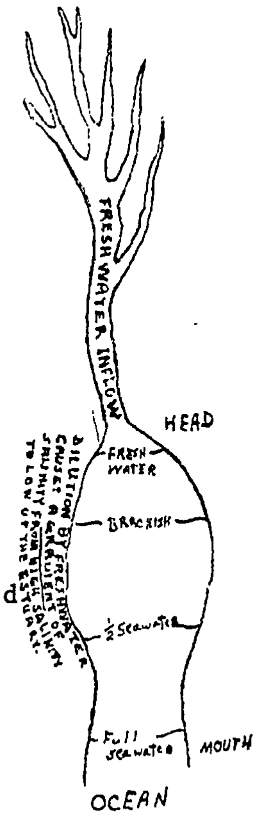
Objectives:

At the end of this exercise, the student should be able to:

1. DEFINE an estuary.
2. DESCRIBE temperature and salinity fluctuations of an estuary.
3. DESCRIBE five types of estuaries.
4. LIST four biological characteristics of estuaries.
5. LIST five responses to environmental salinity in marine animals.
6. DESCRIBE the most important function of a crab's shell.

General Teacher Introduction

Estuaries are semi-enclosed coastal bodies of water having free connections with the open sea. The seawater must be measurably diluted by fresh water draining off the land. The fresh water usually comes from a river or other large source of freshwater.



A SIMPLE ESTUARY

The term "estuary" is therefore restricted to river mouths or bodies of water that have been somehow partially cut off from the open sea. An estuary may be dilluted with freshwater through the size of the freshwater mass, such as a large river, or it may be diluted in more enclosed masses simply because a small enough body of seawater is trapped to show measurable dilution by the runoff from the land.

Quite often, an estuary may be a drowned river mouth. During the last ice age, sea-level fell as much of the water of the world was locked up in great ice sheets. Rivers still flowed to the sea, carving new valleys which opened at the new sea level. As the ice sheets melted and the ice age ended, the sea rose again. The new river valleys were drowned to become estuaries at the higher level of the new river mouths. Charleston Harbor was formed in this fashion, as were the great Chesapeake Bay and many other well-known estuaries.

Salinity and temperature conditions

The presence of ocean water at the mouth and freshwater at the upper reaches, or head, of the estuary results in a salinity gradient from one end of the estuary to the other. The gradient may be very steep in times when freshwater runoff is low, and not so steep when runoff is high. The various positions of particular salinities may change with the tides. At high tide, seawater pushes further up the estuary than at low tide.

Fresh water is lighter than saltwater, so the runoff tends to flow out over the layer of salt water. This means that there is a vertical gradient in salinity as well as a horizontal one.

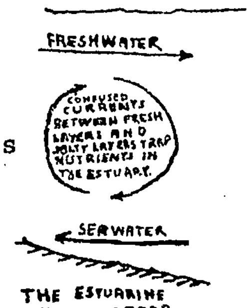
The temperature of estuarine waters also fluctuates. In winter, when the large mass of seawater is maintaining relatively stable temperatures, the freshwater inflow may be extremely cold because of its comparatively small mass. The temperature at a particular spot in the estuary may show a marked change in temperature with the tides.

The reverse condition prevails in the hot summer months. The freshwater run-off will then be meeting relatively cool seawater.

<u>Nutrient levels and other characteristics</u>

The freshwater runoff into an estuary is high in nutrients. Before reaching the estuary, it has run across farmland, percolated through soil, held dying organisms, and otherwise dissolved various organic and inorganic substances in itself. These substances all enter the estuary and contribute to its high nutrient levels.

In some estuaries, the nutrients are held in the estuary and concentrated by a "nutrient trap". The freshwater running out over the salt water of the estuary tends to form a current system which mixes the two layers at the salt-fresh interface. These currents operate to trap the nutrients within the estuary.



THE ESTUARINE NUTRIENT TRAP

Nutrients are trapped in the estuary by other means in addition to the circulatory nutrient trap. Estuaries are sheltered waters not exposed to the strong wave-action of the open sea. The relatively quiet estuarine waters allow salt-tolerant plants to take root. These plants include members of the genus Spartina, the marsh grasses.

As marsh grasses grow, the spaces between the plants slow the water passing through them. The slowing of the water allows particles of silt and organic matter to settle out of the water and be trapped by the stand of marsh grass. In this fashion, the marsh grass actually helps to build the soil in which it grows. The entrapped soil is very rich, and the marsh grasses grow in thick stands. As the stand grows, it traps more and more material. As the materials accumulates it may even rise above the surrounding water levels to become dry land. Because of their self-elevation stands of marsh can gradually fill in an estuary and turn much of it into high ground.

Old marsh plants eventually die. Their decomposition returns the nutrients from dead Spartina to the estuarine waters. Dead Spartina residue contributes to the high nutrient levels already entering through freshwater runoff.

The result of the high nutrient levels is that estuaries are almost like a rich soup. They are among the most productive areas on earth. The high nutrient levels promote a rich growth of phytoplankton which are eaten by estuarine zooplankters.

The estuarine zooplankton include the young of many commercially valuable animals. Older stages of the commercial species may also live in the estuary, feeding on the abundant zooplankton.

Biological characteristics

There is a seeming paradox in the biological characteristics of estuaries. We have just discovered that the high nutrient levels and comparative shelter of the estuaries are factors which make them among the most productive of all the areas of the world. But at the same time, physical conditions in the estuary are quite harsh. Salinity, temperature, and a host of other factors fluctuate widely over short periods of time. The organisms in the estuaries must be able to withstand these wide fluctuations or die.

Osmotic relations of estuarine animals.

The fluctuations in salinity are the most serious fluctuations faced by marine animals. As the water of the estuary becomes lower in salinity, water tends to diffuse into the cells of marine animals.

Too much diffusion of water into the cells could cause them to burst. The fact that there is osmotic stress on marine organisms is reflected in the fact that one finds fewer kinds of marine organisms near the fresh part of an estuary than near the mouth where salinity is high.

