# ARE ESTUARIES NECESSARY?

By J. L. McHugh*

Those of you who are sport fishermen or duck hunters have heard a great deal about estuaries lately. You have been told, over and over again I am sure, that these rich borders of the sea are being altered rapidly by man and that these changes are contrary to your interests. As our population and our technology grow, the characteristics of the water are being changed by domestic and industrial pollution. Widespread use of highly toxic pesticides has been blamed for large-scale fish kills in many parts of the country. Recent fish kills in the Mississippi River have been attributed to pesticides, and some people think that these toxins also have caused the alarming disappearance of pelicans from the Gulf coast. In some places there are fears that artificial radioactivity is a danger to fishery resources. Even the common household detergents are known to have adverse biological effects on marine life. The extreme effects of these various chemical changes, which produce massive kills that everyone can see, often stir up enough public opinion so that something is done about the causes.

Scientists, however, are much more concerned about the more subtle effects of pollution. We do not really know very much about the effects of pollutants, but small pieces of evidence from individual scientific experiments tell us that the foreign substances we add to the water can affect marine life in many ways without killing. Even waste heat is a serious pollutant under some conditions. In the long run these unobserved effects may be more disastrous than those which pile up masses of dead fish on a beach. Changes in water quality may affect spawning, growth, feeding, resistance to disease, and many other characteristics of animals. The causes of these effects are very difficult to identify because natural phenomena also create wide variations in these characteristics.

There is great concern also over the many physical alterations taking place in our estuaries. Channel dredging, filling of marshlands and shallow areas, dams and other water diversion projects, all create changes of one kind or another in the environment. Like the effects of pollution, some of these environmental alterations have obvious effects on marine life. It is not difficult to recognize the adverse effects of silt deposition on an oyster bed. The living oysters are smothered and die, and the bottom is made unsuitable for future generations of oysters. But engineering projects cause other, less dramatic, changes which alter current flows, change the salinity or temperature of the water, and create other conditions which may or may not be harmful to our fishery and wildlife resources.

We also must not forget the effects of these environmental changes on man himself. Animals have a remarkable capacity to concentrate within their bodies large quantities of pesticides and other chemicals. In the laboratory, for example, our scientists have demonstrated that oysters can accumulate concentrations of DDT many times greater than the concentration in the surrounding environment. This amazing power was illustrated dramatically by an experiment in which oysters held in running water containing one part of DDT per 100 million parts of water accumulated residues of 151 parts of DDT per million parts of water in 7 days! This far exceeds the permissible level in meat allowed by the Food and Drug Administration. Fortunately, we have never found such high residues in oysters in the natural environment, but the experiment shows that it could happen.

Engineering projects in coastal waters do not pose threats to man directly. In fact, they

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are carried out for man's benefit. In many ways, however, they may lead indirectly to adverse conditions. For example, a deeper channel will increase the flow of shipping to a port. This will attract new industries, which will add to the load of industrial pollution. Industry in turn will attract more people into the area, adding to the flow of domestic pollution and hastening alteration of the shoreline for residential and recreational development. Growing industry and population will increase the demand for water, some of which will be lost entirely to the estuarine system. The remaining water will be altered in many ways before it is returned to the estuary.

## What Is An Estuary?

We all talk knowingly about estuaries and their importance to man, but are we all agreed on what we mean by this term? The dictionary says that an estuary is an arm of the sea, or a river mouth, where fresh water from the land mixes with salt water from the sea. Nearly everyone agrees that an estuary has an arbitrary seaward boundary. Along the Texas coast this boundary lies across the passes which mark the entrances to Galveston Bay, Matagorda and San Antonio Bays, the Laguna Madre, and other protected coastal waters. On our Atlantic coast the seaward boundary of such well-defined estuaries as Chesapeake Bay, which is really a drowned river mouth, is a line joining the two headlands which mark the entrance from the sea, the historic Capes Charles and Henry.

