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It's only a little Planet

It's Only a Little Planet:

A Primer for Ocean Studies

by

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This book was prepared as part of the Day on the Bay Cruise Program, a sea-going educational experience funded by the National Sea Grant Program. The program offers a 7 hour cruise which samples the waters and life forms of the Gulf of Mexico and the estuarine systems of the Texas coast. The cruises are operated from the Freeport, Texas area which has provided the program with genuine public interest and support. Maximum group size per cruise is 20 persons. A nominal fee per cruise is charged.

CREDITS:

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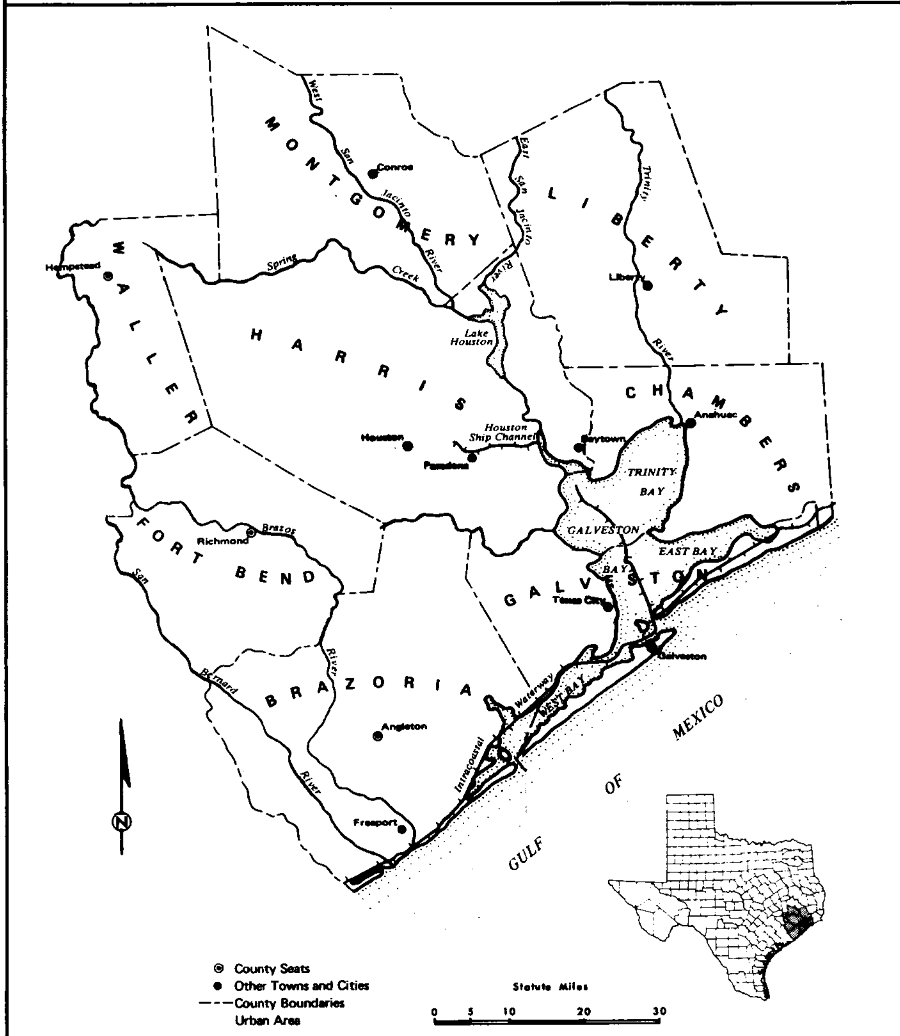
. . . hydrogen and oxygen aren't just transformed immediately in any old way into water. Water has its history too.

Chinese philosopher

GALVESTON BAY AREA



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INTRODUCTION

Of all the things that will eventually be said as historians record their views of the 20th century, it is almost certain that this century will be remembered for the great changes which reordered the relationships between the human race and the planet we inhabit. It should be noted that there have always been individuals who have had a close and understanding relationship with the planet and its creatures. In recent times, however, major regroupings of entire countries into industrial, urban, climatized centers has insulated whole populations from a need for intimate knowledge of the natural, physical world.

In simpler periods of history, people learned by doing. Today, we have developed the technique of learning by reading or being told. We have become isolated from those things about which we are learning. Isolation and insulation from the physical world makes it more difficult to appreciate the intricacies of our planet; the balance and dependencies among its systems and inhabitants that have developed over millions of years.

It is difficult to correct the growth of our isolation, yet important that we do. The Day on the Bay Program is a bridge from the classroom to the sea. During the cruise, you will see how ocean studies are conducted, discover what to look for, how to perform the analyses and understand the results. The cruise will not be perfect; few cruises ever are. You will see a lot of water. The earth will appear large and its resources bountiful. It will seem as if we could never run out of water and yet certainly we can. For in truth, it's only a little planet.

COASTAL ECOLOGY

The coast, in its simplest conception, is the border where the water meets the land. At this boundary, the forces of two opposing environments attack and alter each other and produce the coastal features we know as fjords, bays, beaches, headlands, deltas, marshes and estuaries. Probably the most complex, diverse, and biologically productive of these environmental borderlands is the coastal estuary. It is described as a coastal basin containing water received from rivers and from the ocean. Typically, it may be partially enclosed behind land formations or protected behind offshore features such as barrier islands. Ocean water movement into such a protected estuary is usually funneled through inlets, thereby altering both its inward force and its accessibility to the confined estuarine water.

The essential nature of a coastal estuary is that of a giant mixing bowl, combining various amounts of freshwater from continental runoff and a fairly constant supply of seawater from the oceans. The result of this mixing action is the dilution of the estuarine water's salinity. This dilution procedure is probably the single most important physical process that occurs in the estuaries' confines. Of the two inputs, freshwater and saltwater, it is the freshwater contribution which is the decisive factor because it is a seasonably variable factor while the supply of the saltwater component is fairly stable and constant (under ordinary conditions). This distinction is important for two reasons. First, the volume of freshwater controls the salinity of the estuarine water. Secondly, the volume of freshwater helps to govern the patterns of circulation within the estuary and the rate at which water moves through the estuary. Together, the amount of salinity and the salinity distribution are critical factors influencing both the types of plants and animals found in the estuary and also the physical distribution patterns of estuarine life forms.

While the prime factor affecting water salinity and circulation patterns is the freshwater input, there are other factors influential in producing the dynamic nature of estuarine water movement; among these are the tidal forces, tidal currents, and wind initiated currents and mixing patterns. When these water movement factors are taken as a whole and combined with the physical character of the estuarine basin itself, several common circulation regimes are possible; among these are the stratified and the non-stratified circulation patterns.

Estuaries which show the salinity values of their waters arranged in well defined layers are known as *stratified* estuaries. Commonly found in the deeper estuaries which have large volumes of freshwater flowing into them, a two-way circulation pattern is established in stratified estuaries with the less dense freshwater flowing oceanward at or near the surface and the more dense seawater flowing into the estuary along the estuary's floor. This two-way circulation produces what is known as a "saltwater wedge" which may be detected a long distance past the mouths of the rivers that drain into the estuary. The distance into the estuary that the wedge can be detected is dependent upon such components as the amount of freshwater inflow, the depth of the estuary, the size of the estuarine basin, the size of the estuarine inlets to the ocean, and the tidal cycles and forces. A deep estuary with a high amount of freshwater inflow and large ocean inlets produces a well-developed wedge flowing far into the estuary. The opposite conditions work against the wedge to reduce its penetration, size and well-defined nature.

The well-developed movement of water in the estuary characteristic of a stratified system can be very beneficial in both a physical sense and biologically. Estuarine organisms can use counter-flowing currents to move about the estuary drifting oceanward along the surface flow or landward in the deeper, saltier wedge. This allows plankton to position themselves in the middle and upper areas of the estuary and is one reason why these areas are so productive. Mixing does occur at the boundaries between these counterflows and the net discharge of all water is seaward. A stratified circulation pattern will tend to promote a very healthy estuary due to good distribution of nutrients and the ability to remove or disperse pollutants thereby assimilating the pollution up to a certain pollution load. (See Figure 1).

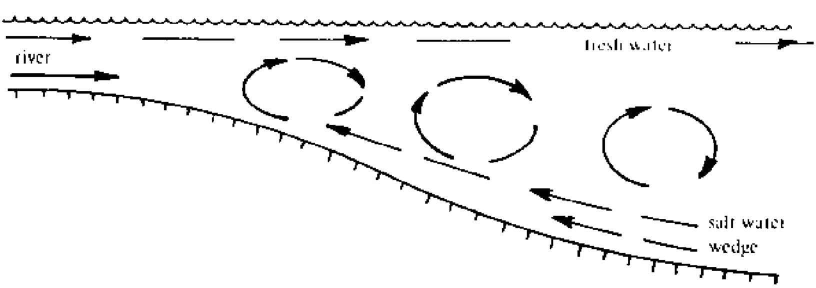


Figure 1. Circulation pattern of a stratified estuary.

Estuaries in which the water is fairly well mixed and homogeneous are classified as having a *non-stratified* circulation pattern. In such cases, the estuary is usually shallow. The limited depth will decrease the amount of freshwater and saltwater inflow while giving more opportunity for the water to blend during their stay in the estuary. Well defined currents are less common here but important. The combined effects of fresh water inflow and tidal currents determine the rate of water movement through the estuary. Winds can be very helpful in setting-up currents that mix the upper layers of the water. If the estuary is very shallow and/or fairly large, wind could accomplish a great deal of mixing within the water column. Because water moves through the non-stratified estuary more slowly than in the stratified system, the non-stratified bays are much more vulnerable to damage by pollution. The amount of pollutants that can be accepted into the bay is reduced because they cannot be dispersed and assimilated as quickly since the water movements themselves are reduced. Non-stratified estuaries, however, can be very productive areas as long as they are not overloaded by pollutants. (See Figure 2).

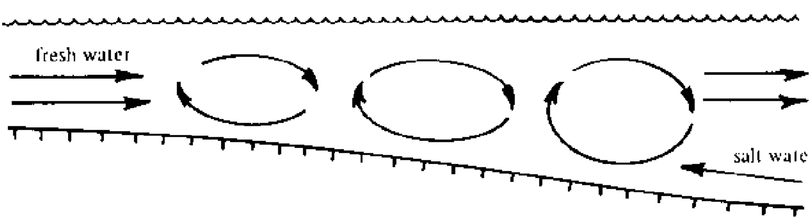


Figure 2. Circulation pattern of a non-stratified estuary.

SPECIFIC WATER QUALITY CHARACTERISTICS OF ESTUARIES

Salinity

Water from the land and water from the ocean converges in the estuary and blends in various degrees to establish a number of specific water quality conditions, such as salinity, nutrient level, dissolved gases, turbidity, temperature, pH, and pollution load. As we have already discussed, the salinity level and circulation of estuarine water is determined by the nature of mixing. Not all organisms which inhabit the estuary will tolerate or prefer the same salinity range. Some organisms, especially those comfortable in open coastal water will prefer the seaward edge of the estuary where ocean water has not been greatly diluted. Other organisms prefer much lower salinity levels and locate themselves in the upper reaches of the estuary where freshwater input is more influential. (See Figure 3).

In addition, some organisms are more tolerant to wider variations in their normal salinity environment or can withstand sudden changes for a longer period of time than can others. Thus, unusually long or large fluctuations of salinity can produce large kills of some organisms, but not others. Finally, an organism's salinity preferences may change as it grows. For example, juvenile shrimp require a much lower salinity level than adult shrimp. (See Figures 3 & 4).

Dissolved Gases

Gases are also found dissolved in the water. The most important gases to a healthy estuary are dissolved oxygen (O_2) and dissolved

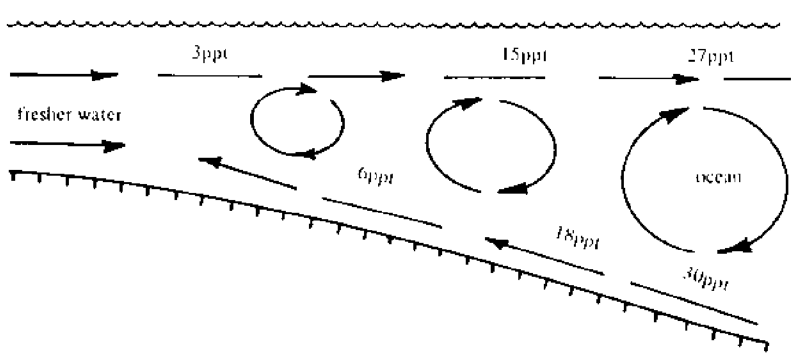


Figure 3. Salinity distribution in stratified estuary.

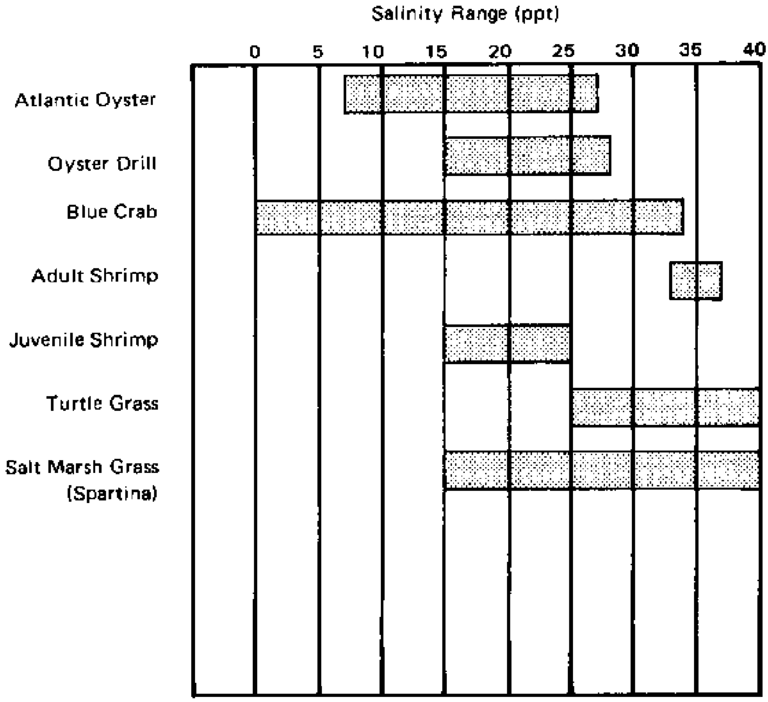


Figure 4. Salinity preference range for typical coastal organisms.

carbon dioxide (CO_2). Oxygen is required for respiration by both plants and animals and is released by plants as a by-product during photosynthesis. Carbon dioxide is released by both plants and animals in the process of respiration and is utilized by plants in the process of photosynthesis. The amount of dissolved carbon dioxide in the water exists in an equilibrium with several carbon containing compounds in the water and the carbon dioxide of the atmosphere so that it remains at a fairly constant level. The amount of oxygen in the water is quite changeable. For a healthy estuary, a balance is maintained between oxygen produced and oxygen consumed with a minimum level of six parts per million (ppm) of oxygen present at all times. If dissolved oxygen levels fall below this minimum, such as 4 or 5 ppm of O_2 or less, certain organisms cannot receive sufficient oxygen for respiration and they may either be damaged, killed or forced to relocate in water with sufficient oxygen for their metabolic rates. For organisms such as clams and oysters which are usually premanently attached or located as adults, extended, low levels of dissolved oxygen means certain suffocation. Estuaries with good water circulation are less prone to extended low oxygen levels due to good mixing and rapid removal of poorly oxygenated water.