The movement of water into hypertonic (higher salinity) media across a membrane is called osmosis. Organisms can be grouped in two classes on the basis of their relationship with environmental osmotic fluctuations.

(1) Osmoconformers (poikilosmotic forms) do not regulate the osmotic concentration (tonicity: osmolarity) of their body fluids. The fluids reflect the salt concentration of the environment.

(2) Osmoregulators (homoiosmotic forms) maintain relatively constant salt concentrations in their body fluids in the face of changing environmental salt concentrations.

There are many intermediate stages between the two groups, and a single species may change in osmotic relationship during different periods of its life cycle.

Some organisms can withstand wide changes in environmental salt concentration. These are euryhaline organisms. Others can withstand little or no change in the salinity of their environment. They are called stenohaline organisms. Both groups of organisms contain both osmoconformers and osmoregulators.

Methods of maintaining optimum internal salt concentrations

Organisms maintain optimum internal salt concentrations against varying environmental salt concentrations by:

(a) walling off the organism from environmental changes

(b) regulating the internal salt concentration with specialized structures, or:

(c) both of these methods.

One of the best examples of walling off the organism from environmental salt concentrations is found in marine invertebrate animals. The body surfaces (shells, skin, etc.) of oceanic invertebrates tend to be permeable to salts and water. Animals living in estuaries tend to have impermeable body surfaces. Species living further up the estuary in fresher water tend to have less and less permeable body surfaces. This brings us to a point which few people realize: <u>the shell of a crab is more an osmotic armor than armor against predators!</u>

One interesting adaptation of the walling-off principle is found in some mullusks. When the outside salinity begins to change too much, the mollusks simply close their shells very tightly, and trap water inside which is still of a compatible salinity.

Other organisms show three basic responses to changes in salinity which may be studied as departing from a curve for a true osmoconformer.

In the true osmoconformer, the internal salt concentration would always be exactly equal to the external salt concentration as in figure 1.

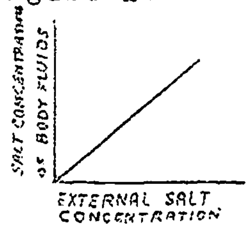


Figure 1. Body fluid concentration of a true osmoconformer.

In a perfect osmoregulator, the body fluid salt concentration would always remain the same, no matter what the salt concentration was outside the body. This is shown in figure 2. The dashed diagonal in figure 2 represents the hyp)thetical curve of the true osmoconformer.

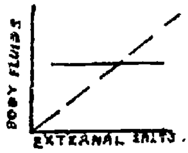


Figure 2. The true osmoregulator

Some animals can only regulate against fresher water. Once the environmental salt concentration reaches a certain level, the salt concentration of their bodies will begin to conform to the increasing salt concentration. Because the animal is maintaining its body fluids at a level <u>above</u> that of the fresh media, but it begins to conform to external salt concentrations above the regulatory level, this form of regulation is called <u>hyperosmoregulation</u>. <u>Hyperosmoregulation</u> is shown in figure 3.

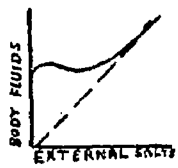


Figure 3. Hyperosmoregulation in dilute media

Other animals approach the perfect osmoregulator. Not only do they maintain constant body fluid concentrations in diluteb media, but they can also keep them lower than the environment when the external salt concentration rises above the normal regulatory level. They depart from perfect osmoregulators because the system breaks down in both very dilute and very salty media. Because the organism can keep its salts both above that of dilute media and below that of too salty media, this type is called <u>hyper-and hyporegulation</u>. It is shown in figure 4.

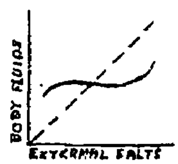


Figure 4. Hyper-and hyporegulation.

A fifth type is sometimes found in which an animal seldom needs to regulate to dilute media, but often needs to fight very high salinities. An example of such <u>hyporegulation</u> is the common brine shrimp, <u>Artemia salina</u>. <u>Artemia</u> lives in salt ponds which are sometimes so salty that the salt actually crystallizes around the edge of the pond. They constantly keep their body fluids below this highly saline medium. <u>Hyporegulation</u> is shown in figure 5.

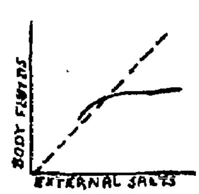


Figure 5. Hyporegulation

Several familiar animals of estuarine waters display specific types of osmoregulation, though few will exactly fit the hypothelical curves shown. The little hardback shrimp, Paleomonetes, may be found in our little creeks and all the way to quite saline water. It is also found in inland ponds and other bodies of freshwater. It approaches the curve of the perfect osmoregulation, with a little swing upward at high salinities.

Some fiddler crabs, Uca, are also excellent hyperregulators, and they may be found in various brackish parts of the estuary. The blue crab, Callinectes sapidus, has been found from very salty water all the way into fresh water.

The change in osmoregulatory ability during the life cycle is shown especially well with fiddler crabs. The adults are hyperregulators, but the larvae fail to develop if the seawater is very brackish. This is reflected in where one finds fiddler crabs. The adults are normally found fairly far up the estuary where there is considerable freshwater dilution. The larvae are found as zooplankters in the saltier parts of the estuary.

Fishes display virtually all types of regulations. Some fishes which migrate in freshwater return to the sea and go back to fresh water to spawn. Their osmogulatory powers change as they develop. An example of such a fish is the salmon. Some fishes also spawn in salt water, grow up in fresh water, and return to the sea to spawn. Their osmoregulatory powers also change with development. An example of such a fish is the common eel.

ESTUARIES AND MAN

Objectives:

At the end of this exercise, the student should be able to:

1. LIST five major uses of estuaries.
2. LIST three commercial firms, three government agencies, and three types of fisheries which use waters of the local estuary.
3. DISCUSS the economic impact of his state's ports on the economy of his state.
4. LIST three types of commercial vessels using his local port.
5. DISCUSS the possibility of oil spills and disturbances of the local harbor bottom based on the amount of traffic in the harbor.
6. LIST three types of recreational activities involving local estuarine waters.
7. DISCUSS mariculture in world estuaries and its status in local waters.