Yet the notion of a geographically defined seaward boundary, to mark an area which owes its definition to mixing of river water with the sea, is quite illogical. You who live on the Gulf of Mexico know that the effect of the great Mississippi River is felt far beyond its mouth. The whole northern part of the Gulf is diluted with Mississippi water. As a child I remember reading and marvelling at stories of mariners approaching the Atlantic coast of South America who met the muddy waters of the mighty Amazon hundreds of miles at sea. The flow of these rivers varies seasonally to a remarkable degree. The legendary floods of the Mississippi carry more than 30 times the volume of water that flows into the Gulf during times of drought. Fluctuations in the Amazon drainage probably are even greater. It is inevitable that the seaward extent of mixing of land drainage with the sea fluctuates widely. This, in turn, must have profound effects on the fishery resources and on all marine life.

We know that the kinds of fish and their abundance in the enclosed coastal waters vary seasonally and from year to year. Some of these variations are caused by temperature changes, but changes in the salinity or salt content of the water are important, too. I prefer to define an estuary entirely on the basis of mixing of fresh and salt water and to consider that this is a dynamic, fluctuating environment, not tied to fixed geographic boundaries. This coincides much more nicely with the habits of the fish, their migrations, movements, and fluctuations in abundance.

## What Are the Typical Animals of An Estuary?

A complete catalog of the life of an estuary would be far beyond the scope of this article. Most abundant are the microscopic plants and animals, including bacteria, which drift freely in the water or cover the surface of the mud, sand, or other materials which form the shores and bottom. The most typical estuarine animals from the popular point of view probably are drifting jellyfish, so common at some times of the year; the various mollusks such as oysters, clams, mussels, and snails; and crabs of various kinds, especially the toothsome blue crab of the Atlantic and Gulf coasts. Then there are the abundant shrimp, especially the large species which support our most important fishery; and numerous migratory fishes. To most of you, I suspect, the most important fishes of the inshore waters are the croakers and sea trouts, jacks, and perhaps mullet. To me they are the anchovies and menhaden, for these herring-like fishes, although not eaten by man or caught by him for sport, are our most abundant estuarine fishes.

An important characteristic of these estuarine animals--the oyster and its molluscan relatives and a few other species excepted--is that they do not remain within the boundaries commonly considered to be the limits of the estuary. Instead, they migrate periodically into the open sea, sometimes far from land. We do not know very much about these migrations, but offshore sampling has told us that large quantities of marine life useful to man are to be found over the Continental Shelf in the Gulf of Mexico. This is a fairly recent discovery, for it was only a few years ago that scientists were saying that the Gulf was almost a biological desert, unable ever to yield a large fishery harvest.

Why Are Estuaries Important?

Much of the commercial fish catch of the United States is made up of animals which spend important parts of their lives in estuaries. Of the 10 most valuable kinds of fish in our commercial lands, 7 are typically estuarine. These 7 kinds--shrimp, salmon, oysters, crabs, clams, menhaden, and flounders--account for about 58 percent of the total value of our commercial fishery landings. In the Gulf of Mexico, estuarine-dependent resources supply about 90 percent of the commercial catch. For the entire U. S. seacoast, the catch is about two-thirds estuarine-dependent. Large numbers of these and other kinds of estuarine fishes also are caught by sportsmen. In fact, sport fishermen land greater quantities of some kinds of marine fish than commercial fishermen do. Thus, estuaries are very important to us as producers of commercial and sport fishery resources.

The sheltered waters near shore, which we commonly recognize as estuaries, are equally as vulnerable to alteration by man as are our inland lakes and rivers. We are using our rivers to a greater and greater degree as sewers for waste disposal. We are transforming the channels and shorelines with almost frightening speed. We are developing plans for water diversion which promise to perform miracles for flood control and agriculture, but which will alter forever the characteristics of our coastal waters. These developments are certain to affect the ecological balance in the estuarine environment. It is only prudent in the absence of thorough knowledge to assume that many of these changes will be adverse.

There are many gaps in our understanding of the estuarine environment. It is human nature to emphasize what we know, or what we think we know. Because we concentrate our human population on coastal areas, and move out on to the shallow coastal seas for our recreation, we are impressed with the the wealth of life that we observe in these edges of the sea. There might be abundant life farther offshore in oceanic waters, but we venture out there less frequently and in smaller numbers. When we move offshore we do so in larger vessels, and in so doing we lose our intimate association with the sea surface and its bottom. Small wonder that we have become impressed with the bounty of our shallow waters. Our harvest from these waters is greater than from any other natural area of equal extent. There is no doubt that the inshore estuaries are of great importance. For example, we know that shrimp, menhaden, and other important fishery resources spawn offshore, but great numbers of young find their way into the shallow, protected, inshore waters soon after hatching. The offshore waters influenced by land drainage also are important and we need to improve our knowledge of those waters. They may be as important as the inshore estuaries, and the offshore estuary can be affected by man's activities, too.