Nutrients

Besides carrying dissolved salts, estuarine waters contain other chemical constituents of importance such as nutrients, dissolved minerals and even vitamins. These are all compounds which are required by organisms for proper growth. Nutrients are probably the most important. They are brought into the estuary by both freshwater and the ocean. All plants, both phytoplankton (phyto = plant; plankton = drifter) and anchored plants such as algaes and marsh grasses extract nutrients such as phosphates (PO_4) and nitrates (NO_3) from the water and use them in the production of plant tissue. Since all other organisms in the estuary are dependent directly or indirectly upon the primary food source, the plants, then plant health and abundance is essential to the health of the whole estuary. Lack of sufficient nutrients limits plant growth while over abundance of these nutrients can encourage over growth of the plant community which can produce undesirable effects (eutrophication). Generally, it is the amount of nitrate in the water which acts as a limiting factor to plant growth. Another constituent only recently recognized as important components of estuarine water are the vitamins which are released in areas of plant decay such as marsh grasses. Juvenile animals using the estuary as a nursery have been shown to require such vitamins for their early growth periods. Destruction of marsh areas in estuaries removes a source of vitamins and reduces the ability of the estuary to support juvenile life forms.

Water Temperature

The temperature of the water in a coastal estuary will be determined by the combined influence of a list of components. This list includes location of the estuary (latitude), depth and area size of estuary, proximity to coastal ocean currents, land geography, circulation pattern of the estuary, and common weather patterns. Animal behavior is influenced by water temperature in ways such as growth and development, metabolic rates, feeding efficiency, swimming speed, spawning and migration cycles. In shallow estuaries, the water temperature may be very nearly the same from surface to bottom, but in deeper estuaries where stratified circulation patterns exist, water temperature is usually much cooler near the bottom. Since organisms are usually adjusted to existing temperature conditons, sudden temperature changes can be very detrimental to the health and balance of the estuary ecosystem.

Light Penetration and Water Clarity

Plants are the primary producers of the estuary. All other life forms receive their energy, their food, as a derivative of the plants by either eating the plants or eating something else that eats plants. Plants are on the ground floor of this food pyramid because they make their own food during the process known as photosynthesis.

$$\underset{\text{carbon dioxide}}{6\,CO_2} + \underset{\text{water}}{6\,H_2O} + \underset{\text{sunlight}}{\text{energy}} \overset{\text{presence of chlorophyll}}{\rightleftharpoons} \underset{\text{sugar}}{C_6H_{12}O_5} + \underset{\text{oxygen gas}}{6\,O_2}$$

This combining process is powered by light in the presence of chlorophyll, the pigment that makes plants look green. In order for an estuary to be efficiently productive, light should penetrate the water sufficiently to allow most of the water to support plant life. Phytoplankton have the ability to position themselves within the water column in order to receive the optimum amount of light. Some plankton prefer certain wave lengths of light. Since all wave lengths of light do not penetrate the water equally well, this can effect phytoplankton distribution. The red wave lengths of light are absorbed by the water first, so plankton which prefer the red wave length will be found near the surface. Plankton utilizing the blue-green wave length which penetrates the water best, can be found through a larger section of the water column. The rooted plants need light also and light penetration must reach the bottom in sufficient amounts to support rooted-plants growth.

Estuaries act as a sediment trap for suspended material carried to it by streams and rivers. This suspended material affects the turbidity of the estuary, that is, the clarity of estuarine water. Because of this settling basin function of the estuary, its water is considerably less clear than coastal water. If an estuary is very turbid, light penetration through the water is greatly reduced, thus affecting plant productivity. Besides the natural load of suspended material a river may bring into an estuary, pollution can considerably increase the turbidity due to waste materials such as manufacturing dyes, industrial wastes, oil and organic waste such as from fish packing plants. If wastes are rich in plant nutrients such as nitrates and phosphates, this causes rapid phytoplankton growth resulting in a very thick concentration called a *plankton bloom.* A bloom can be so intense that is can color or cloud the water and further decrease light penetration. A certain amount of turbidity can be beneficial to juvenile life forms since it helps screen them from predators. Some fish depend on their sight for food gathering and very turbid water reduces their hunting capability.

The reduction of light intensity in water (light extinction) occurs as light is scattered and absorbed by suspended particles and water molecules. Light extinction increases with depth. Almost 60% of all light entering even the clearest water is absorbed in the first meter. Light extinction, however, does not occur uniformly among different types of ocean water. In the diagram below, for one meter of seawater, curve A shows the extinction of various wave lengths of light in very clear, open ocean water. Curve B is for tropical waters which are more turbid. C is the extinction of light in mid-latitude waters. D represents the clearest coastal waters. E, F, and G show increasing light extinction for increasingly turbid coastal waters. Violet to yellow light penetrates water well in the open ocean. Organic material in the coastal waters strongly absorbs the blue and violet wave lengths.

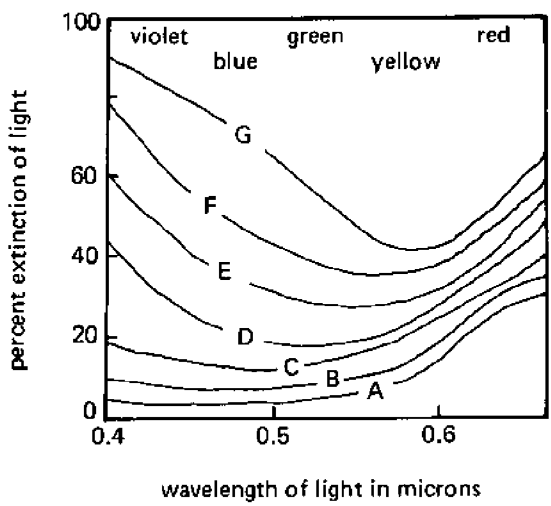


Figure 5. Light extinction in seawater.

GALVESTON BAY

The largest and one of the most important estuarine systems of the Texas Gulf Coast is that of the Galveston Bay estuary. Covering an area of about 520 square miles, this naturally formed basin is the remnant of the drowned valleys of several rivers (mainly the Trinity and San Jacinto) that drain toward the coast. Upper and lower Galveston Bay, Trinity Bay, East Bay and West Bay make up the bay system which lies behind the protection of Bolivar Peninsula (a sand spit) and Galveston Island (a barrier Island). There are two main inlets, Bolivar Roads and San Luis Pass, connecting the estuary with the ocean. Though the estuary is large in size, it is quite shallow with the average water depth only about 7½ feet and maximum depth about 10 feet. The bay, however, has been extensively modified by the dredged ship channels that run through it to connect Texas City, Houston and the Trinity River with the ocean. Water depth within the channels ranges between 40 to 120 feet. Small spoil islands and banks have also been created by accumulating waste during dredging and maintenance of the channels. These modifications have considerably altered the natural flow of water in the bay-estuary system.

Galveston Bay is greatly different from the bay the early settlers of Texas found. Wildlife once abounded its shores and flocks of wintering birds, geese, ducks, whooping cranes and roseate spoonbills used the bays, marshes and lagoons as nesting areas and flyways. Much of the shoreline was edged by marsh grasses, Spartina and Zostera, which extended out into the shallow margins of the bay. Clams and oysters littered the bottom of the bay and fish crowded its water. Now, a large amount of land surrounding the bay has been developed. Galveston, Texas City, Seabrook, Clear Lake, the Houston Ship Channel and Baytown are just a few of the communities on the bay's perimeter. This development, both municipal and industrial, has resulted in major changes in the Galveston Bay estuary system.

Characteristics

1. The bay area is underlaid by a series of sand and clay layers which transmit a large amount of freshwater. Industry, cities and private individuals alike have used the aquifer system under their land as a source of good quality freshwater, pumping about 550 mgd*. Until recently no guidance or pumping controls were ex-

*million gallons per day

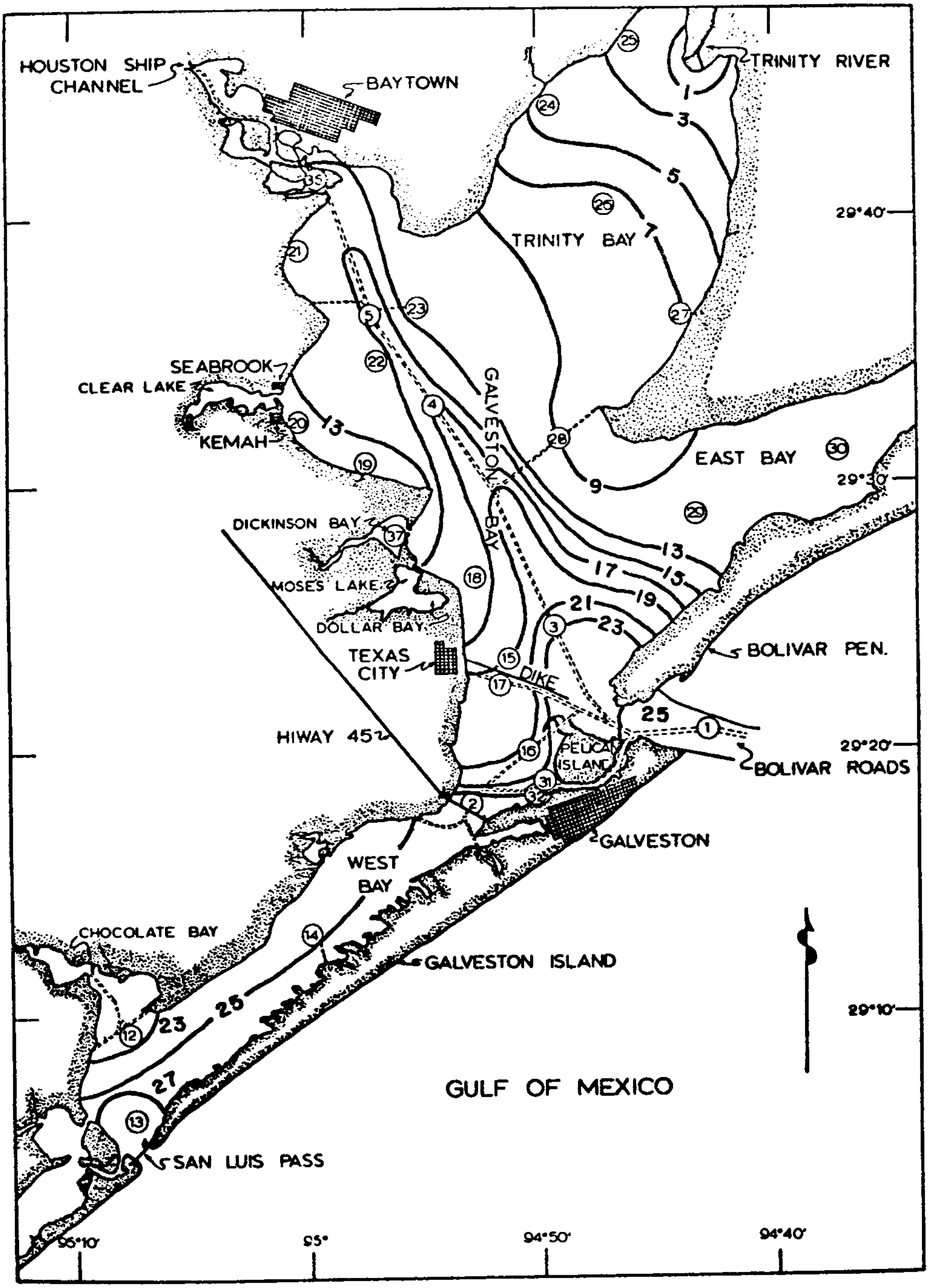
ercised and as a result excessive amounts of water were pumped from the aquifer. The water provided support for the overlaying land. When the water was removed, the land lost some of its structural support and slowly began to sink or subside. As a result, structures near the bay which were once well above water level have been lowered to sea level or below sea level. Some areas have subsided as much as 10 feet. This has allowed the waters of the bay to flood these low lying areas and buildings around the bay have been abandoned or damaged as a result.

2. In its natural state, the circulation pattern of the Galveston Bay estuary would have been classified as *non-stratified*. Because the bay is so shallow, large, and narrowly connected with the ocean, sufficient time existed for the waters to become well mixed and homogeneous. Since the navigation channels have been dredged, the circulation pattern is now different. The spoil banks and dikes deposited along the channels effectively divide the bay into smaller, more isolated units. The waters of these units have a much more individual nature determined essentially by the source of the water and the residence time of the water in the unit.

Saltwater moves up the bottom of the channels in the classical saltwater wedge. The channels act like salty rivers flowing through the fresher water of the naturally shallow bay. Looking at a yearly average of the surface salinity of the bay, the influence of the main deepwater channel through the bay leading to the Houston Ship Channel is apparent. (See Figure 6). Presently the bay has a stratified circulation pattern in the channels with a difference of as much as 15 ppt between surface and bottom. The shallow areas still maintain a fairly homogeneous nature to the waters isolated from the channels.

3. Not only has the bay been altered by dredged channels through and around it, but the margins have also been transformed by activities such as spoil disposal, industrial development and municipal development. What were once marsh grasses and wetlands are now filled and bulkheaded dry lands changed into residential communities, marinas and docking areas for industry. Most of the western section of the bay margin from Texas City to the Houston Ship Channel has been developed and is no longer in its original, natural state. Along the eastern section of the bay from Smith Point to the Trinity River, the bay has been dredged to create the Trinity River Channel with the spoil material piled along the edge of the bay.

Figure 6. Galveston Bay Salinity Pattern.



Isohalines for the Galveston Bay system plotted from mean annual salinity (ppt) at each station.
(From *Ecological Studies of Galveston Bay,* 1969)

The remaining undeveloped areas of the bay consist of the north corner of Trinity Bay, the north edge of East Bay, the north side of the Bolivar Peninsula and the north side of Galveston Island west of Galveston City proper. Coincidentally, these locations also comprise the remaining productive nursery areas of the bay. The largest nursery area still within the main part of the bay is the Trinity River system. Though this area is undeveloped physically, it is still environmentally stressed. The water of the Trinity River as it empties into the bay is highly polluted and is only slowly diluted by other bay waters. (See Figure 7).