Rationale: Why study estuaries?

The coastal regions of the world are dotted with river mouths, small bays, and other semi-enclosed bodies of water whics are freely connected to the open sea but are strongly influenced by fresh-water drainage into the watermass. These coastal semi-enclosed bodies of water are known as estuaries.

Estuaries are important for several reasons. Many estuaries form snug harbors for world commerce. The fresh water drainage into the estuary usually carries considerable quantities of mud and silt with it. When these particles settle out, they may begin to fill the estuary, rendering it useless for navigation unless it is frequently dredged. Silting can be modified through changes in the estuary. Knowledge of estuarine dynamics is required to pre-evaluate any proposed changes.

Many estuaries are centers of shrimp, crab, oyster, and fin fisheries. The life cycles of many commercially-fished species depend on estuaries as nurseries. Upsetting biological conditions in the estuaries can harm the fisheries in the estuaries as well as in the surrounding sea.

Many estuaries are the site of heavy recreational use. Swimmers, boaters, skiers, and fishermen all use estuaries in their leisure time. They spend much money on their leisure activities. If the estuary becomes unfit for use by these individuals, a considerable sum of money will not be spent, and recreational firms in the area of the spoiled estuary may be hurt badly.

These three uses of estuaries often conflict with one another. Decisions as to who should benefit most or whether all shall be able to use the estuary to the fullest extent are matters of public concern. If the public is to make wise decisions on estuarine use, the average citizen should know at least the basics of what an estuary is and how it works.

Teacher Introduction

Estuaries have been important to man long before their scientific study began. They are by definition sheltered waters, for centuries, they have offered haven to ships and men from the storms of the open sea.

The good natural harbors formed by many estuaries became permanent centers of trade. As overland transport within nations developed, the harbor became the port of entry for foreign goods which were distributed within the nation by overland transport centers in the vicinity of the harbor.

As the trade importance of the harbor vicinity grew, so did its population, as more and more people settled where the action was. Eventually, great cities grew up around the harbor, and burgeoning industries headquartered there to gain access to world markets. In this fashion grew New York, Philadelphia, Boston, and other great cities of the coastal United States and other parts of the world.

Fishermen also found ready markets in the growing estuarine cities. The nutrient-rich waters of the estuaries supported a bountiful crop of oysters, shrimp, crabs, fish and other delicious seafoods which found ready markets in the prospering harbor cities. With the advent of salting, freezing, and other methods of preservation, the seafoods began to be shipped all over the country. Some enterprising fishermen were not content with the bounty of nature. Very early in the history of the world, some people began raising important sea animals such as the oyster. Mariculture, or the farming of the sea, had already begun.

As industries grew and new technologies were born, a need arose for cooling machinery or for actually driving it by water power. More industry came to the estuary. Not all the industry located directly on the estuary. Many factories located on the rivers above the great harbors, where swift streams drove their millwheels and carried away the wastes from the plant's activities.

In this century, electricity became the driving force of the world. Hydroelectric power was found to be a cheap source of power, and rivers were dammed up to provide energy to drive great turbines.

This caused a shifting of river courses and changes in the salinity of some estuaries below the dams. The shifting of the river courses often unloaded unusual amounts of silt into the harbor beneath them, giving greater impetus to another business: dredging.

In the midst of all the vigorous business on the harbor, some people still had leisure time. Boating, swimming, and fishing were favorite forms of recreation. As changes were made in labor laws, people found more time for leisure, and spent more money on it. Water recreational businesses are now a significant part of the business enterprise of cities by any sort of water. Estuarine cities are especially important in this regard. The estuaries are centers for freshwater sportsmen, others who putter about the harbors, creeks and marshes of the estuaries themselves, and the bold adventurers who set out across miles of open ocean with thousands of dollars worth of boats and equipment hoping to outwit creatures whose brain is about a tenth or less the size of their own.

As we have seen, there are five major areas in which the estuaries are important to man; as harbors, sites of industry, as fishing grounds, as actual seafarms, and as recreational centers. All these functions have far-reaching effects.

The trade that enters a nation through its harbors is the very lifeblood of that nation's industrial position. The blockading of a few selected ports by a foreign power is almost enough to bring most nations to their knees. The ports are the only way to bring in essential raw materials and export finished goods in the quantities necessary to maintain a strong economy.

The animal protein derived from estuaries and coastal waters is a valuable part of the diet of many people all over the world. Fish is one of the cheapest animal protein sources available. Even coastal fisheries which operate in open waters of the continental shelf depend heavily on estuaries. The estuaries are important breeding gounds for many of the commercial species or for some of their principal food organisms.

The recreational opportunities of the estuaries draw participants from hundreds of miles away. Not only boaters and fishermen come, but bathers come from all over the country to take advantage of the beautiful beaches located in the vicinity of the lively harbor towns.

Activity 1 (Life Science, Biology)

1. The class should prepare a report on the use of their local harbor as a port. This activity is specifically designed for Charleston Harbor and other ports in South Carolina, but could easily be modified for other localities. There is a lot of student work involved in this study, so the whole class should be used.

   The function of this activity is to allow the class to gain an appreciation of the economic importance of a local port. The biological health of an estuary depends heavily on the location of industry on its shores and the concentration of population on its margins. Heavy port use is intimately related to these two factors. After completing the following portrait of a living port, the class should have a better appreciation of the commercial activities affecting the ecological health of estuaries.

   Divide the class into three groups, with the following report assignments:

   Group A - Economic analysis of the ports

   Group B - Military and commercial firms using the port

   Group C - Ship movements

2. Group A may build their report around an economic analysis that was done on South Carolina Ports in 1966. This report is:

   Pender, David R., 1966
   <u>An Economic Analysis of South Carolina's Ports</u>,
   University of South Carolina,
   Columbia, S. C.
   College of Business Administration

Part 2 of this report, "Summary and Conclusions", should be most helpful. The group's report will reveal the basic operation and financial impact of ports on the economy of port cities and the states. One member of the group should call the local office of the state Ports Authority or visit them to update the information contained in the report. They may even be able to have a representative of the state Ports Authority speak to the class on the economic importance and the future of the ports, particularly Charleston Harbor.