Many people believe that the rich biological productivity of estuaries is caused principally by the constant renewal of nutrients brought down by the rivers from the land. The rivers do contribute minerals and other substances essential to life, it is true, but the total amounts brought into the estuary by this mechanism often are small compared with the quantities brought in from the sea. It is not commonly understood that the relatively light river water flowing down from the land tends to spread out over the surface of the denser, saltier water of the sea, almost as a layer of oil will stay at the surface of the water. Oceanographers know that the energy contained in this seaward-moving land runoff at the surface generates a return flow of sea water along the bottom. The volume of nutrients in the deeper sea water flowing toward the land, in most estuaries, is several-fold greater than the natural nutrient load of the rivers. Thus, the secret of estuarine productivity is the constant inflow of ocean water, "plowing" and fertilizing the entire coastal zone. If runoff from the land increases, this process of enrichment increases in proportion. If runoff ceases, enrichment ceases, too. River runoff is the cause of estuarine productivity, but usually for a different reason than most people believe.

Along the Texas coast are two extreme types of estuary, the kind I have just described, in which runoff generates an inshore flow of salt water, and a kind like the Laguna Madre, in which loss of water by evaporation exceeds the total contribution from the land. The first is called a positive, the second a negative, estuary. The third kind, the neutral estuary, is one in which land runoff and evaporation just balance. It is interesting that a negative estuary also is enriched steadily with nutrients. Excess evaporation tends to

lower the surface of the water, and ocean water moves in to restore the balance.

The counter flow of fresh and salt water can extend far beyond the limits of the conventional inshore estuary. The entire North Pacific Ocean, north of about 45° N. latitude, is an estuarine zone by this definition, and it has been shown that beneath the vast surface lens of relatively low salinity water the deeper oceanic water flows in toward the land. On our east coast, off Chespeake Bay, bottom-drifting markers released near the edge of the Continental Shelf have been recovered inside the Bay. This and other evidence show that the entire northwestern Atlantic north of Cape Hatteras and west of the Gulf Stream is an estuarine zone. A wide band of water along the northern coast of the Gulf of Mexico has similar characteristics. These are among the richest fishing grounds of the world.

## What Is Man Doing to the Estuaries?

Fly over the coastal areas of the United States and marvel at the intricate patterns that nature creates. Over much of the Atlantic and Gulf coasts one still can be impressed by the vast salt marshes with their serpentine, branching drainage patterns, and the extensive bodies of quiet shallow water protected by offshore bars, peninsulas, and islands. But wherever one flies over this fascinating shoreline, one cannot fail to see scars created by man. In some areas miles upon miles of coast have been scalloped by residential developments in which every site is a waterfront lot. Marshes are criss-crossed by drainage and navigation channels. Waters are roiled by the furious activity of dredges, maintaining the controlling depth of navigation channels or making them deeper. Unsightly banks of mud and sand pile up in shallow water or on marshland as these dredges bite into the bottom and spew out their load. Great industrial plants throw smoke and flame into the atmosphere, almost blotting out the view in some areas. For miles downstream from these belching factories, the water is foul and discolored. Thousands of small boats churn the muddy bottom, or lie at their moorings, each a potential despoiler of the waters. Outboard motors, discharging their exhausts underwater, pour lead and combustion products into the environment. One thinks of the abundant marine life in these crowded waters and cannot conceive that these resources benefit from all this human activity.

Yet some of these same effects are produced by natural events. Strong winds scour the bottom, muddy the waters, and pile silt and sand in places new. Heavy rains or melting snow change runoff patterns, altering sharply the natural chemical characteristics of the water, and carrying tremendous loads of oxygen-demanding organic material down from the forests, the farmlands, and the marshes. Sudden weather changes cause sharp rises or drops in air temperature, which in these constantly moving, shallow waters quickly alter the temperature of the water. This is a harsh environment for animals, and it is certain that large numbers have been killed by such natural catastrophes from time to time, long before man appeared on the scene.