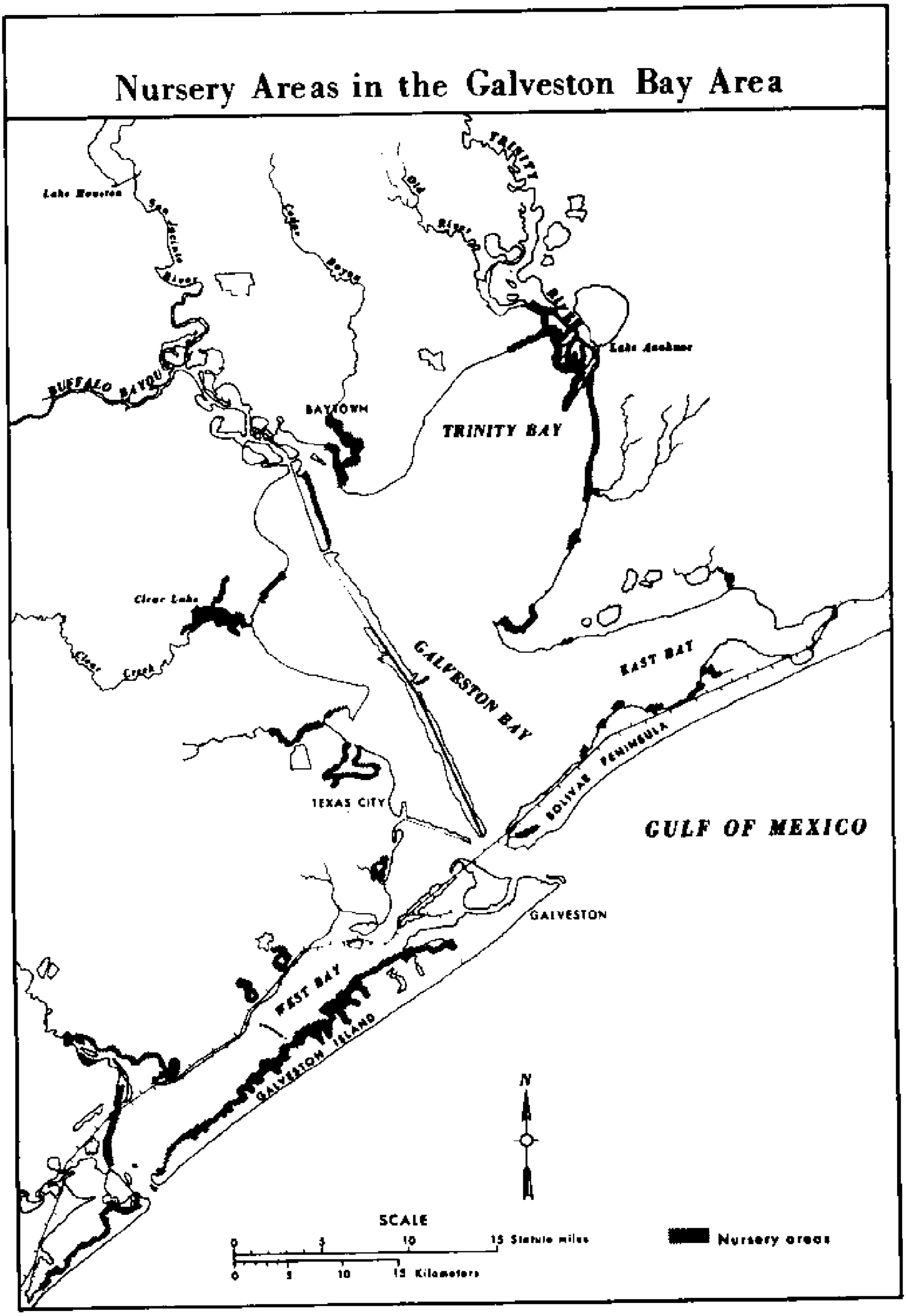
4. This brings up the problem of the quality of the water that comes into the bay by the rivers, bayous and inlets. The most significant sources of inflow into the bay are the Trinity River, the Houston Ship Channel and Bolivar Roads. The Trinity River and the Houston Ship Channel contribute highly polluted waters. Bolivar Roads inlet contributes water from the Gulf of Mexico which has a cleasing or at least a diluting affect and helps to flush the polluted waters from the bay.

The most toxic water entering the bay comes from the Trinity River. This conclusion was drawn from experiments that showed Trinity River water suppressed the growth of phytoplankton more than any other water collected from the bay or its tributaries. Although the exact nature of the toxins is not known, they are added to the river between the Lake Livingston Reservoir and the entrance into the bay. Petrochemical facilities and housing development exist along this stretch of the river.

The waters of the Houston Ship Channel are also highly toxic due to the waste added by industry along the channel. Pollutants added include petrochemical wastes, acids, phosphates, nitrates, and assorted chemical wastes. High concentrations of toxic metals including boron, beryllium, barium, strontium, manganese, zinc, lead and chromium are present. Significant concentrations of pesticides such as deldrin, DDT and its derivatives and heptachlor epoxide have been found in the sediments of the channel. It was estimated in 1969 that the channel adds about 426,000,000 gallons of industrial waste per day to the bay.

Within the ship channel, from Morgan Point to the turning basin, very little can live in the water, especially as you proceed up the channel. The condition of fish taken from the mouth of the channel has been poor. Some fish have had parts of their fins eaten away by acids and hard deposits encrusted over their eyes. Other areas of the bay expected to show good water quality were

Figure 7. Nursery Areas in the Galveston Bay Area.



(From *Activities and Resources of Galveston Bay,* 1972) unexpectedly polluted. Hannah's Reef in the middle of East Bay was expected to be an example of a relatively unpolluted, healthy ecosystem. However, during the spring and winter months, the water quality of the reef was closely associated with the water quality coming from the Trinity River due to a plume of water spreading around the point and into East Bay thus indicating the large influence the freshwater inflows have over the entire bay and the detrimental effects resulting from the input of pollutants.

5. The dissolved oxygen concentration of the water of Galveston Bay is highly variable. The water coming from the Houston Ship Channel is at times essentially anoxic (lacking in oxygen). Normally the ship channel water is very low in dissolved oxygen. This nearly anoxic water is diluted as it enters the bay, helping to increase the general oxygen content of the water with increasing distance from the ship channel. Fish inhabiting the poorly oxygenated waters of the bay are usually small in size due to the slowing effect on metabolic rates. Areas near the ship channel and along the channel floor often have sediments which contain little or no oxygen making them uninhabitable to all except certain bacteria which prefer oxygenless environments. Such bacteria give off hydrogen sulfide gas as a metabolic waste product and this causes the sediment to have a very offensive odor.

6. Most bays which receive river water act as a settling basin for the fine sediment carried by the river and Galveston Bay is no exception. The bottom of the bay is mainly soft mud. This is ideal for burrowing animals such as worms and clams. The numerous shells found among the mud are indicative of the attractiveness of the soft substrate to bottom dwellers or infauna. Toward the coast, more sand is mixed with the mud.

7. The nekton or the free-swimming, mobile animals are the most economically important animals inhabiting the bay. They include the sports fish, shrimp, commercial fish and crabs. General abundance of the nektonic organisms in the bay is as follows: croaker, anchovy, catfish, shrimp, blue crab, sand trout, menhaden, spot and others. (See Table 1). The greatest abundance of nektonic organisms in the bay occurs around April due to the spring migration of organisms using the bay as a nursery. Around October the lowest level of organisms is found due to the seaward migration to spawn in the Gulf.

The nektonic organisms, generally the larger and more biologically complex of the life forms living in the bay waters, are especially sensitive to the quality of the waters they inhabit. Because Galveston Bay is a multi-stressed environment receiving a combina-

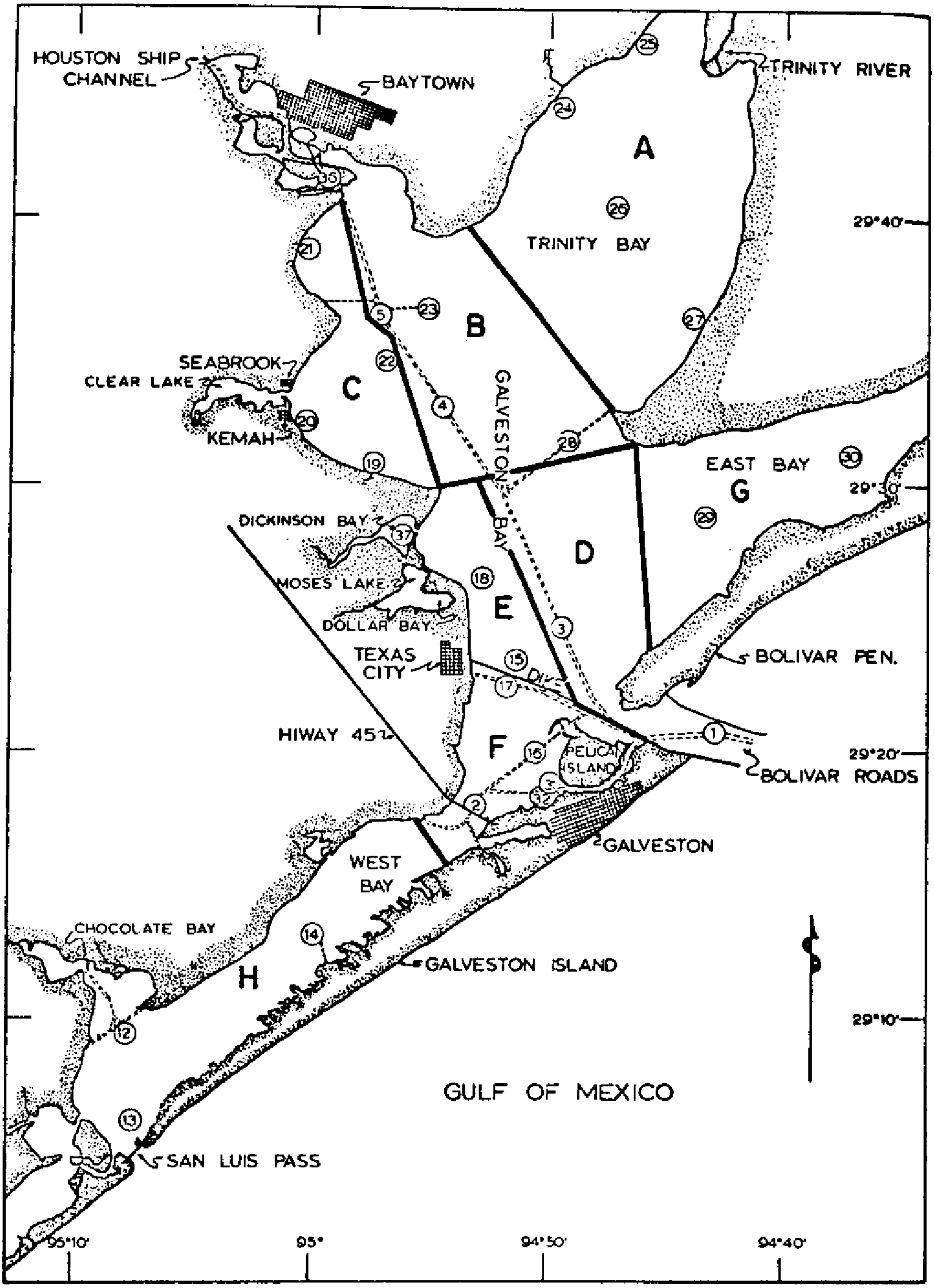
Table 1. Dominant Fish Communities in Galveston Bay

Area	Season	Most Abundant	2nd	3rd
A	Feb.	Anchovy	Croaker	Menhaden
	Apr.	Croaker	Anchovy	Menhaden
	Jul.	Croaker	Anchovy	Sand Trout
	Oct.	Anchovy	Croaker	Sea Catfish
B	Feb.	Croaker	Anchovy	Spot
	Apr.	Croaker	Anchovy	Menhaden
	Jul.	Croaker	Catfish	Anchovy
	Oct.	Catfish	Anchovy	Croaker
C	Feb.	Anchovy	Croaker	Spot
	Apr.	Croaker	Anchovy	Menhaden
	Jul.	Croaker	Sand Trout	Threadfin
	Oct.	Catfish	Anchovy	Shrimp Eel
D	Feb.	Croaker	Whiting	Tonguefish
	Apr.	Croaker	Threadfin	Anchovy
	Jul.	Catfish	Sand Trout	Croaker
	Oct.	Catfish	Croaker	Whiting
E	Feb.	Anchovy	Croaker	Sheepshead
	Apr.	Croaker	Anchovy	Spot
	Jul.	Threadfin	Croaker	Anchovy
	Oct.	Catfish	Sand Trout	Anchovy
F.	Feb.	Croaker	Tonguefish	Anchovy
	Apr.	Croaker	Tonguefish	Anchovy
	Jul.	Croaker	Star Drum	Sand Trout
	Oct.	Tonguefish	Fringed Flounder	Anchovy
G	Feb.	Croaker	Anchovy	Mullet
	Apr.	Croaker	Anchovy	Spot
	Jul.	Croaker	Sand Trout	Catfish
	Oct.	Catfish	Anchovy	Croaker
H	Feb.	Croaker	Anchovy	Stingray
	Apr.	Croaker	Spot	Anchovy
	Jul.	Croaker	Spot	Sand Trout
	Oct.	Anchovy	Puffer	Stingray

(See Figure 8 for sample areas.)

(From *Ecological Studies of Galveston Bay*, 1969)

Figure 8. Division of Galveston Bay sampling stations by areas.



(From *Ecological Studies of Galveston Bay*, 1969) tion of highly polluted freshwater and fairly clean seawater, the abundance and variety of nekton, their size and weight and their location in the bay are all a factor of water quality. As a result, certain parts of the bay have a fairly normal and healthy balance of nektonic species while other parts of the bay have been reduced to a rather limited and numerically reduced assortment of such free-swimmers. As a rule of thumb, the quality, quantity, and variety of various nekton improves and increases with distance from the Houston Ship Channel. The most pollution sensitive species have been eliminated from the mouth of the ship channel. This leaves primarily croakers and anchovies as the dominant species. The size and weight of these specimens, however, is smaller than in other areas of the bay. This is a response to the highly stressful environment since small fish with lower metabolic requirements can withstand the stresses of pollution better than large fish which have more body mass to support and less extra energy available to combat the effects of pollution. Pollution tends to increase an organisms's demand for oxygen which in turn demands of them a greater energy expenditure to maintain normal body functions. In areas such as the ship channel which already has a very low level of oxygen available, this increased oxygen demand, especially by larger organisms, cannot be adequately furnished due to the low oxygen content of the water and thus the larger organisms do not tend to survive.

A similar situation exists in Trinity Bay. As with the ship channel, the larger organisms do not cope well with the polluted environment. The most common fish found here, such as anchovy, croaker, menhaden and catfish are usually small in size and either feed on plankton or are unspecialized feeders able to adapt to a wide range of environments.

Texas City is another area which adds large amounts of municipal sewage to the bay. However, the effects of the pollution were unexpectedly small, due primarily to the change in circulation patterns caused by the dike and the tidal flushing action of Gulf water passing through Bolivar Roads.

To summarize, Galveston Bay supports a large crop of fish indicating the water is habitable. Fish kills do occur, however, and large patches of very toxic, undiluted water are known to move through the bay and can have lethal or sublethal effects. By being sublethal, the water can cause slowed metabolism and thus decreased growth rates. Larger fish and specialized or unadaptable fish are usually eliminated by death or migration to more favorable locations. The decreased size of animals using the bay as a nursery means these organisms will probably not grow to their normal size at maturity thus damaging the entire fishery system.

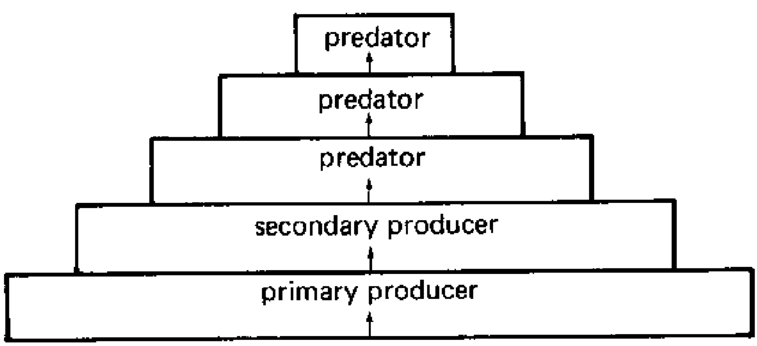
WHAT TO LOOK FOR

When scientists collect samples or organisms from the waters of the bay or ocean, they may be looking for a number of things--that is to say, from the samples they collect, they hope to be able to draw certain conclusions in a general way from the specific things they find. For example, they may seek to know just which organisms use the bay as a home. Do the organisms live there all year long or for just part of the year—or for just part of their life cycle? Do the organisms live only within the bay but move about rather than remain in only one area? Another consideration is the role that each organism plays in the total ecological balance of the estuary. This type of study attempts to determine the trophic levels of organisms within the bay. Trophic levels are a fancy way of looking at who uses what for their food source. The plants, which produce their own food from the water, CO_2, and light (photosynthesis), do not rely on any other organism to supply them with the food (energy) they need to live. They are self-sufficient in producing their own food from the raw materials in the environment. Because the plants are the only organisms capable of this independent mode of existence, they are on the bottom rung of the trophic pyramid and as such are called the *primary producers* (primary = first or principal). The plants are the ultimate source of food (energy) upon which the rest of the organisms depend. Remove the plants and the whole system collapses and is destroyed. In the bay, plants may be of the attached type such as the marsh grasses or they may be the floating, drifting type living directly in the water as are the phytoplankton, which are known as the grasses of the oceans.