2. Group B can approach their problem from several directions. They should first divide themselves into two subgroups, one to handle military aspects of the port, and the other to handle the commercial firms.

   The military group should:

   (a) Check the "United States Government" listings of the local telephone directory to see what federal naval installations are in their vicinity. For instance, in Charleston, there are mine forces, destroyer squadrons, ballistic missile submarine bases, Coast Guard, and other installations which use the harbor.

   (b) One member of the group should call the public relations office of a local installation or go to the office. He should try to interview public relations officers to discover the assigned mission of each major naval unit.

   (c) The group should attempt to get a representative of the navy and/or Coast Guard to talk to the class on the significance of the military installations on the estuary.

   The commercial group should:

   (a) Consult the yellow pages of the

local telephone directory for harbor businesses. Some possible entries include shipping companies, steamship lines, ship chandlers, ship builders and repair yards, import-export firms, the local harbor pilot associations, towboat companies, and dredging concerns. They may find even more.

Each member of the group should call or visit one of these businesses to determine:

(a) its size, including number of employees and amount of equipment.

(b) its primary business, and where it gets most of its jobs.

(c) the current employment prospects with the company.

3. Group C is to study shop movements in and out of the harbors. This will probably be the most enjoyable part of the activity. A wise teacher can discuss the espionage activities of various spies whose duty was to watch ship movements in enemy harbors. The cloak-and-dagger, "I Spy" atmosphere of this section of the activity will make this an exciting period for group C. Assign good spy-type code names to your "operatives", and assign them various roles in the game. Three major types of operations can be carried out to study ship movements;

(a) Harbor watching

(b) Census of harbor shipping

(c) Study of port listings in local papers.

The group should divide itself into three subgroups. This should usually involve about 3-4 people in each subgroup. The easiest task is port listings. One or two individuals should be involved.

The following code names are only suggestions. If you wish to run this as the game it should be, then you may wish to use other names. Each group should make a two minute report to the class each day on their findings. Operations should be carried out in the following manner:

I. Code group Orange (Newspaper shipping lists)

A long list should be prepared with space for at least 30 ships. The headings of the list should be arranged as in the sample list shown in figure 1.

The data are gathered on the basis of posted arrivals. When the ship arrives, it is put on the list. The newspaper listings are then watched each day for its departure. A large master list may be kept in class to allow the class as a whole to keep track of published movements.

II Code group Red (Harbor watchers)

This group should watch the harbor to look for ships at anchor and underway into or out of port. The watch should be kept for at least a week.

Each afternoon, members of this group should find a good vantage point from which to scan the harbor. They may split up the duties so that each member has only one day to work.

The census should include the number of ships present out in the harbor or moving through it or past the piers. Distinguishing marks may be recorded to give later identification of the ship.

Some distinguishing marks which may be recorded are:

(a) Type of vessel. The general types are shown in any book on merchant ships (tankers, freighters).

(b) Color of hull.

(c) Color, shape, and location of superstructure. Quick sketches of the ship may help.

Ship Movements from October 8 to October 15, 1973 Charleston Harbor, S.C.
Source (Newspaper) News and Courier

Ship name	Registry	Owner	Country Coming from	Next Destination	Cargo Landed	Cargo Picked up	Terminal	Date of Arrival	Departure Date	Total days in port
SS Juicy Fruit	Liberia	Imports,	Guatemala	New York	Lumber	Paper	Columbus St	10/9	10/13	5
SS Oil-slick	England	Gasser Co	Venezuela	Wilmington	Oil	None	oil dock	10/11	10/14	4
SS Package Deal	U. S.	Containers, Inc	Mexico	Norfolk	Household Goods	Electronics	Columbus St	10/11	10/12	3
SS Competition	Germany	Bug, Inc	Germany	Wilmington	Auto.	None	Columbus St	10/13	10/15	3

Figure 1. A sample listing of ship movements as reported in newspaper shipping lists

(d) Markings on smokestacks (usually a company insignia)

(e) Firm name (often in large letters on the side)

(f) Any other peculiar features.

A telescope or binoculars will help very much if available. If the vantage point is good enough, the students may be able to pick out even the name of the ship and the country of registry. The flag of that country will be flown from the stern. Flags of all nations are available in any good encyclopedia and in many dictionaries.

A chart of the harbor may be obtained from local boating suppliers or the local office of the U. S. Coast and Geodetic Survey. Look under "charts" in the yellow pages. Get a large one. Have the students locate their ships on the chart each day. Small map pins may be used. Tag the pins with a letter (a, b, c, ...) for each ship. The letters will correspond to ships on the list compiled by the harbor watchers. It will be helpful if the harbor watchers can take the chart with them to locate the ships on it as they are seen. They may be located with light pencil marks in the field. A sample listing of one day's survey is shown in figure 2a. A sample harbor charting is shown in figure 2b.

III. Code group Brown (Dock watchers)

The dockwatchers should locate ships at the various port facilities of the harbor. They should be able to read the names of most ships because they will be so close. An excellent way to survey the Columbus Street docks in Charleston harbor is to ride north on the Cooper River bridge. Names of the vessels in port there can be easily read off the bow or stern of the vessels berthed at the pier. The flag of the vessel may be seen as well as the firm name on her side. A look at the dock where she is berthed or close scrutiny of dockside operations may reveal either landing or loading cargo. Other methods will have to be used for the other port facilities. The