Thus, it is difficult often to identify the causes of fish kills, or of natural variations in abundance or migration patterns, because these effects can be produced by nature or by man. The principal difference is that nature's effects are not permanent, and the resources eventually recover from natural catastrophes. In fact, the animals have evolved for survival in this constantly changing environment, and many are favored by the natural changes they experience. Man-made changes, on the other hand, usually are permanent. We must be firm in opposing those environmental changes which we know are harmful to marine life. We must be equally as reluctant to accept changes which have less clear-cut effects, until we learn more about the influence of these changes on estuarine life. But we had better be quick to get the information we need, or we will not be able to stem the flow of "progress" very long.

Above all, we must be cautious about diverting the fresh waters that enter our estuaries. It is this flow which provides the energy to plow and fertilize estuarine waters and which creates the rich fishery resources with which our coastline is blessed. If this flow is stopped, or even substantially reduced, the fisheries will suffer accordingly. It is that simple.

## Is Commercial Fishing Detrimental to Sport Fishing?

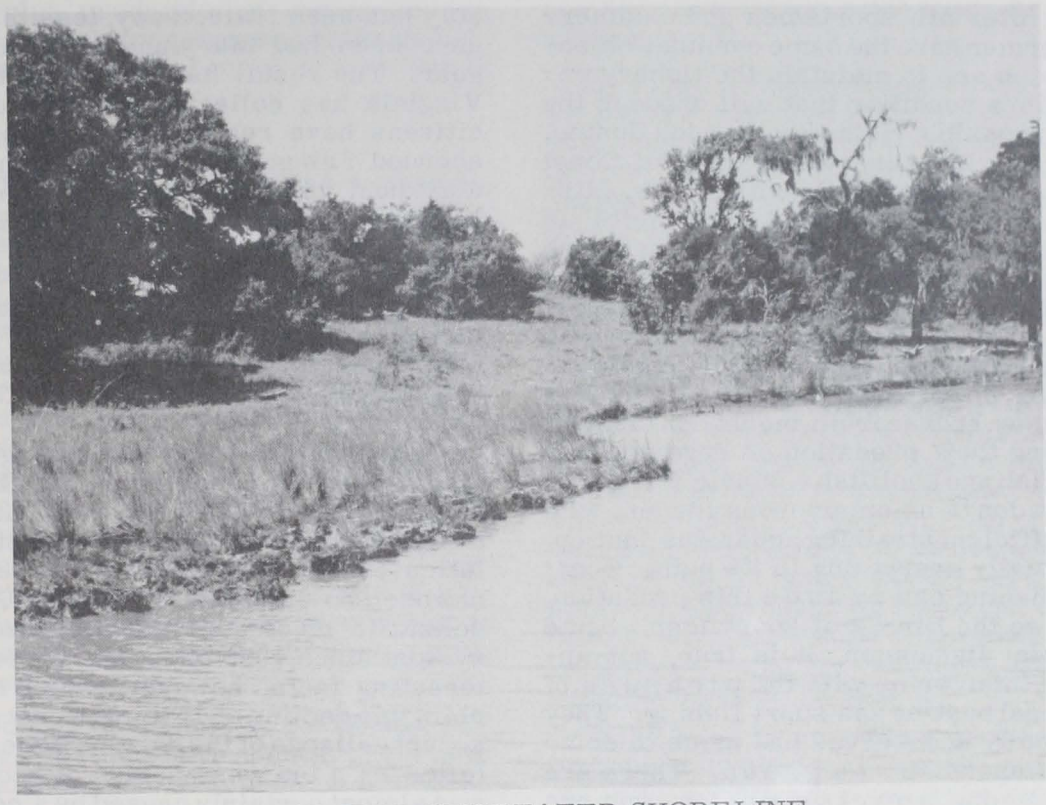
I cannot conclude without referring to the controversies that divide our fishermen and weaken their power to combat mutual problems. It is discouraging to see these conflicts between you, absorbing much of your

Fig. 1 - Transformation of an estuary to increase the number of waterfront homesites. Such developments are typical of many estuarine areas in the United States. Marshland important to fish and wildlife is destroyed and the biological productivity of the area usually is seriously reduced.