On the next level of the trophic pyramid are the organisms which use the plants as their source of food. These organisms are incapable of making their own food directly from the raw materials around them and instead, eat the plants and simply reorganize the plant tissue for their own needs. Most notable of the organisms in this category are the zooplanktons. They are water born drifters not much larger than some of the phytoplankton, but animals nonetheless and capable of a certain amount of direct movement. These are the grazers on the grasses of the oceans. Still further up the trophic pyramid are the organisms which feed on the organisms which eat the plants. Now the original raw materials (energy) have passed through or have been incorporated into at least 2 levels. With each climb up the pyramid, a reduction in energy occurs and therefore, the organisms at each level must eat more to get an equivalent amount of energy. Organisms such as humans are generally at the top fo the pyramid. The food they use for energy may have passed through 3 or 4 levels before humans acquire it. (See Figure 9).

Animal or plant *diversity* is a determination of the variety of organisms of a particular type which inhabit a given area. Animal diversity is a common characteristic looked at, for example, in studying fish populations. Diversity gives an indication of the health of the environment. A healthy environment usually has a broad range of diversity because this means the living conditions are favorable enough to support a variety of living requirements. An area which would support shrimp, anchovy, trout, croaker, and catfish as compared to an area which supports only anchovy indicates the second area is so unfavorable that only a general, nonspecialized fish such as anchovy can survive. Scientists also take samples just to find out what is the "normal" condition. In this

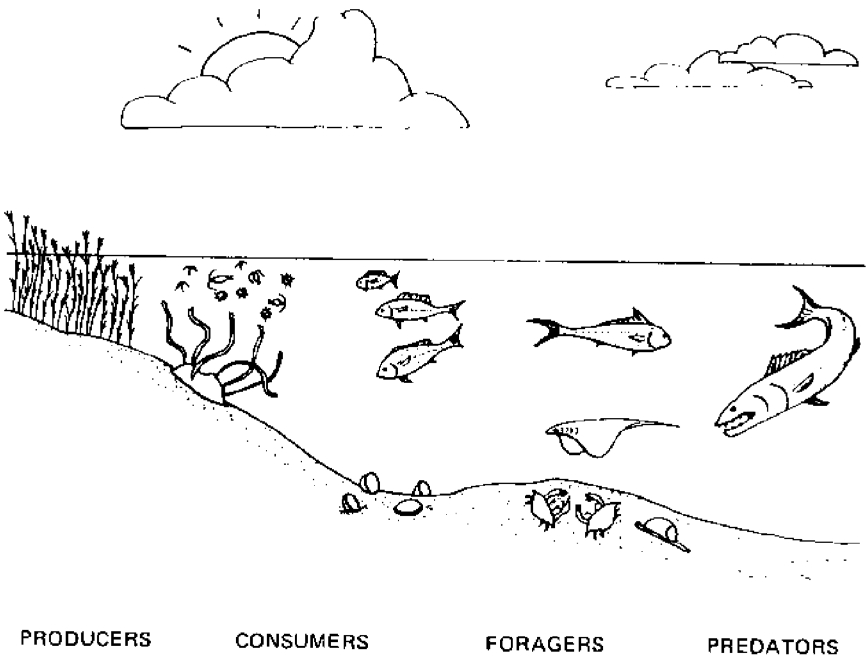
Figure 9. Trophic-pyramid.



A typical food chain would be:

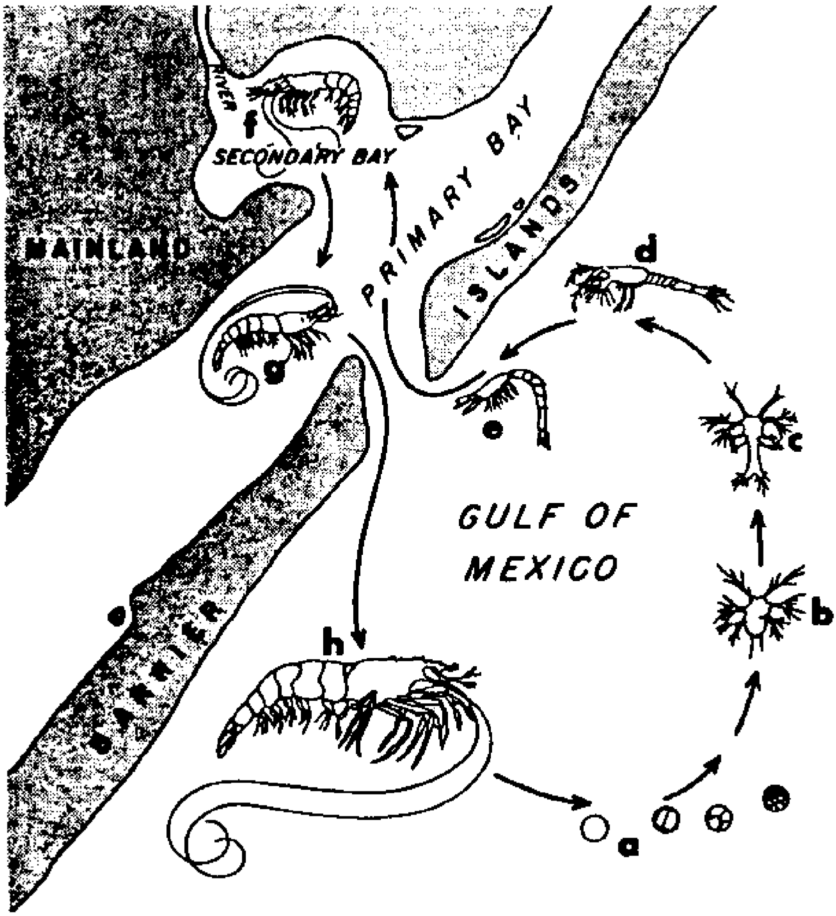
Phytoplankton Zooplankton Small Fish Bird Human

Figure 10. Typical marine food chain.



way they can better understand how the system works and can then have a basis upon which to judge when the system begins (for some reason) to change.

Figure 11. Shrimp life-cycle.



Life-cycle of shrimp in the Gulf of Mexico: (a) shrimp eggs, (b) nauplius larva, (c) protozoa, (d) mysis, (e) postmysis, (f) juvenile shrimp, (g) adolescent shrimp, (h) adult shrimp.[3]

PHYTOPLANKTON

The plants which make up the phytoplankton are small, often single-celled units. They may be divided into four groups based on common features of each group.

The first group is commonly known as the *diatoms* (division - Chrysophyta). The diatoms are the most numerous and common phytoplankton in the bay. They are characterized by an outer shell which fits together in two halves like the bottom and lid to a box.

The second group of phytoplankton is the *dinoflagellates* (division - Pyrrophyta). The distinguishing feature of this group is the whip-like appendage called a flagellum. The flagellum or flagella (if there are two or more) are waved in a swirling motion to propell the dinoflagellate through the water but not with enough force to overcome the general flow of the water. The dinoflagellates can be either armored with small plates or naked, without armor.

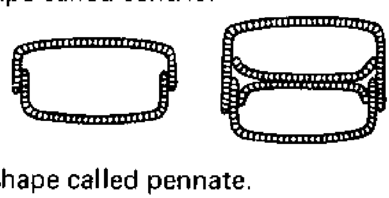
The third group is the *blue-green algaes* (division - Cyanophyta). Although they are known as blue-green algae often they also contain a reddish pigment which gives them a red color. This group is more common in the open coastal and ocean waters than the estuary of Galveston Bay.

The *green algaes* comprise the fourth group (division - Chlorophyta). These algaes are a green color because the chlorophyll is not masked by other pigments. They can be found as large, multicelled plants as well as small, single-celled drifters.

Diatoms

Diatoms are found with one of two general shapes.

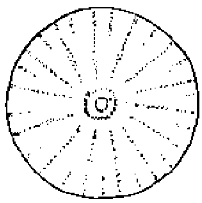
A. Box-like shape called centric.



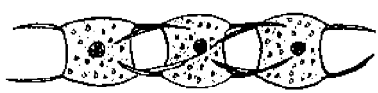
B. Long, oval shape called pennate.

Diatoms commonly found in the Gulf of Mexico.

Centric:



Arachnoidscus

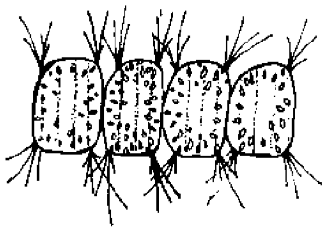


Biddulphia

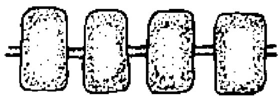
Triceratium

Rhizosolenia

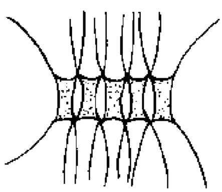
Diatoms - continued



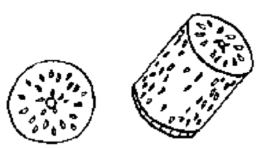
Lauderia



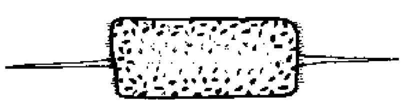
Thalassiosira



Chaetoceros

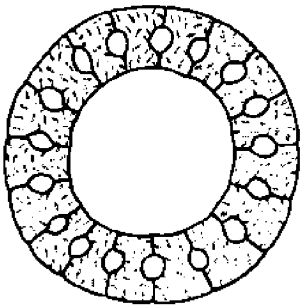


Coscinodiscus

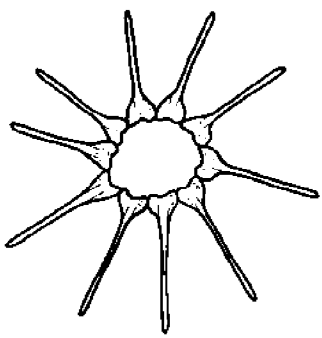


Ditylum

Diatoms - continued



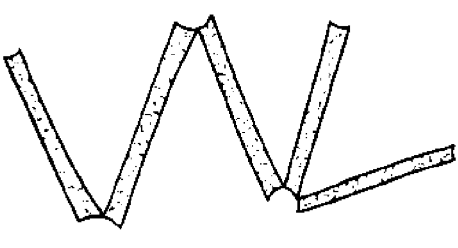
Eucampia



Asterionella

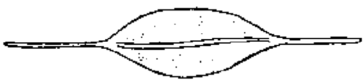
Skeletonema

Pennate:

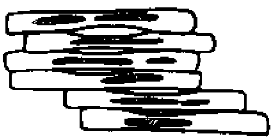


Thalassionema

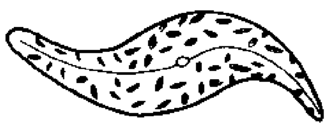
Diatoms - continued



Nitzchia



Bacillaria



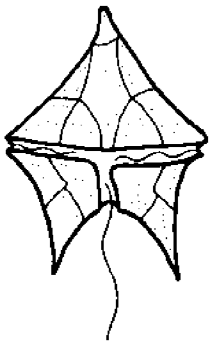
Pleurosigma

Stauroneis

Dinoflagellates

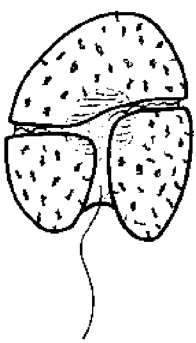
The Dinoflagellates may take one of two forms.

A. The armored body is covered by small plates.

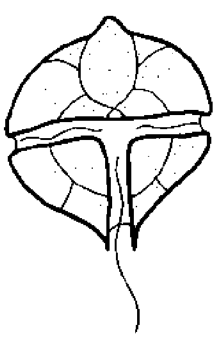


Peridinium

B. The unarmored or naked body lacks protective plates.

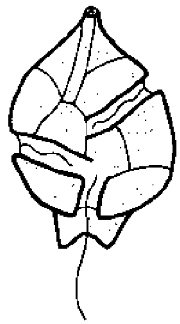


Commonly collected Dinoflagellates.

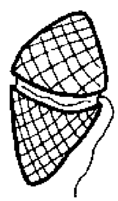


Peridinium globulum

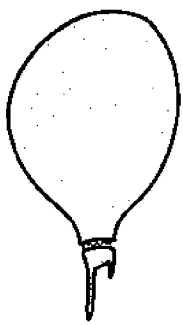
Dinoflagellates - continued



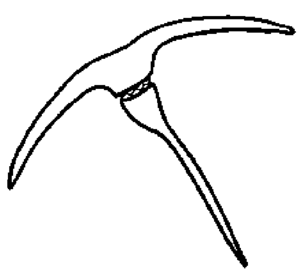
Gonialax



Phalacroma



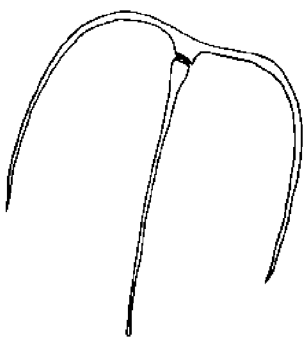
Ceratium



Ceratium

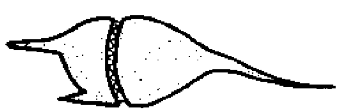
Dinoflagellates - continued

Ceratium

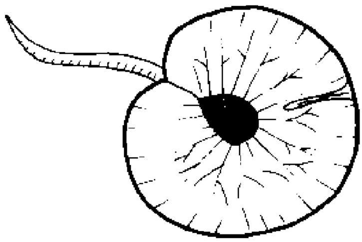


Ceratium

Ceratium



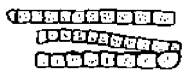
Ceratium



Noctiluca

Blue-Green Algae

This phytoplankton is long and hair-like in form.

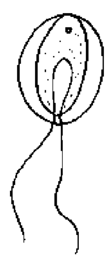


Trichodesmium

Nostoc

Green Algaes

These algaes are usually rounded, sometimes with lobes, and with 2 - 4 flagella.



Sphaerellopsis

Playmonas

ZOOPLANKTON

A number of different organisms are grouped under the heading zooplankton - drifting animals. Some members look very much like the phytoplankton due to their small size, delicate shapes and single-celled nature. Other members are obviously small animals. Not all zooplankton are permanent members of the zooplankton classification. Some animals spend only part of their life cycle as zooplankton. They generally grow out of their zooplankton stage (juvenile or larval stage) by settling and becoming permanently attached to a fixed location or they may grow into bigger animals which are more mobile. Thus, they are temporary members of the zooplankton community.