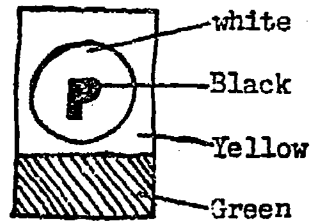
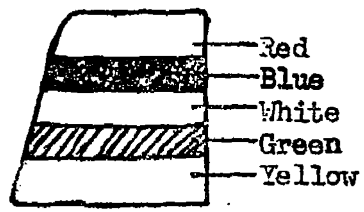
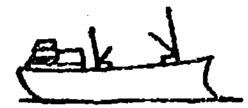
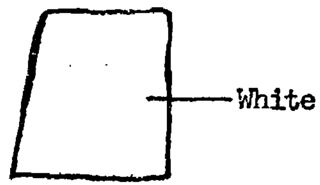
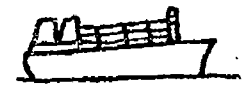
	Type	Status	Hull color	Superstructure	Stack markings (sketch)	firm	Name (if determined)	flag	sketch of ship
a	Tanker	Underway (arriving)	Green	Large yellow house aft Tall yellow bridge forward		Petro-leum Ltd.	Kuwait Carrier	Liberia	
b	Frighter	Anchored	Red	Large house Aft, Several on-board derricks		Auto Export	Auto Transporter	Ger-many	
c	Contain-er ship	Underway (leaving)	Blue	Large house Aft, Small bridge forward deck piled with trailers		Trailer Transport	Seatrailer	U.S.	

Figure 2a. Sample listing of ships in harbor on one day's coastwatching.

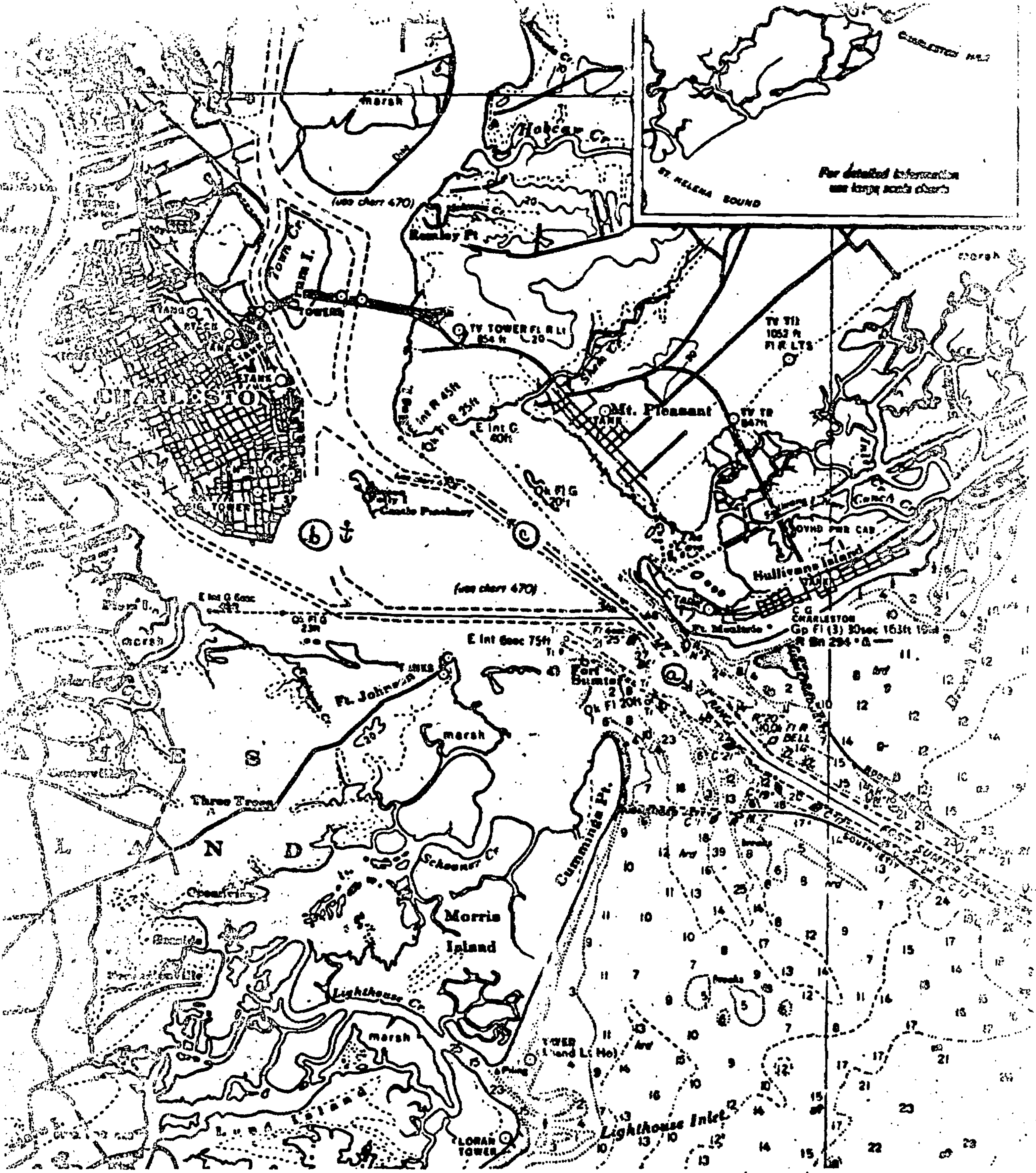


Figure 2b. Typical sample of ship movements in Charleston harbor on one afternoon.

same list can be used as for the harbor-watch, but an additional column should be added to show the pier at which the ship was berthed.

The dockwatchers may plot their findings on the same chart used by the harbor-watchers. When a ship disappears from the harbor, it may be found at one of the docks. A line should be drawn from its location in the harbor to its location at the docks. When it disappears from the docks, it may be found leaving the harbor.

4. All groups should work together in the following manner:

   (a) The newspaper watchers should inform the other two groups of expected arrivals or departures.

   (b) The harborwatchers and dockwatchers should attempt to find the ships concerned and confirm their discovery to the newspaper watchers. When an arrival or departure is confirmed, a check (✓) should be placed beside the name of the ship.

5. At the end of the week's exercise, a series of lists and a large chart should be available which give a portrait of a busy port. This data can be used as:

   (a) A maximum limit for the chances of harbor oil spills by commercial shipping.