BEFORE

AFTER

Fig. 2 - Destruction of valuable estuarine marsh by spoil from hydraulic dredging for real estate development. The mound in the right background is the discharge end of the dredge line. The widespread effect upon the marsh and water areas is readily evident.



NATURAL VEGETATED SHORELINE

BULKHEADED SHORELINE

Fig. 3 - A valuable nursery area for small shrimp destroyed by bulkheading. This is a typical example of man's increasing encroachment on our estuarine areas.

energy. After all, sportsmen and commercial fishermen have the same eventual objectives, which are to maintain the fishery resources in a condition that will produce the maximum possible yield. Dr. Gordon Gunter, the well-known Director of the Gulf Coast Research Laboratory at Ocean Springs, Mississippi, recently published an article[1/] in which he exploded the principal myths which people use over and over again to "prove" that menhaden fishing is harmful to sport fishing. Although he dealt effectively with the alleged adverse affects of the commercial fishing, he failed to suggest some benefits that may accrue from menhaden fishing, by reducing their predation on eggs and tiny young of fish and shellfish valuable for sport. The menhaden is an omnivorous feeder, with a highly efficient straining apparatus that engulfs virtually everything in its path. Commercial fishing can reduce this predation, probably to the benefit of sportsmen. Some commercial fishermen, it is true, act unwisely by interfering with the pleasure of recreational boating and sport fishing. They give a wholly undeserved bad name to commercial fishermen as a group. There are hotheads among sportsmen, too, who are quick to condemn something they do not fully understand. To me, it is tragic that these two groups expend so much energy in criticism of each other, when they should be trying to understand each other and work together against common threats.

One or two examples might help to stress this point. Back in the early 1930's there was great concern in the State of Maryland over the apparent decline in production of striped bass. The Chesapeake Bay commercial catch had dropped rather steadily from about two million pounds in the 1880's to about half a million in 1934, and there was strong feeling that commercial fishermen were destroying the resource. At that time, it was believed strongly that large nets like purse seines, used to catch densely schooling fish like menhaden, were "destroying" large numbers of striped bass and other food and sport fish. Consequently, the Maryland Legislature enacted a complete ban on purse seines in Maryland waters. This law has been enforced rigidly ever since. Virginia, however, did not follow suit. Consequently, the menhaden fishery prospered in the Virginia portion of Chesapeake Bay, and the total catch of menhaden by the "destructive" purse seines probably has been little, if any, less than it would have been had Maryland not prohibited this gear. The result has been that the State of Virginia has collected the revenue, and her citizens have reaped the profits, that have accrued from this thriving fishery, while Maryland has gained nothing. And what has been the effect of this "destruction" on the striped bass resource? Catches have risen steadily. In the past 5 years, the average annual commercial catch has been about 9 million pounds, at least 18 times as great as it was 30 years ago! The sport catch probably has increased as much or more than this.

On the Pacific coast the once-great sardine fishery has gone. From a peak of almost 800,000 tons in 1936, the catch has dropped to insignificance. Despite very strict regulation of the fishery in recent years, there has been no evidence of recovery. Intensive scientific studies of the California Current system since 1950 have uncovered some interesting facts, however, which help to explain this decline and failure to recover. The abrupt collapse of the sardine fishery in 1946, following a ten-year period of good catches, was almost certainly caused by a combination of intense fishing and a sharp reduction in success of sardine spawning. The spawning failure probably was caused by a temporary change in oceanographic conditions. The sharp reduction in sardine abundance allowed the Pacific anchovy, a species well fitted to compete with the sardine, to multiply and fill the gap. The evidence pieced together by the scientists shows clearly that the anchovy has increased tremendously in numbers. It now is at least as abundant, possibly more abundant, than the sardine ever was. What is needed is a carefully controlled scientific fishing experiment to measure the effects of an anchovy fishery on the numbers of anchovies and sardines. But the powerful California sport fishermen's organizations, convinced that anchovies are an essential food of the most important sport fishes, were for years successful in blocking such proposals. The commercial anchovy fishery is so severely regulated that it is producing only a very small fraction of the catch that it probably could sustain. The result is that hundreds of thousands of tons of Pacific anchovy are living their normal life span and dying a natural death, wasted so far as man is concerned. Uncontrolled commercial fishing should not be allowed, but we need to know the