The most common groups of the permanent members are:

1. Foraminifera
2. Radiolaria
3. Copepods
4. Euphausids
5. Chaetognaths
6. Ostracods
7. Tintinnids
8. Cladocera

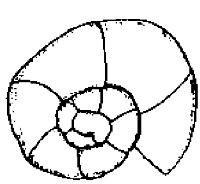
The temporary residents are often larval forms. Especially common among these are:

1. Crab zoea - juvenile crab form
2. Barnacle larvae
3. Shrimp larvae
4. Fish eggs and larval forms
5. Various larval forms of worms, crustaceans, and mollusks
6. Medusa

Permanent Zooplankton

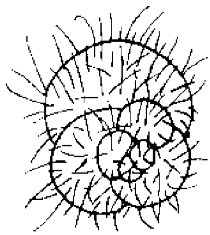
Foraminifera

Globigerina



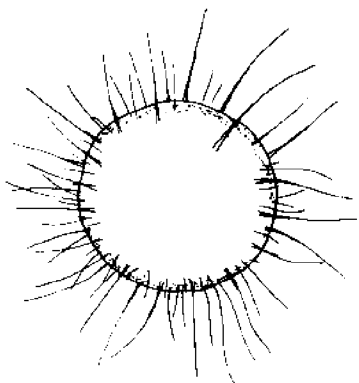
Globigerina

Zooplankton - continued

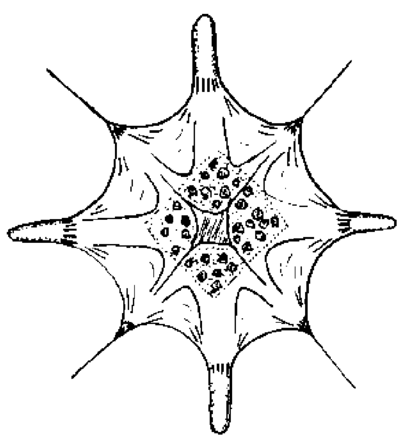


Globigerina

Radiolaria



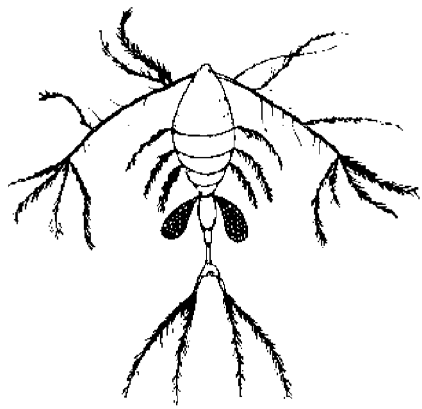
Orbulina



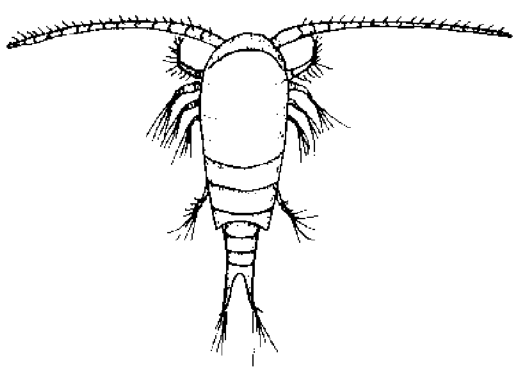
Acanthostaurus

Zooplankton - continued

Copepods

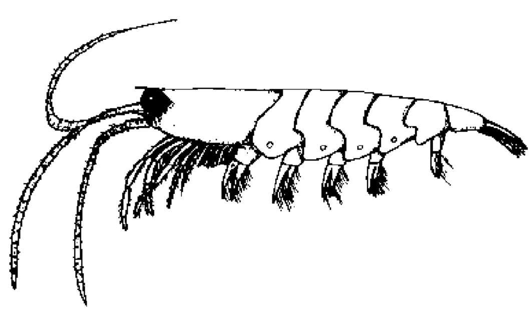


Calocalanus



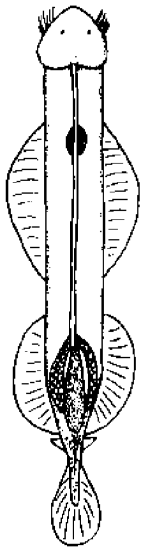
Calanus

Euphausids

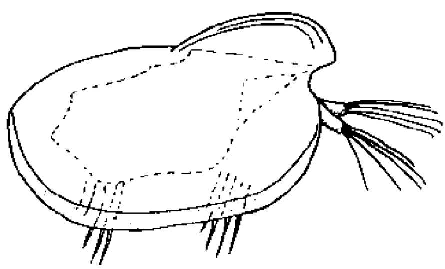


Zooplankton - continued

Chaetognaths

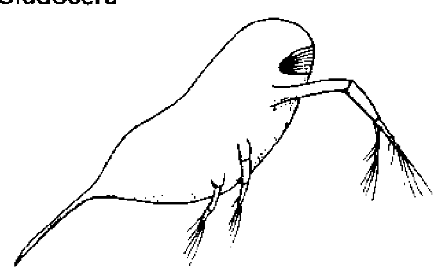


Ostracod



Conchoecia

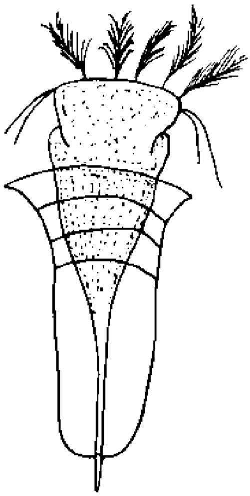
Cladocera

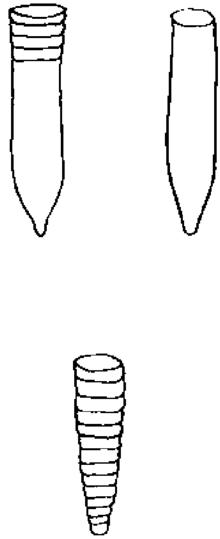


Daphnia

Zooplankton - continued

Tintinnid

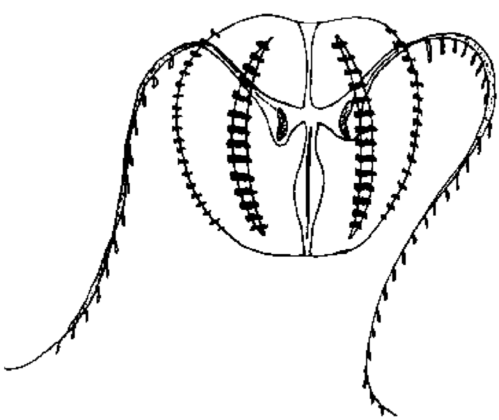




Tintinnid loricas

Temporary Zooplankton

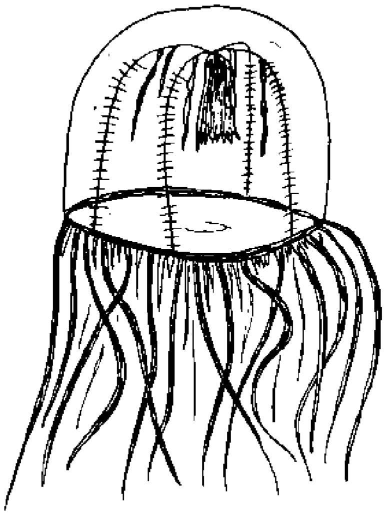
Ctenophores



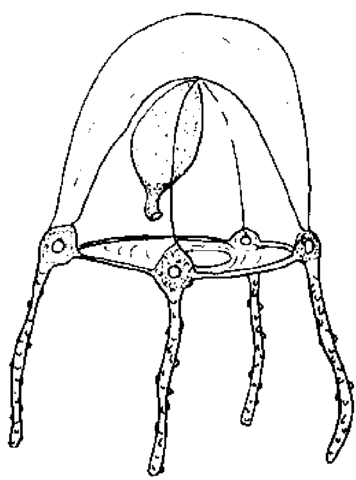
Pleurobrachia

Zooplankton - continued

Medusae



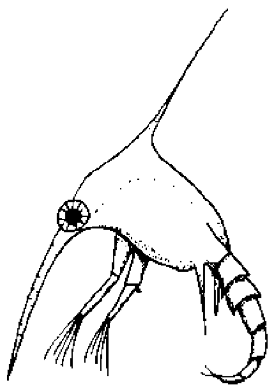
Polyorchis



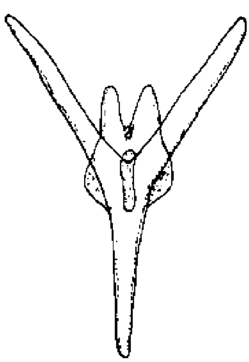
Sarisa

Zooplankton - continued

Crab zoea



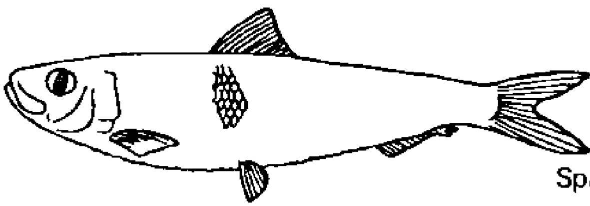
Echinoderm
Larvae



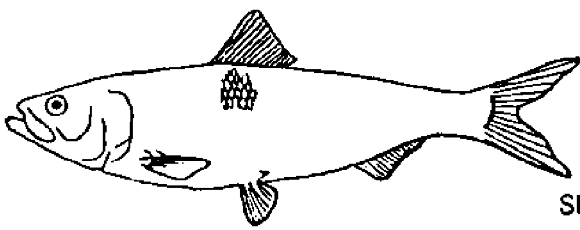
NEKTON

The nekton are the mobile, swimming organisms of the bay and are very important to commercial fishermen. These organisms are caught with a trawl such as an otter trawl.

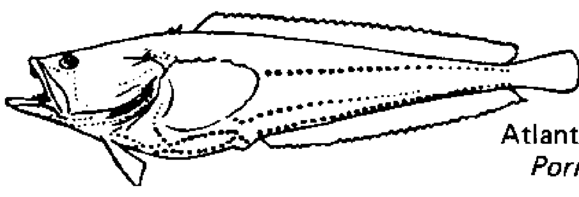
The following are some of the most common nekton of Galveston Bay and the Gulf of Mexico.



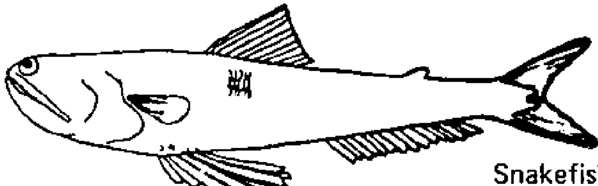
Spanish Sardine
Sardinella anchovia



Skipjack Herring
Alosa chrysochloris

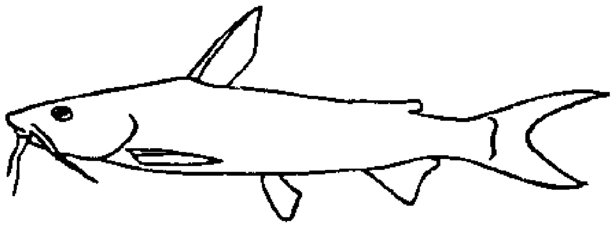


Atlantic Midshipman
Porichthys porosissimus

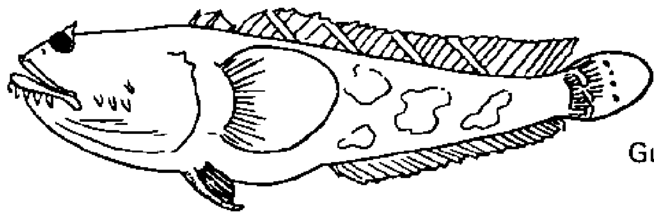


Snakefish
Trachinocephalus myops

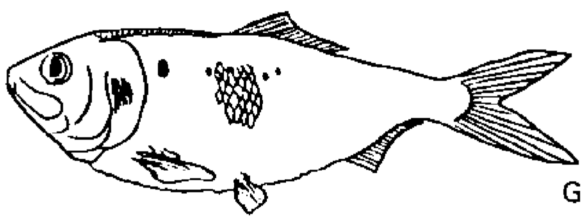
Prints taken from *Key to Estuaraine and Marine Fishes of Texas.*



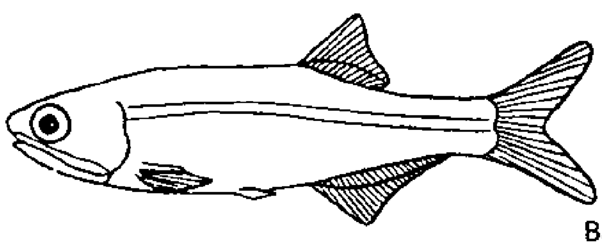
Sea Catfish
Arius felis



Gulf Toadfish
Opsanus beta

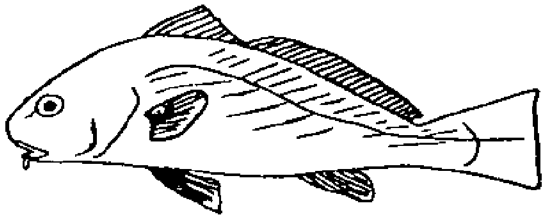


Gulf Menhaden
Brevortia patronus

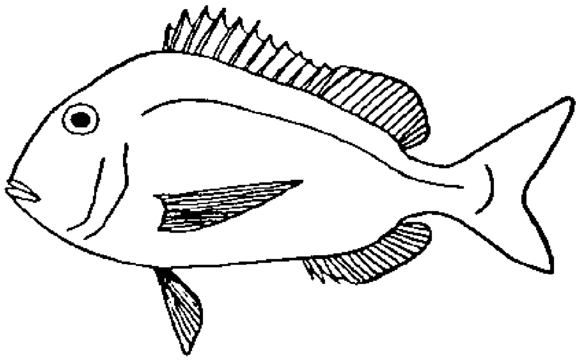


Bay Anchovy
Anchoa mitchilli

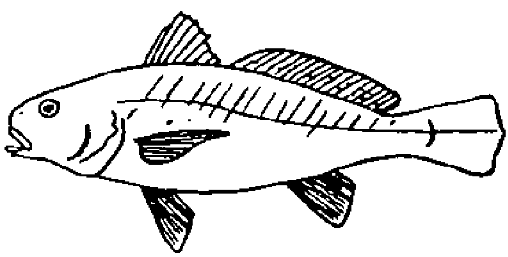
Nekton - continued



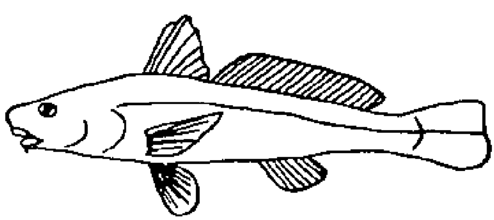
Sand Drum
Umbrina coroides



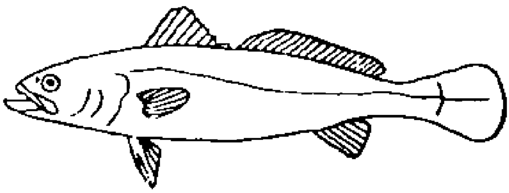
Saucereye Porgy
Calamus calamus



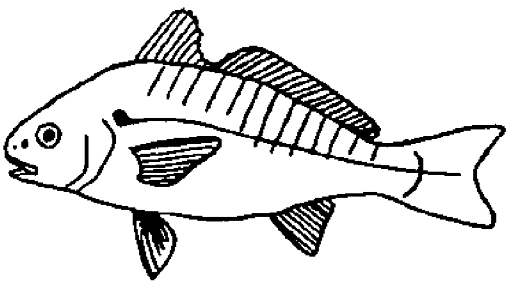
Atlantic Croaker
Micropogon undulatus



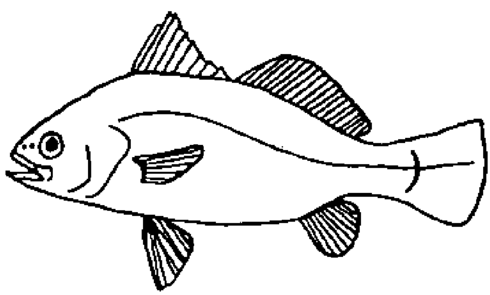
Gulf Kingfish
Menticirrhus littoralis



Silver Seatrout
Cynoscion nothus



Spot
Leiostomus xanthurus



Silver Perch
Bairdiella chrysura

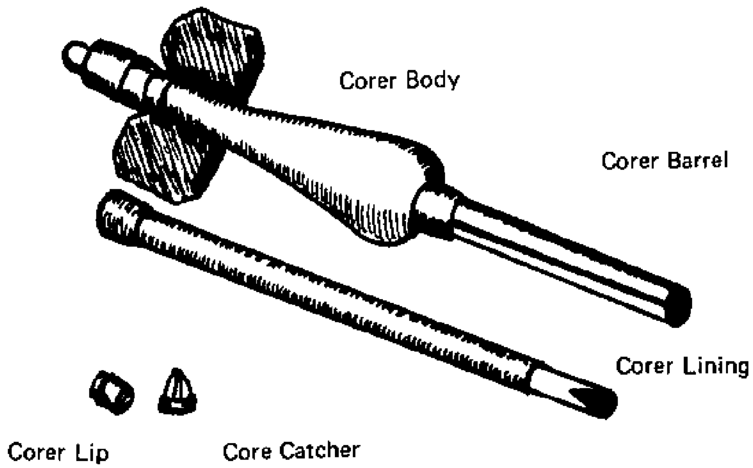
FIELD EQUIPMENT

1. Corers: A corer is simply a weighted metal pipe used to punch a column of bottom material with as little distortion to the sample as possible and retrieve it aboard the research vessel. The parts of the corer are:

a. core body - a weighted lead or steel mass with fins for stability and a shackle at the end for attachment to the hydrowire for retrieval.
b. core barrel - a threaded metal pipe which screws into the core body. These come in different lengths.
c. core liner - a plastic pipe, slightly smaller than the internal diameter of the metal core barrel. The liner fits inside the pipe and is used as the storage container for the retrieved core.
d. core-catcher - a metal ring with thin, overlapping metal blades that converge toward the back of the ring. The blades point to the inside of the liner and will spread apart to allow material to enter the liner but close during retrieval to keep material from seeping back out. The core-catcher sits inside the core barrel in front of the core liner.
e. core lip - a stainless steel lip that fastens to the end of the core barrel in front of the core-catcher. It gives a sharpened edge to the barrel for better penetration into the bottom.

Use of Corer: The corer is assembled and attached to the hydrowire. The winch picks up the corer and lowers it over the side until the corer is completely submerged. The corer is then allowed to freefall to the bottom. The stabilizer fins help to keep the corer oriented properly and the weight of the body gives extra force for best penetration. Once the corer has impacted the bottom, the winch slowly retrieves the corer. Back on board, the corer is disassembled. The barrel is removed from the body, the core lip and core-catcher are detached and the core liner is pushed out of the core barrel. The core liner is usually made of clear plastic so ready observation of the core can be made. Caps are put at either end of the core to seal it. Cores should be stored in a cool place until further study can be made. Cores are used for many different types of studies such as sediment grain-size analysis, sediment composition, layering, age dating, organic components, and chemical studies. Cores similar to these produced by drilling rigs are used in oil exploration.

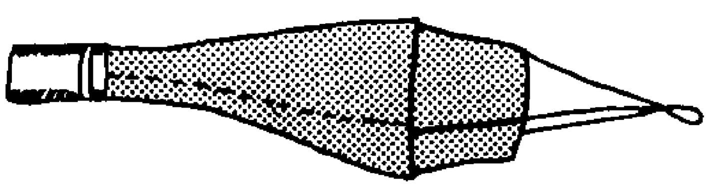
Figure 12. Gravity corer



2. Plankton nets: Plankton nets are cone-shaped sampling nets used for collecting the small, floating or very slow swimming organisms called plankton that are found dispersed through the water. The nets come in assorted sizes measured at the diameter of the mouth of the net. Common sizes are .5m and 1m mouth diameters. There is a bridle around the mouth that allows the net to be attached to the hydrowire. The net mesh can also be specified. The net tapers or narrows toward the back of the net. Here, a collecting cup is attached.

The net may be either pulled through the water or the net may be kept stationary to allow the water current alone to carry water through it. Sample time may vary between 10-30 minutes: 15 minutes is a common sample length. At the end of the tow, the net is brought aboard and the inside of the net is carefully hosed down to rinse all collected organisms into the collection cup. The collection cup is then removed and the sample is transferred to the

Figure 13. Plankton net



sample jar. Preservatives may be added to the sample at this point. Samples may then be observed under the microscope.

3. Niskin bottles: These are plastic or non-metallic collecting bottles. The sampler body consists of a hollow cylinder. The ends of the cylinder are sealed by semi-circular plugs or stoppers. The two stoppers are connected by a rubber strap that runs through the inside of the cylinder body. The stoppers may be set in either the open or the closed position. In the open position, the stoppers are pulled out and attached to a tripping mechanism on the side of the cylinder body. In the open position, the bottle is attached by clamps to the hydrowire and lowered through the water to a depth at which a sample is desired. The bottle, with the ends open, is flushed with water as it descends through the water column. When

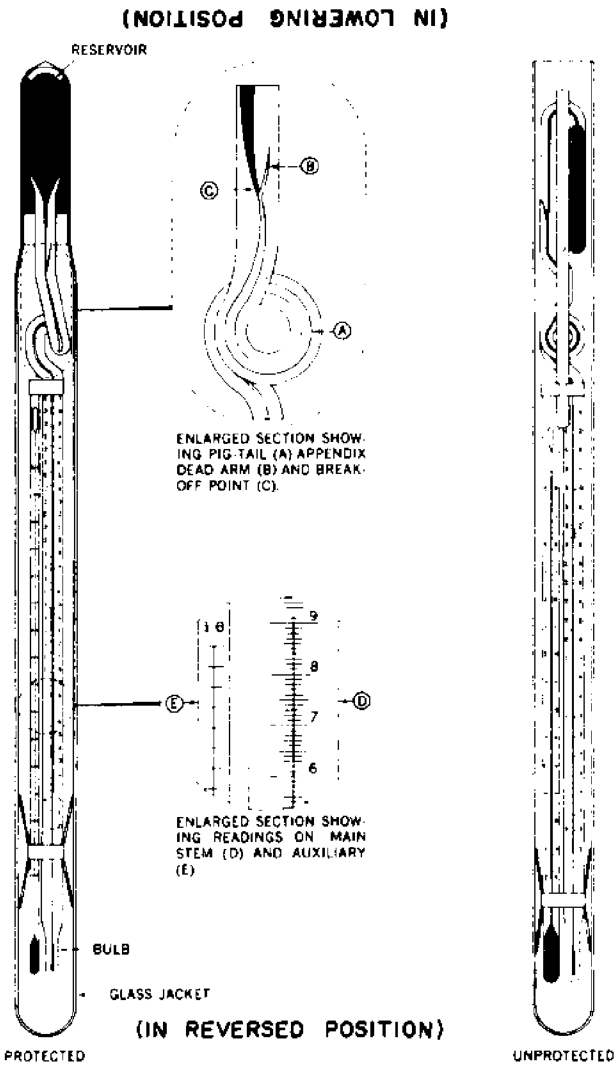
Figure 14. Niskin bottle

the sampler is ready, it is tripped by sending a "messenger" down the wire. When the messenger reaches the bottle, it hits the tripping mechanism, which releases the stoppers. The tension on the rubber strap connecting the two stoppers pulls them together, plugging both ends and trapping the water that fills the inside of the bottle. With the stoppers now in the closed position, the bottle is brought back aboard the boat. Samples of the collected water may now be drained from the faucet in the side of the bottle, into sample bottles. Determinations such as dissolved oxygen content of the water, salinity, carbon dioxide, nutrients, and others can be made. Unused water is dumped and the bottle stored until next needed.

4. Reversing thermometers: A reversing thermometer is a special purpose, very accurate thermometer designed to take the temperature of the water anywhere between the surface and the bottom. There are two types, the *protected* (completely glass encased) and the *unprotected* type (which is open to the water at one end). In the unreversed position, the thermometer is effectively inactivated. In this position, it is placed on the sampling bottle in a special thermometer rack which gives protection to the fragile instrument. Thus, the sample bottle, such as a Niskin bottle, is the vehicle which carries the thermometer to its desired depth. Once at depth, the bottle is allowed to sit for up to ten minutes, allowing the thermometer to adjust to the surrounding water temperature. When the messenger is sent down to trip the Niskin bottle, it also trips the reversing thermometer rack attached to the bottle. The rack spins 180°, now positioning the thermometer upside-down or in the reversed positon. In the act of reversing the thermometer, the water temperature is recorded by the thermometer. When the bottle is brought up, the thermometer is read, giving the temperature of the water at the depth at which it was reversed. (See Figure 15).

5. Secchi disc: This is a circular, white-faced, flat dish, weighted on the bottom, used to determine the visibility of water, that is, how clear the water is. It is simple to use. When the boat is on station, and all forward motion has stopped, the secchi disc is lowered over the side. The line attached to the disc is marked off in meters, and in finer units if desired. The disc is lowered until it can no longer be seen at all, then pulled back up until it is just barely visible. At this point, the depth is recorded, according to amount of line played out, below the surface. This is an indication of how well light can penetrate the water. In very clear water, the

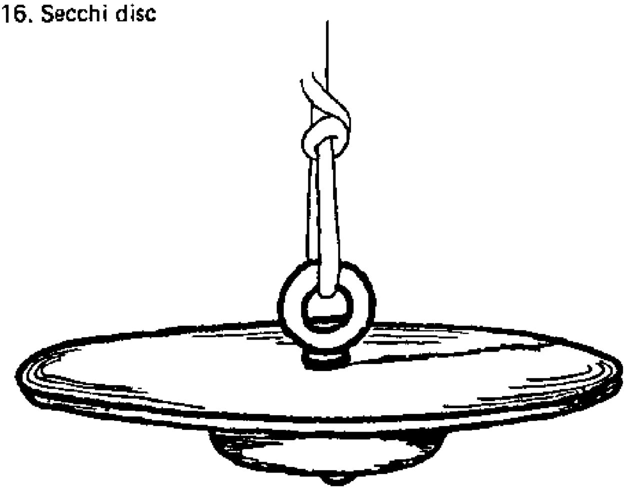
Figure 15. Reversing thermometer in the reversed position



secchi disc may remain visible for 15-20 meters. In very muddy water, it may become invisible in less than a meter of water.

6. Ule scale: The Ule scale is a metal frame containing eleven glass vials filled with a colored solution. Each vial is numbered and represents a particular water color condition. The Ule scale is used

Figure 16. Secchi disc



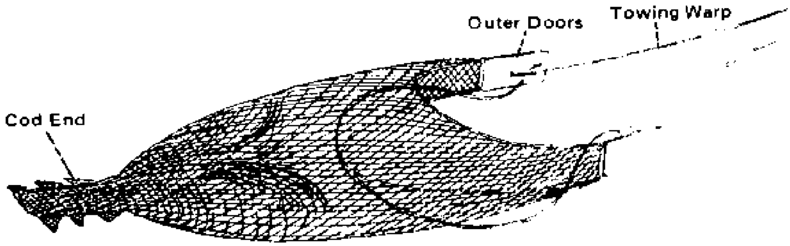
for inland and coastal waters and the vials vary in color from blue-green to brown. For the open ocean and lakes, the Forel scale is used. It is similar to the Ule scale except the colors of the vials range from deep blue to green.

To use the Ule scale, lower the secchi disc into the water to a depth of one meter. Hold the Ule scale so the surface of the secchi disc can be seen through the spaces between the glass vials. Match the color of the water above the secchi disc with the vial of the same color and record the number of the vial. When taking a Ule reading, the secchi disc should be lowered from the shaded side of the ship.

7. Otter trawl: The otter trawl is a large, V-shaped net used for catching fish. It is pulled or towed behind the boat and can be positioned at different depths (commonly mid-water or near the bottom) depending on the speed of the boat and the distance it is towed behind the boat. The mouth of the net is kept open by two wooden boards, called the doors, positioned one at each corner of the net mouth. Water pressure against these doors as the net is

Figure 17. Ule scale

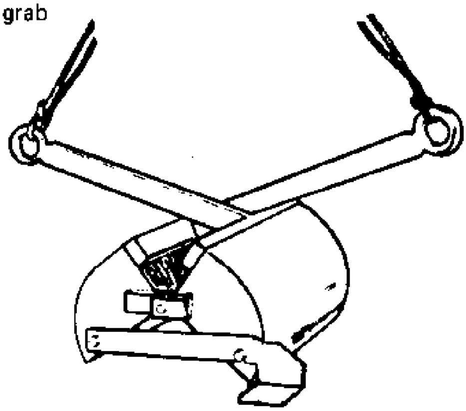
Figure 18. Otter trawl



towed keeps the net mouth spread apart with the body of the net ballooning out behind. Fish are caught as the net moves through the water and collect at the tapered end of the net known as the cod end. When the net is brought back on board, the cod end is untied and the catch removed.

8. Bottom grab: A grab is a device to scoop up a sample of the bottom material. There are several different designs but the main idea is usually the same. The grab has a set of jaws that are spread apart in preparation for taking a sample. The grab is shackled to the hydrowire and lowered over the side until it is submerged. If the water is not too deep, the grab is allowed to free fall to the bottom. The force of the impact with the bottom trips the jaws which takes a "bite" of the bottom. The bite may go as much as 6 inches deep - depending on the design of the grab. The jaws are now closed and the grab is brought back on board. There, the jaws are opened and the sample taken. Some of the sample may be stored for future analysis for things such as grain-size analysis, mineral and organic composition. Part of the grab sample can be run through a set of seiving screens to collect any small organisms living in the bottom sample.

Figure 19. Bottom grab



ANALYTICAL PROCEDURES

SALINITY DETERMINATION USING S-C-T METER

Theory:

Salts, such as table salt (NaCl) are chemical compounds which are combinations of a metallic element such as (Na^+, Sodium) and a nonmetallic element such as (Cl^-, Chloride). When salt is added to water the nature of the salt changes. The salt dissociates meaning it splits apart, producing free charged individuals known as ions (a charged form of the substance). The ions may have either a positive (+) or a negative (-) charge. This means that in the process of separating, the individual elements either give up or receive one or more electrons. (Electrons are negatively charged particles which help make up the element.) If the element gives up an electron, then it becomes positively charged (Na^+). If the element accepts an electron, it becomes negatively charged (Cl^-). This process occurs in the ocean as easily as in a glass of water.

Saltwater, in addition to allowing salts to split apart, also has the ability to conduct an electric current much the same way a copper wire conducts an electric current to a light bulb. It is actually the charged particles of former salts, the ions, which are doing the work. Naturally, it makes sense that the more ions the water contains (the saltier it is), the more current is can conduct.

The special ability of saltwater to conduct an electric current is used by the S-C-T meter to measure salinity. In essence, the meter measures the ability or the ease with which the sample being tested conducts an electric current. Since we know that with more salt, the greater the conductivity, while with less salt there is less conductivity, we see that *conductivity* and *salinity* (the saltiness of the water) are directly related. The S-C-T stands for S (salinity), C (conductivity), and T (temperature). The temperature is important because it is another factor which will influence the ease of conductivity. To correctly correlate conductivity to salinity, the temperature of the sample must be known and taken into consideration.