   (b) The passage of a large ship causes a disturbance in the water. If the channel is small, this probably stirs the bottom considerably. The number of passages in the harbor for the week may be counted from the final chart. The class should now have a great appreciation of one of the most important uses of the estuary: as a port.

   (c) The average number of days spent in port by each type of ship can be calculated from the gathered data.

Activity 2 (Life Science, Earth Science, Biology)

1. Estuaries are popular sites for recreation and commercial fishing. They offer wide opportunities for boating, fishing, swimming, diving and skiing. This activity is to give the student some insight into opportunities for their own recreation as well as learning about an important phase of estuarine use.

2. Divide the class into three groups. The duties of each group are as follows:

   Group I: Look in the yellow pages of the telephone directory for all boating categories, diver's equipment, fishing tackle dealers and charter boats. Enumerate the concerns in each category.

   Each member of the group should pick a company to visit. He should get an idea of the size of the company and its scope of business. Each visitor should report his findings to the class.

   Group II: One member of this group should go to the Chamber of Commerce and secure all available pamphlets on water-related recreation in their county and state. The estuarine activities should be pulled out separately for study.

   A group report should be prepared on the Chamber of Commerce bulletins. The report should be a comprehensive listing of types of estuarine recreation available in the students' area.

   Another member of the group should interview a member of the staff of the Chamber of Commerce. He should find out the problems of local recreational facilities and the projected future of recreational developments.

   Group III: One member should visit the local fish and wildlife office. In Charleston, this is the:

South Carolina Wildlife
Resources Department
Division of Marine Resources
2024 Maybank Highway
Charleston, S.C. 29407

This member of the group should pick up all pamphlets relating to private and sport fishing in South Carolin marine water. Two or three students together should prepare a group report on the pamphlets.

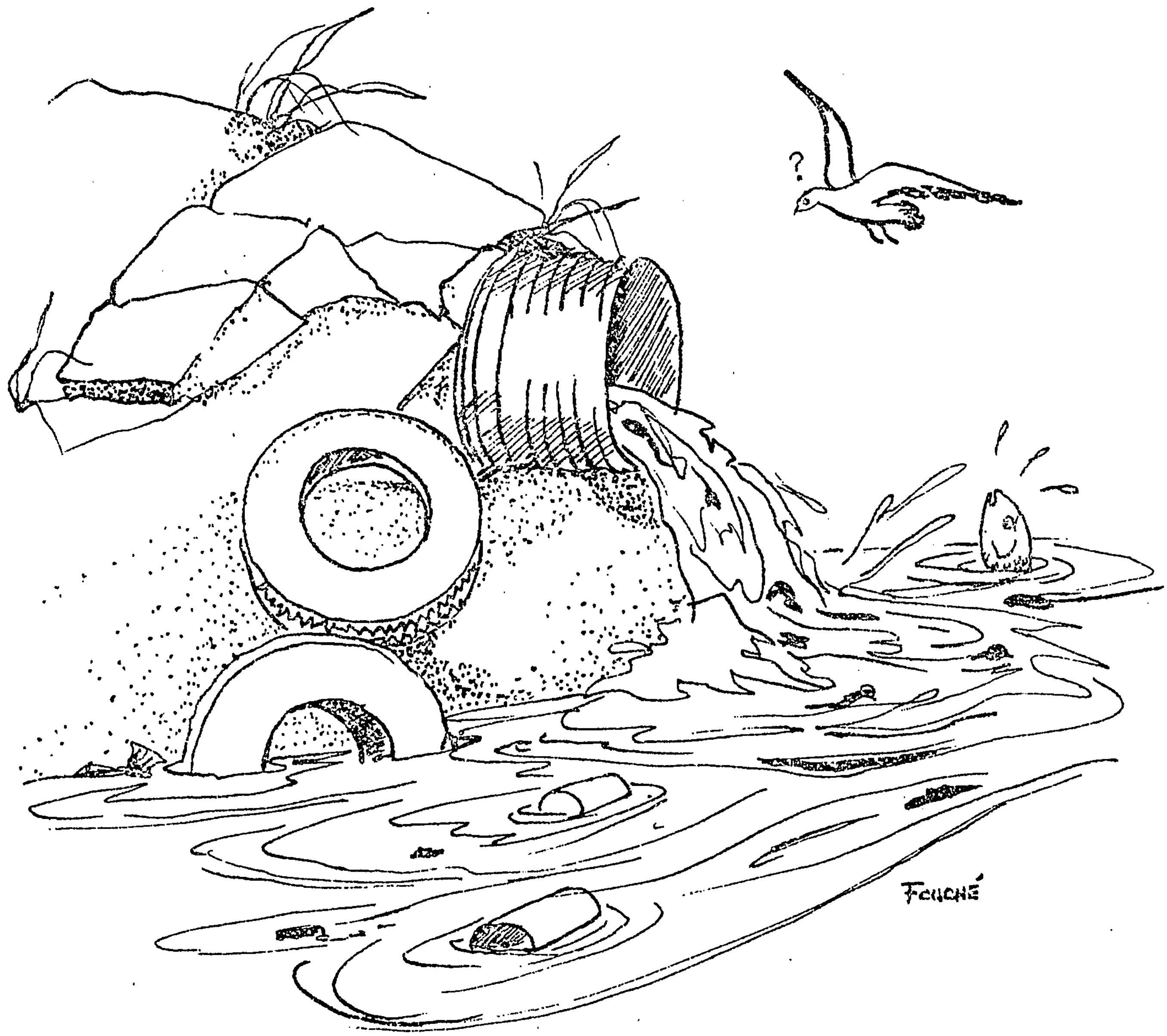
Another member of the group should interview a key member of the marine resources staff to inquire into the nature and condition of South Carolina's marine resources: What is used, how good the catch has been in recent times, and how the recent catch compares with catches of previous years. He should also find out what efforts are being made to develop marine resources, particularly in the realm of mariculture, the farming of the sea. He should ask such questions as: "Are there now or expected to be, attempts to farm shrimp or oysters in the state of South Carolina?"