1/"The Gulf of Mexico menhaden fishery in relation to the sports fisheries." Proceedings of the Gulf and Caribbean Fisheries Institute, 16th Annual Session, Nov. 1963, pp. 99-108.

annual surplus production of anchovies that can be taken safely by commercial fishermen without damaging the resource or interfering with sport fishing.

What Can We Do?

By now I am sure it is clear to you that the question posed in my title has only one answer: "Yes, estuaries are necessary to maintain the rich harvest of the edges of the sea around our coasts." I am sure it is also clear that we do not know all we need to know about this important environment and its living resources. Moreover, I hope you have recognized that many of the things we think we know do not fit the facts. For example, from the point of view of the fisheries, we should recognize the estuaries often extend their influence many miles seaward. The most important thought I can leave with you is to urge that you recognize the need to improve our understanding and to give weight to demonstrated facts instead of opinions in planning for better fishing.

The Federal Government, the States, and private organizations have spent a great deal of money in scientific research on the ocean and its living resources. The knowledge that has accumulated is scattered in a great variety of scientific journals, official reports, personal files, or in the minds of those who did the work. Other valuable information on fishery resources is contained in fishermen's logs, license records, and in the personal experience of commercial and sport fishermen. Never has this vast store of information been gathered together and analyzed thoroughly. On the rare occasions when limited attempts have been made to synthesize existing knowledge, a surprising wealth of useful knowledge was revealed. It seems to be a common failing to ignore this treasure trove of existing knowledge in the rush to deal with urgent problems of the moment. We should encourage competent specialists to accumulate, analyze, and interpret what has already been gathered.

Such summaries have two distinct benefits. They demonstrate, usually to the surprise of everyone, that we know much more than we had realized. Secondly, they sharpen our planning by pointing out the gaps that need to be filled. By proceeding in this systematic fashion, it is possible to put available knowledge to work immediately and to fill in the missing pieces as quickly as possible. These simple principles are the essence of any successful business enterprise. It is quite astounding that we so seldom have applied the same principles to our resource utilization problems.

We must recognize that change is an inherent characteristic of natural events. Thus, the abundance and behavior of marine life are certain to fluctuate from natural causes, and it will be a long time before we learn how to control these natural variations, if indeed we ever can. We will always be tempted to blame these natural fluctuations on the disturbing forces created by man. Indeed, there will be many occasions when it will not be possible to say whether nature or man was the culprit. When our lack of knowledge forces such a conclusion it is impossible to deal effectively with human causes. We will always be able to cope most efficiently with man-made causes if we keep open minds and recognize that natural forces sometimes, although by no means always, are far more powerful and widespread than our own. And finally, we must always remember that well established facts and judgment are the best tools for solving problems.

In the long run we will protect our natural resources best and will gain the greatest use and enjoyment from them if we bring all the facts and all the interests together. We cannot wait for complete information before we act to conserve our resources, for our information never will be complete, nor will the necessary steps be as clearly defined as everyone would wish. But the wisest actions, even with incomplete knowledge, are those which attempt to marshal all available facts objectively. We should avoid the traps that we so very often set for ourselves by attacking only one small part of the problem, creating much more heat than light. By hasty action we often dissipate our energies on details and so have no power left when it is needed most.

Are Estuaries Necessary?

Yes, estuaries are necessary if we are to preserve the natural productivity of our coastal waters. But we had better be sure we know what an estuary is. Water flow is the answer, and reduced runoff could be the most crippling blow. We could, of course, provide artificial sources of energy as a substitute, but the cost would be prohibitive. Maintaining the water supply is not the only requirement, however. The quality of that water must be guarded just as jealously as we guard the supply. Finally, we must make full use of existing knowledge, and interpret it intelligently. With the present status of our knowledge thoroughly understood, we can proceed to fill the gaps with facts instead of opinions.

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