S-C-T METER AND SALINITY DETERMINATION PROCEDURES

I. Equipment and Supplies

1. S-C-T meter
2. Bucket
3. Sample bottles
4. Data sheets and pencils

II. Drawing of Instruments

Parts of instrument and probe labeled (See Figure 20).

III. Setup and Calibration

1. With master switch OFF, adjust meter needle to O μHMS by turning flathead screw on face of meter scale. (This step is usually not necessary).
2. Plug probe into instrument.
3. Calibrate - turn master switch to RED LINE. Using RED LINE control knob, line up needle with RED LINE.

IV. Analyzing the Samples

1. Place the probe in the sample. (At least 2 inches of water should surround probe. Raise it up and down to create flow across probe.)
2. Temperature
   a. With the probe in the sample, turn switch to TEMPERATURE
   b. Allow sufficient time for probe to adjust to sample temperature
   c. Read sample temperature off the bottom scale of meter
   d. Read to nearest ½° celsius and record.
3. Salinity
   a. Turn the TEMPERATURE DIAL to read the temperature recorded in step 2.
   b. Turn master switch to SALINITY, read salinity off the salinity (S°/oo) scale. Record.

4. Conductivity
   a. Conductivity has three (3) possible settings:
      x100, x10, x1 μOHMS/cm
   b. Turn switch to x100 setting.
   c. If needle does not read above 50 on the μOHMS scale, then switch to (x10) setting. If still below 50, turn switch to (x1).
   d. Record final reading and switch setting.
   e. Final answer is produced by multiplying meter reading by switch setting.

      Example: meter reading = 247, switch setting (x10)
      (247) (x10) = 2470 μOHMS/cm

V. Clean-up

At the end of all sampling, turn master control switch to OFF, remove probe from instrument, rinse probe with fresh water, and store equipment. Clean-up sampling area.

Figure 20. The S-C-T meter

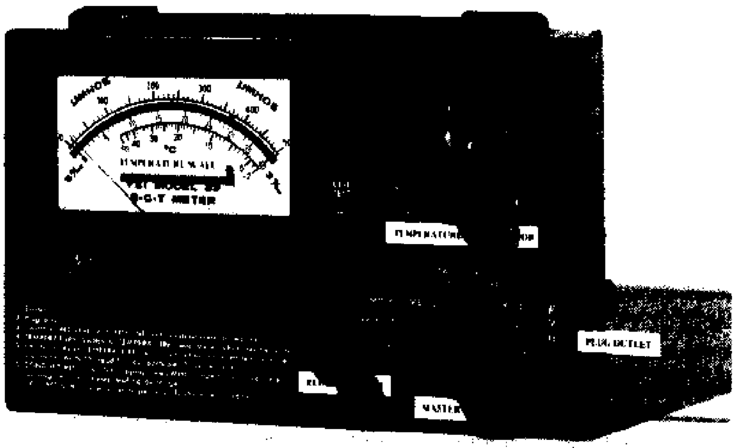
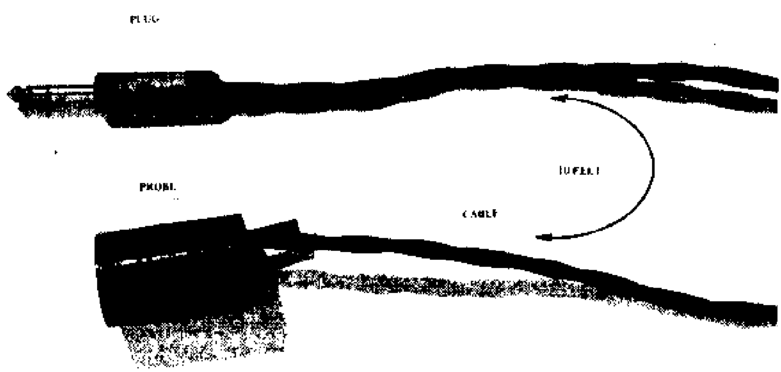


Figure 21. Probe cable to S-C-T meter.



DISSOLVED OXYGEN DETERMINATION

Theory:

The atmosphere is made up of a number of gases. Nitrogen (N_2) is the most abundant. Oxygen (O_2) is the second most abundant. Argon (Ar_2) is next. Altogether, the gases of the atmosphere form a gaseous blanket that wraps the earth, and their combined weight presses down on the surface of the earth producing atmospheric pressure. Since oxygen is part of the atmosphere, then part of the atmospheric pressure is produced by oxygen. Total atmospheric pressure at sea level is 14.7 pounds per square inch.

Gases are also found in liquids such as water. They can be dissolved by the liquid and dispersed throughout it much the same way as the salts dissovled in water. Three important conditions will determine the amount of each gas that can be dissolved in the water: temperature, salinity, and partial pressure. As the temperature or salinity of the liquid increases, the amount of the gas it can hold decreases, all other conditions being constant. As the partial pressure of the atmospheric gas increases, the amount of that gas the water will accept also increases, all other conditions being unchanged. The classic example is the carbonated soft drink. Here, gas is forced into solution, or dissolved, in the soft drink by increasing the partial pressure of the gas (CO_2). Once the gas is in the liquid, the bottle is capped, maintaining the high pressure so the gas stays in solution. When the cap is finally removed, the pressure inside the bottle is suddenly lowered. The lower pressure means the solution can hold less gas, so the CO_2 comes out of solution and the liquid bubbles and fizzes as the gas comes out. You may have also noticed that a warm drink may bubble and fizz more than a very cold drink. Again, the cold temperature allows the solution to retain more of the gas initially while the warm solution cannot hold as much so more of the gas comes bubbling out.

Water and atmosphere make contact at the water surface. Here, depending on temperature, partial pressure, and salinity, the gases of the atmosphere will dissolve into the water or escape from the water until a balance or equilibrium has been reached. In the uppermost layers of water, the amount of oxygen dissolved in the water should be equal to the maximum amount possible for the water to hold, under the existing temperature, salinity and partial pressure. The water should be saturated with the gas.

Nitrogen, the most abundant atmospheric gas, is also the most abundant gas in the natural waters of the world. Since gaseous nitrogen is not directly usable by most living organisms, there are not many situations where the nitrogen content of the water is substantially altered so it is fairly uniformly mixed throughout the waters of the world. Oxygen, however, is used in the process of respiration by most living organisms. It is also released as a biproduct of the process of photosynthesis by green plants. Below the boundary of water and atmosphere, there are then two major processes, respiration and photosynthesis which can alter the amount of oxygen found dissolved in the water. Environmentally, the amount of oxygen found in the water tells something about what is going on in the water. If there is abundant oxygen throughout the water, this indicates the water is probably well-mixed and there should be sufficient oxygen to support a well-developed biological community. If there is a very sharp drop in oxygen levels with depth, this indicates oxygen demand is very strong with a lack of sufficient replenishment. Very low oxygen levels signal that the productivity of the water in a biological sense is severely limited.

Measuring the Dissolved Oxygen with a D.O. Meter

The probe of the dissolved oxygen meter electronically measures the amount of oxygen dissolved in the water sample. In the probe housing, protected from the water by the *semipermeable membrane* are two electrodes, one positive (+) and the other negative (-). In the presence of oxygen, an electric current will pass between the electrodes. When the probe is submerged in the sample, oxygen passes through the semipermeable membrane, but the water does not. The partial pressure of oxygen dissolved in the sample determines the amount of oxygen that diffuses through the semipermeable membrane and into the probe. As the amount of oxygen in the water increases, the partial pressure also increases. This moves more oxygen across the membrane. Once in the probe, the increased oxygen allows an increase in the current flow between the electrodes. The current meter records this flow and the corresponding oxygen content is read off the meter.

The probe also contains a thermometer to measure water temperature. The temperature affects the ability of the membrane to pass the oxygen. Temperature also influences the amount of gas the water can hold. Cold water can hold more dissolved oxygen than warm water can.

Salinity also affects how much oxygen the water can hold so the salinity of the sample must be determined. High salinity water can hold less dissolved oxygen than low salinity water.

DETERMINATION OF DISSOLVED OXYGEN WITH A D. O. METER

I. Equipment and Supplies

1. Sample bottles
2. Data sheet and pencil
3. Bucket
4. Dissolved oxygen meter (See Figure 22).

II. Calibration

1. Prepare probe for calibration. Place the probe in the calibration chamber that has 100% relative humidity at ambient temperature (room temperature).
2. Connect probe to D. O. meter.
3. Turn selector switch to ZERO and adjust meter to read ZERO using ZERO adjustment knob.
4. Turn selector switch to FULL SCALE. Using FULL SCALE knob, adjust meter to read 15 ppm. Replace batteries if such adjustment cannot be achieved.
5. Turn selector switch to CALIB O_2 and allow time for probe to adjust to temperature of the calibration chamber atmosphere.
6. Using CALIB knob set the meter to read local altitude on the altitude scale at the upper right corner of meter face.

NOTE: For Galveston Bay, altitude will be sea level (S.L.) During calibration, probe should be damp and in a chamber of 100% relative humidity, but there should not be droplets of water on the membrane.

III. Sample Analysis

1. Submerge probe in sample to be anlayzed. Probe should be raised and lowered about 6 inches every 5 seconds to create a water flow across the membrane.

2. Turn master switch to TEMP and read temperature from the lower scale on the meter. Record temperature.
3. From the salinity determination already made on this sample, determine chlorinity.

$$Cl\ ^{o}/oo = \frac{S\ ^{o}/oo}{1.80655}$$

or

$$S^{o}/oo = 1.80655 \times Cl^{o}/oo$$

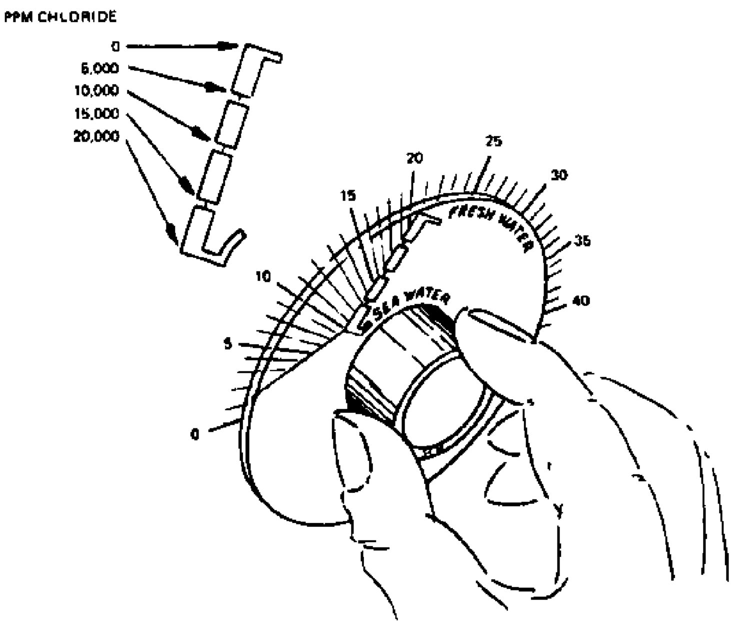
Example:

$S^{o}/oo = 14\%$

$Cl^{o}/oo = 7.7$

4. Using O_2 SOLUBILITY FACTOR knob, dial in observed temperature and Cl ppm. Temperature values in °Celcius are calibrated around outside edge of dial. A series of white bars on face of dial represent Cl ppm. Each bar represents 5,000 ppm chloride, and altogether cover a range from 0-20,000 ppm. A short hand method is to divide the salinity value by one half and set that value on the chlorinity dial.

To set the dial, the sample temperature line should intersect or meet the bar at the determined chloride concentration.



For example, with a sample temperature of 17° C and a chlorinity of 17,000 ppm, the 17° line would hit the 4th bar as indicated.

5. Turn master switch to read O_2 and read the amount of dissolved oxygen in ppm (parts per million) off the meter. Record value.
6. Repeat Steps 1-5 for each sample.
7. When all analysis is completed, rinse probe with fresh-water, turn switch to OFF, store and clean work area.

Figure 22. Dissolved oxygen meter.

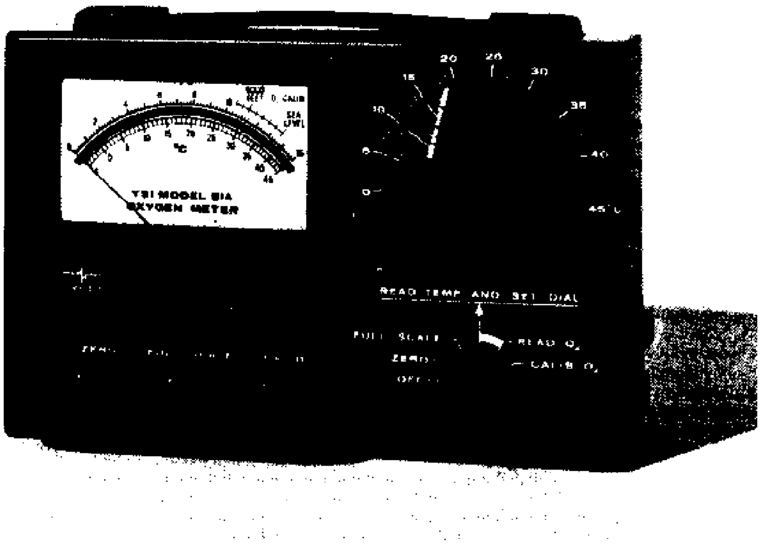
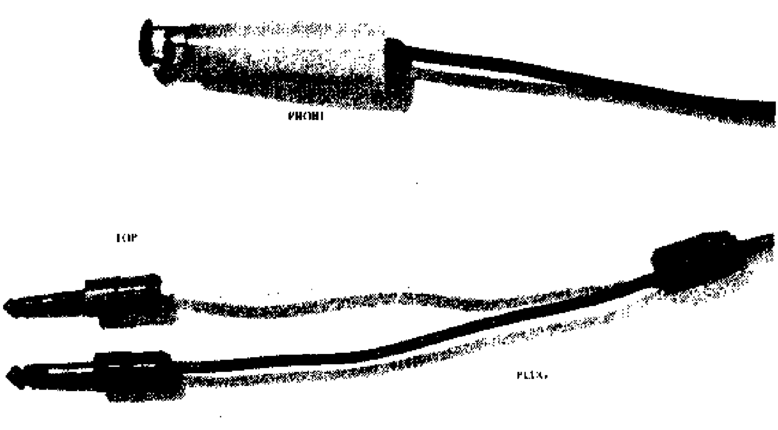


Figure 23. Cable for oxygen probe



DETERMINATION OF DISSOLVED OXYGEN BY TITRATION (Modified Wrinkler)

I. Equipment and Supplies

1. Titration buret (100 ml)
2. Support base and rod
3. Erlenmeyer flask (300 ml)
4. Graduated cylinder (250 ml)
5. Transfer pipet (2 ml)
6. Sample bottle (amber - 300 ml)
7. Magnetic stirrer
8. Data sheet and pencils

Reagents

1. Manganous Sulfate Powder
2. Alkaline Iodide-Azide Powder
3. Sulfamic Acid Powder
4. Standard PAO Solution, 0.025 N
5. Indicator Starch Solution

II. Procedure

1. Collect the sample in the sample bottle. Allow bottle to overflow 2-3 minutes. Carefully stopper bottle so that no air bubble is trapped beneath stopper.
2. Remove cap and add the following reagents in the given order:

   one pillow of manganous sulfate powder
   one pillow of alkaline iodide-azide powder

   Carefully restopper the bottle so that no air bubbles are trapped beneath the cap. Water will probably overflow the bottle as the cap is replaced. This is desirable.
3. Shake the bottle to dissolve and mix the powders. A brown precipitate will form in the bottle if O_2 is present in the sample. Allow bottle to sit until the precipitate has settled to bottom half of bottle.