One member of the group should be assigned a book report on:

Iversen, E.S., 1968
Farming the Edge of the Sea
Fishing News (Books) Ltd.
110 Fleet Street
London, E.C. 4, England

The report should cover the reasons for farming the sea, its past development and future outlook, procedures, species presently farmed and other potential species, and the problems of sea farming.

DESTRUCTION AND RESTORATION



What do we know about estuaries?

Human destruction and restoration

Objectives:

At the end of this exercise, the student should be able to:

1. LIST two principal sources of pollution.
2. DESCRIBE two damaging effects of human and industrial waste.
3. LIST three damaging effects of dredging.
4. DISCUSS three disadvantages to the use of marsh as spoil areas.
5. DESCRIBE the effects of overfishing in an estuary.
6. DESCRIBE estuarine damage from unrestricted recreational use.
7. IDENTIFY maximum sustainable yield.
8. LIST three questions whose answers will help us to restore estuaries to the state of healthy parts of the world ecosystem.

Teacher Introduction

Human damage to estuaries

All the uses of estuaries described in "The importance of estuaries" can have damaging effects when improperly managed.

One of the most widespread damaging effects is pollution of estuarine waters. As estuarine cities grew, they discharged more and more human sewage into the estuary. The excess nutrients and various petroleum products, pesticides and other elements coming from city sewer systems have severely damaged many estuaries.

The excess nutrients have caused great overgrowth of algae and other plant life. This growth can cause noisome odors to pervade the countryside as a result of decomposition processes. In addition, the plants use oxygen for respiration. At night, photosynthesis is not going on to replace the oxygen level of the estuary to drop considerably, killing other organisms in the estuary.

The petroleum products, pesticides, and other toxic elements of city sewage may kill animals outright, stunt their growth, stop reproduction, or otherwise injure the sealife in the estuary.

Industrial pollution is also a source of damage. Some industries in the city may use the city sewer. Others may have their own effluent systems. In either case, chemicals from factory waste may cause significant damage to the estuary and surrounding ocean waters.

Not all the pollution originates on the estuary. Any harmful substance entering the estuary via one of its tributary rivers will act as part of the general estuarine pollution. For instance, if a long-lived pesticide is applied to land anywhere in the watershed for the Mississippi River, it will eventually drain off the land into the Mississippi. From its entry into the river, it will eventually pollute the Mississippi delta and the Gulf of Mexico. For this reason, insecticide bans and other environmental protective measures must be used on a wide scale. If they are directly aimed at cleaning up a particular estuary, the measure must be enforced throughout the watershed of the tributary rivers of the estuary.

Almost all estuaries tend to be geologically temporary. They have a great tendency to fill in or at least to change the patterns of depth distribution such as channels, deep holes, sandbars, and the like. It is in the interest of commercial shipping to keep the depth and location of navigable parts of a harbor constant. For this reason, many harbors are frequently dredged.

The dredging is usually done from a ship or barge especially constructed for dredging. The business end of the dredge is a large bit at the end of a long hollow pipe. As the bit digs up the bottom mud, the long pipe sucks it up into the ship. If the dredge is a "hopper dredge", it retains the mud within the ship and goes to dump it far at sea. If it is a conventional harbor dredge, it feeds the mud through a long pipeline and dumps it in empty marshes around the harbor. In this way, the use of "spoil areas", as the bare marsh is called, can result in land being reclaimed from the sea.

Spoil areas are centers of some controversy. While it is true that valuable land is often reclaimed from marshes through filling them in as spoil areas, the destruction of the marshes constitutes severe damage to the environment.

In the first place, spoil areas can be a place of truly foul smells, as organic matter contained in the muds decomposes in the open air. The areas of standing water which can be trapped on the surface of old fill can become excellent breeding places for mosquitoes. In addition, buildings located in dredging spoils no longer have the marsh serving as a buffer against wave action. They are open to severe damage in heavy weather. If marshes were preserved, damages from hurricanes and other storms would be reduced because of the buffering action of the marshes.

The above two drawbacks pale to near insignificance beside the basic fact that spoil areas represent destroyed marsh. It has been repeatedly mentioned in this program that marshes are among the most productive areas in the world. Many commercial fisheries depend on the marshes and their small creeks as a nursery ground for the animals they catch or as profitable fishing grounds for the animals themselves. When the marsh is destroyed, that productivity is lost.

Land resulting from spoil may be sold

and make a few people very rich. But it is a one-time purchase. There may be taxes paid on the land each year, but unless taxation is truly severe, the land actually looses value over the long hand. Before the marsh was filled in, shrimp, crabs, oysters, and other animals grew every year. Every year the marsh was the site of growth of a considerable cash crop. When the marsh becomes a spoil area or is otherwise destroyed for development, the yearly profits are eliminated.

The bulletin of the Sportfishing Institute (No. 213, April, 1970) recently listed some estimates of the value of marshes and estuaries as productive areas. Several estimates have been made to assess the yearly value and therefore capital value of the estuaries. If a certain amount is gathered each year, it may be treated as interest, just as the interest is gathered each year on a savings account. If one were to know how much he would make each year from a savings account, he could easily calculate how much was in the bank on the basis of a known interest rate, usually five or six percent. That is how the capital value of estuaries was calculated.

One of the highest values was in the state of Maine. In the state of Maine, a large shellfish and polychaete worm fishery exists. The polychaetes are sold as bait to sport-fishermen at prices as high as $1.50 per pound. The yearly harvests of shellfish and worms were the only figures used to assign a value $33,563 per/acre/year to scientifically managed estuaries. The value of fish dependent on the estuaries showed yearly harvests valued at $15,750 per acre per year. If we look at these harvests as interests on a capital investment at a conservative 5% interest rate, the capital value of Maine marsh ranges from $313,000 per acre in unmanaged areas to $671,000 per acre in areas receiving sound management. These figures illustrate graphically the differing values of managed and unmanaged areas. Wildlife management does work. Even more important it shows that if the estuary were dredged and the marshes and mud flats were used as spoil areas, a just compensation to the people of the state should be paid at the rate of $313,000 to $671,000 per acre of destroyed marsh. Acreage adds up quite fast in spoil areas, and if just compensation were paid probably very few areas in the state of Maine would be profitable to dredge.