   Shake the bottle again and allow the precipitate to settle a second time.

4. Remove stopper and carefully add:
   one pillow of sulfamic acid powder.

   Replace stopper avoiding any air bubbles and shake several times to completely mix the powder. The precipitate will disappear and a yellow colored solution will be produced.
5. Measure 200 ml of the treated sample and pour it into a 300 ml Erlenmeyer flask.
6. Add a mixing magnet to the flask. The buret should be filled with STANDARD PAO solution. Slowly add PAO solution to the sample until the sample turns a pale yellow color. (Do not let the color get too light.)
7. Add 2 droppers full of INDICATOR STARCH solution and mix. The sample will turn a dark blue color.
8. Continue titration by adding PAO solution until the precise point at which the solution color changes from BLUE to CLEAR. This is called the END POINT. Be careful so that titration is not carried beyond the end point.
9. At the end point, read from the buret the amount of PAO solution used. This reading is equal to the mg/l of dissolved oxygen. Record the reading.
10. Retrieve the stirring magnet, then discard sample. Refill buret with PAO solution.
11. For other samples, repeat steps 1 - 10.
12. When all samples have been analyzed, clean all glassware and store. Clean lab area.

BIOCHEMICAL OXYGEN DEMAND (BOD) DETERMINATION

In polluted waters, oxygen is consumed by other things besides just the animals and plants living in the water. The pollutants themselves can have a significant ability to combine with oxygen and thus may compete with the living organisms for the dissolved oxygen the water contains. If the supply of oxygen to the water is limited, then this competition can act to inhibit or stress certain organisms and affect the health and productivity of the water.

The *biochemical oxygen demand* or BOD is a concept that addresses the question of how much oxygen is demanded by those things in the water besides the living organisms. The BOD determination compares the amount of oxygen present in the water at the time the sample is taken to the amount present at the end of an incubation period which is commonly about 5 days later. The difference between the two oxygen levels tells the amount of competition with which the living organisms must cope.

The initial level of oxygen present in the water is another factor to be considered in evaluating the BOD. If there is a large oxygen demand and the initial oxygen level is low (6 ppm), then at night when no photosynthesis is occurring, the combined use of oxygen by the organisms and the pollutants could reduce the oxygen level below ($<$ 3 ppm) which is the minimum concentration needed by some organisms to survive. Such low concentrations would eliminate those organisms from that section of water, and decrease both species diversity and water productivity.

PRESERVATION

Plankton should be stored in 5-10% formalin (preferably neutralized).

Formalin will affect specimens with calcium carbonate structures but is suitable for temporary storage.

Formalin and alcohol will cause many organisms to contract. Hot FAA (formal - acetate - alcohol) when poured over the concentrated plankton will kill numerous specimens in the expanded conditions.

FAA: for plants and animals

FORMALDEHYDE: commercial, 10 parts for animals, 2 parts for plants
ALCOHOL: 95%; 50 parts
ACETIC ACID: 2 parts
WATER: 40 parts

FORMALIN:

This term always refers to a solution of formaldehyde. Formaldehyde comes in a saturation solution of ~39-40% and thus may be referred to as commercial formaldehyde. Always treat commercial formaldehyde as 100% formalin when making a formalin solution. In other words, 10 parts water and 1 part commercial formaldehyde makes a 10% formalin solution.

FORMALIN, BUFFERED NEUTRAL:

For longterm storage where neutral or slightly basic (pH 7.5) formalin is required, add 6 oz. of hexamine to each quart (liter) of formaldehyde.

FORMALIN, NEUTRAL:

For general use, add borax or boraxo, check with litmus paper to be sure that a neutral or basic pH is obtained.

Data Sheet: Gulf of Mexico__________ Date: ____________

Work Group No. ____________________Time: ____________

DECK INFORMATION

wind speed _______________ wind direction _______________

relative humidity: wet bulb___________; dry bulb: __________

calculated relative humidity _______________

secchi disc reading. _________________ meters

water color reading: no. _________________

sky color or conditions: _______________________________

bottom material: color _______________________________

type _______________________________

layering _______________________________

composition _______________________________

plankton tow: length of time _________________________

depth _______________________________

composition:

____________, ____________, ____________, ____________

WATER ANALYSIS DATA SHEET

GROUP NO.

SALINITY: $^{o}/oo$

_____ $^{o}/oo$ at surface

_____ $^{o}/oo$ at _____ m

_____ $^{o}/oo$ at _____ m

_____ $^{o}/oo$ at _____ m

_____ $^{o}/oo$ at _____ m

_____ $^{o}/oo$ at _____ m

TEMPERATURE: ^{o}C

_____ ^{o}C at surface

_____ ^{o}C at _____ m

_____ ^{o}C at _____ m

_____ ^{o}C at _____ m

_____ ^{o}C at _____ m

_____ ^{o}C at _____ m

OXYGEN - BY YSI METER

_____ ppm at surface

_____ ppm at _____ m

_____ ppm at _____ m

_____ ppm at _____ m

_____ ppm at _____ m

_____ ppm at _____ m

mg/l = ppm

OXYGEN: BY MODIFIED WINKLER METHOD

_____ mg/l at surface

_____ mg/l at _____ m

_____ mg/l at _____ m

_____ mg/l at _____ m

_____ mg/l at _____ m

_____ mg/l at _____ m

GLOSSARY

aerobic - Living organisms or reactions which exist in the presence of oxygen.

algae - Chlorophyll-containing plants which usually grow submerged in water and can take a wide variety of forms.

anaerobic - Living organisms or reactions which occur in the absence of oxygen.

atmospheric pressure - The force exerted on a surface due to the weight of the air pressing on it.

barrier island - Long, usually narrow seafront islands produced by wave action and longshore transport of sand.

bay - An indentation in the shoreline of an ocean, sea, or lake which produces a partially restricted body of water.

beach - The edge of the shore which lies generally between the limits of the high tide and low tide water levels.

benthic - That part of a marine environment where organisms live permanently in or on the bottom.

biochemical oxygen demand - (BOD) - A measure of the amount of oxygen required to oxidize compounds by biochemical processes.

biomass - The amount of living material in a given living space.

brackish - Fresh water mixed with a small amount of sea water.

calibrate - To determine the amount of difference from a standard to which all other samples are compared in order to calculate proper correction factors.

chlorinity - The quantity of chloride, plus bromine and iodine found in one kilogram of seawater. Given in parts per thousands ($^{o}/oo$) or grams per kilogram of water.

chlorophyll - A group of green pigments which occur mainly in special containers known as chloroplasts and which conducts the process of photosynthesis in the presence of light.

conductance - The ease with which a medium transmits an electrical current.

delta - A large deposit of sediment at the mouth of a river.

density - Mass per unit volume. The amount of material contained within a specific volume.

diversity - The variety of different species living within a biological community.

dynamic - Relating to an active, changing force or process.

effluent - Waste material such as smoke, liquid industrial refuse or sewage being emptied into the environment and often contributing to problems of pollution.

ecology - The study of the relationship of organisms with their environment.

ecosystem - The complex relationships between an environment and the living community which inhabits it.

electrode - A conducting terminal of an electrical circuit.

electrolyte - A material which dissolves in a solution, forming ions which are then capable of conducting an electrical current.

electron - The negatively charged (-) particle which rotates around the nucleus of an atom.

end point - A point marking the end of the determination or process, usually apparent by a color change of a solution.

equilibrium - A state of balance between opposing forces.

Erlenmeyer flask - A special piece of glassware often used in chemical determinations. It has a narrowed neck and a cone shaped, flat bottomed base.

estuary - Any confined coastal body of water which is connected to the sea and receives both fresh water and salt water input, producing a salinity greater than .5 ppt.

eutrophication - Excessive nutrient enrichment, usually within a water body, which results in excessive plant growth and which can be detrimental to other organisms inhabiting the same water body.

fauna - A collective term for plant species present in an ecosystem.

fjord - A narrow, deep inlet to the sea between steep cliffs or mountains.

flora - The collective term for plant species present in an ecosystem.

food chain - The step-by-step transfer of food energy and materials, by consumption, from the primary source in plants to increasingly higher animal forms.

headland - A high, steep-faced point of land which extends into the ocean.

incubate - To maintain in conditions favorable for growth or development.

infauna - Animals which live buried in the soft bottom.

ion - An atom or molecule (2 or more atoms) which carries an electrical charge (positive or negative) due to the loss or gain of a electron.

juvenile - A physically immature and undeveloped organism.

marsh - An area of soft, wet land, often containing standing water.

metabolism - The sum of the processes involved in maintaining living organisms including the breakdown of food to release energy, and assimilation of nutrient material for repair and growth.

molecule - The smallest particle of a substance that retains the properties of the substance. It is formed by the combination of one or more atoms.

nekton - Water borne animals which are active swimmers and can overcome the natural flow of the water.

nursery area - A place where young organisms come because it offers them the proper food, protection and environment conditions favorable for proper growth and development.

nutrient - Organic and nonorganic materials upon which primary producers feed and which are essential for proper growth. Compounds like nitrogen and phosphorus are essential nutrients; those which the organisms cannot do without.

Ocean buffer system - The sequence of chemical combinations combining carbon dioxide and water in an equilibrium reaction. This helps keep the pH of sea water fairly constant.

$$CO_2 \text{ (gas)} + H_2O = H_2CO_3 = H^+HCO_3 + 2H^{++} + CO_3$$

Carbonic hydrogen carbonate
ion bicarbonate

ohm - A unit of measurement of electrical resistance.

partial pressure - That part of the total atmospheric pressure contributed by a specific gas.

phytoplankton - Small, drifting plants found in fresh and salt water.

photosynthesis - The production of carbohydrate molecules (sugar and starch) from the raw materials of water (H_2O) and carbon dioxide (CO_2) in the presence of chlorophyll by the energy of light and with the release of oxygen.

pillow - A small plastic, sealed pouch containing a measured quantity of a chemical compound to be used in a chemical determination.

plankton - Passively drifting or weakly swimming, usually small to microscopic organisms.

plankton bloom - A large increase in the population of plankton, usually due to optimum environmental conditions which results in an enormous concentration that is sufficient to discolor the water.

pollution - The contamination of the environment with excessive amounts of undesirable substances.

primary productivity - The amount of organic matter produced through photosynthesis by the primary producers such as the plants.

precipitate (noun) - A substance which has come out of solution and is no longer dissolved.

reagent - A substance used in chemical determinations because of its special chemical activity.

respiration - The chemical reaction which releases energy through the reaction of oxygen with another substance resulting in oxidation.

salinity - The total amount of dissolved salts contained in a kilogram of seawater. Given in parts per thousand ($^{o}/oo$) or grams per kilogram of water. Can be calculated by: $S(^{o}/oo) = 1.8\ Cl\ ^{o}/oo + 0.03$

salt water wedge - The inflow of salt water along the floor of an estuary or river.

sand spit - A small point of land extending into a body of water, usually as a result of sediment build-up by persistant longshore currents.

saturated - The condition which exists when a substance is filled with as much of another substance as it can hold; (i.e. - when the amount entering = the amount leaving).

semi-permeable membrane - A membrane which allows certain molecules and not others to pass through it.

solubility - The amount of a substance which will dissolve in a given amount of another substance.

species - A group of similar individuals having common characteristics and designated by a common name, which are a division of the grouping Genus.

spoil island - Material accumu- during dredging operations which eventually rise above water level and remain for some period of time as an island.

supersaturation - A substance which is filled with another substance beyond its normal saturation point due to some outside influence such as an increase in pressure.

tideland - An area which is covered and exposed by the cycles of the tides.

titration - A chemical test used to find the concentration of a substance by determining the smallest amount of a reagent which reacts with it to produce an observable change within the solution.

trace minerals - A mineral present in a very small but measurable concentration.

turbidity - Reduced water clarity due to the presence of suspended material.

wetland - Naturally vegetated areas that exist on the land between the normal high tide and yearly normal maximum high water level.

zooplankton - Small, drifting animals found in fresh and salt water.

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McConnaughey, B. H. 1970. *Introduction to Marine Biology.* C. V. Mosby Co., St. Louis, Mo.

McIntyre, J. 1974. *Mind in the Waters.* Charles Scribner's Sons, New York, N. Y.

Newell, G. E. and R. C., 1966. *Marine Plankton.* Hutchinson Educational, London, England.

Parker, Jack. 1972. *Key to Marine and Estuarine Fish of Texas.* Sea Grant Publication, TAMU.

Smith, D. L. 1977. *A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae.* Kendall/Hunt Publishing Co., Dubuque, Iowa.

Equipment Sources

Fisher Scientific Co.
711 Forbes Ave.
Pittsburgh, Pennsylvania 15219

Hach Chemical Co.
P. O. Box 907
Ames, Iowa 50010

Kahl Scientific Instrument Corp.
P. O. Box 1166
El Cajon, California 92022

Wildlife Supply Co.
301 Cass Street
Saginaw, Michigan 48602

Yellow Springs Instrument Co.
Yellow Springs,
Ohio 45387

CONVERSION FACTORS

Length

1 kilometer (km) = 0.621 mile (1 mi = 1.610 km).
1 meter (m) = 39.4 inches = 3.28 feet (1 ft = 0.305 m).
1 centimeter (cm) = 0.394 inch (1 in = 2.54 cm).
1 angstrom (A) = 10^{-8} cm.

Area

1 square kilometer (km^2) = 0.386 square miles (1 mi^2= 2.590 km^2).
1 square meter (m^2) = 10.8 square feet (1 ft^2 = 9.29 X $10^{-2} m^2$).
1 square centimeter (cm^2) = 0.155 square inch (1 in^2 = 6.452 cm^2).

Volume

1 cubic kilometer (km^3) = $10^9 m^3$ = 0.24 cubic mile (1 mi^3 = 4.17 km^3)
1 cubic meter (m^3) = $10^6 cm^3$ = 35.3 cubic feet = 264 U.S. gallons.
1 cubic centimeter (cm^3) = 6.1 X 10^{-2} cubic inch (1 in^3 = 16.39 cm^3).

Mass

1 metric ton = 10^6 g = 2205 pounds = 1.1 U.S. ton.
1 kilogram (kg) = 2.205 pounds (1 lb = 0.454 kg).
1 gram (g) = 3.53 X 10^{-2} ounce = 2.2 X 10^{-3} pound (1 lb = 454 g).

Temperature

To convert degrees centigrade (°C) to degrees Fahrenheit (°F), °F = 1.8 °C + 32.
To convert °F to °C, °C = (°F − 32)/1.8.

Force

A force of one dyne will produce an acceleration of 1 cm/sec^2 when applied to a mass of 1 g.

Pressure

1 bar = 10^6 dynes/cm^2 = 14.22 lb/in^2 = 0.968 atmosphere (atm).

Density

1 gram per cubic centimeter (g/cm^3) = 62.43 lb/ft^3 = 0.036 lb/in^3.

Velocity
1 kilometer per second (km/sec) = 2237 mi/hr = 3281 ft/sec, c= speed of light in vacuum = 2.998×10^{10} cm/sec.

Gravity
G = universal gravitational constant = 6.67×10^{-8} in cm-g-sec units.