The contribution of estuaries to fisheries on the continental shelf is considerable, because of the role of estuaries as nursery grounds and other connections with continental shelf ecology. For each acre of destroyed estuary on the Atlantic coast in general, whether it be filled marshes or polluted waters, there is a loss to continental shelf fisheries of 535 pounds of fisheries products with a retail value of $214. The capital investment represented by this loss on the basis of 6% interest is $3,567. If the loss is in sportfishes, this value rises to $3,580 per acre. This figure is for general Atlantic coast estuaries. Certain ones may be even more important than others.

Other capital-investment figures included $400 for New York estuaries, $2240/acre in the Merrimack estuary and $3500 per acre in the North River in Massachusetts.

In Texas, the Galveston-Trinity-East

Bay estuary was found to represent a capital value of at least $6,663/acre for a total value for the 330,000 acre complex of $2,208,660,000! This figure was based strictly on commercial and sport fisheries, with no estimate of other recreational values.

In Delaware Bay, the capital value was found to be $9,665 per acre based on sport fisheries alone. Net value added to the economy ($2 per fisherman-day) gave yet another figure - $3300 per acre solely for sport fisheries.

All of these values have been conservatively estimated. Good management could up the figures considerably. One great tragedy is that a small industrial complex, representing only a few tens of millions, or a large city which will not spend a few million on effective pollution control, can destroy a dynamic estuarine system worth billions of dollars in potential earnings. These are the sorts of values we must begin weighing heavily when we think of tampering with estuaries. Other values-the bird life, the sparkling clean waters, and the aesthetic enjoyment of unspoiled areas, can be measured in dollars and cents according to their tourist value, but the figures are not so readily available. However, there is more dollar value here. The unspoiled sea is a treasure that is a way of life, and dollars and cents cannot begin to measure its value.

Aside from the destruction of marshes, dredging is in itself often harmful. Dredging changes the geometry of the estuary by forcing the flow of the tributary rivers and the waters of the estuary into new channels which may not follow the natural sourse of drainage of the estuary. The act of dredging itself destroys bottom habitats in the path of the dredge.

The commercially valuable species of an estuary can be destroyed by overfishing. If all the breeding stock is taken, the population will disappear. In a less extreme situation, enough of the breeding stock can be removed so that not enough young survive natural deaths to perpetuate the population at a commercially valuable level. Very few young marine organisms grow up. Most are eaten by other organisms before they have a chance to mature and reproduce. This is the function of minimum size limits for an organism taken for market. If all the animals below a certain size are returned to the sea in good health, there will still be plenty of young members left to repopulate the fishing grounds.

If we assume that very few larvae live to adulthood then a certain number of breeding pairs must be present to continue the stock at its present levels. This means that we may remove only a certain portion of the fishable stock if the fishery is to remain profitable. This portion is called the "maximum sustainable yield." Much research is required to determine the maximum sustainable for a certain fishery in any particular area. Some factors which must be considered are the size of the population, how long adults breed, and the percent mortality of the young stages. The MSY can vary as a result of management. If we wish to build up a fishery, we may temporarily lower the allowed field for a while. This may result in a permanently improved MSY for that particular fishery.

However we look at it, a fishery in a particular area has a definite MSY which is a property of the population and which if surpassed will damage the fishery. If it is surpassed to a great degree and followed by a few naturally poor years, the fishery in that area may be damaged beyond repair.

The MSY principle applies to recreational fishing as well as to commercial fishing. Recreational fishes can be fished out quite as easily as commercial ones. This is only one aspect of recreational damage to the estuary. Others include oil pollution from motorboats, the disturbance of the bottoms of small creeks where marinas are located, and the filling in of marsh for resort centers.

Restoration of Estuaries

If we learned more about better management of our estuaries, we could exert a less destructible influence on them and preserve them for future generations.

Some examples of questions we might ask to begin the restoration of estuaries are the following:

a. How can we restore polluted estuaries to good health?

b. Can all the present uses of estuaries be made compatible with each other?

c. Can the nutrients in an estuary be used more effectively to increase productivity of commercial species?

The beginning of an answer to the first question would be pollution control. Public concern over all types of pollution has grown in recent years. As a result of the public furor and legislation passed to control pollution, cities and industries have begun to clean up their wastes. Much pollution control remains to be done, but some efforts are already proving to be effective. Some estuaries that were almost completely ruined are beginning to have reasonable populations of fish and benthic organisms which display patterns typical of healthy communities.

The question of compatibility of estuarine uses is one deserving much study and cooperation among the various groups who use the estuary. Eventually, ports authorities, fishermen, industrialists, and recreational groups will all have to sit down together with a group of estuarine scientists and economists and work out some solutions. Some instances of compatibility might include more expensive dredging to remove all the plowed-up bottom to offshore dumping grounds instead of using marshes as spoil areas. This change may come as a natural result of figuring lost marsh benefits as part of the cost of dredging. If the dredging economists were forced to include the capital value of marsh, such as the $313,000-$671,000 per acre cost of Maine marshes into their cost analyses, the cost of the dredging operation using spoil areas would be greatly increased.

The question of compatibility also includes certain restricted types of pollutants. For instance, thermal pollution from plants using sea water for cooling has been of considerable concern in the last few years. If the thermal pollution (warmed water) is properly regulated, it can be useful. There have been several successful attempts to use the warm water in thermally polluted areas to speed the growth of shellfish cultures.

Some organic sewage could also be used,

if we knew how. Organic sewage exerts much of its damage in the role of excess nutrients in the estuary. If we know enough about the nutrient cycles in an estuary and the needs of the organisms in the estuary, it might be possible to harness our pollution and other aspects of estuarine nutrition to increase our harvest of commercial seafood in the estuarine areas.