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PHYSICAL CHARACTERISTICS OF THE INSHORE ENVIRONMENT¹

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INTRODUCTION

Oceanography, especially in the United States, has advanced very rapidly during the last two decades. This is true not only of the amount of data collected but also in the development of theories, the improvement of instrumentation, and in the training of investigators. At the same time there has been a tremendous increase of interest in the possible applications of oceanography to other fields of science and to various economic and military problems. Particularly in the phases of economic and military interest, attention is now focused upon the nearshore environment, a realm that most oceanographers have neglected in the past. In all sciences there is a strong inclination to go and graze in the far fields that look so green. Oceanographers, no less than others, have followed this lure and whenever opportunity has offered have turned their ships toward the deep sea. The relative simplicity of the great depths may be as responsible as their romantic appeal, because in many ways the problems of the inshore, shallow waters are far more complex than those of the open ocean.

Because of the increasing interest in the coastal regions, it is the purpose of this paper to discuss some of the characteristics of this environment and to indicate the means that must be employed in this investigation. The terms *inshore* and *nearshore* will be used synonymously without strict limitations of either depth or distance from shore. The terms do imply, however, that the regions under discussion are in some way or ways influenced by proximity to land and to shallow depths. By *physical characteristics*, all the physical, chemical, geological, and meteorological phenomena in or acting upon the water that influence the organisms living in the water and upon the sea bottom will be implied. As the enumeration of these phenomena alone would more than outrun the length of this discussion, only the

¹ Presented at a symposium on "Ecology of Inshore Waters," September 10, 1948, sponsored jointly by The American Society of Limnology and Oceanography with the Ecological Society of America.

broadest terms will be employed and the reader must supply the details.

The inshore environment is, of course, unique in that it represents the region where the atmosphere, the ocean, and the underlying sea bottom mutually intersect. Because of the rise and fall of the sea surface caused by tide and wave action, there is truly a marginal zone that is by turn marine and terrestrial. The coastal realm therefore brings together the students of the land sciences and those of the sea. In certain regions, where there are almost completely landlocked bodies of water or where rivers enter the sea, the science of oceanography merges imperceptibly into that of limnology.

The inshore environment is complex, indeed, but the study of the physical characteristics and of the plants and animals found therein has been exceedingly fruitful. From the economic point of view, it is the region where most of the world's great fisheries are conducted. It is where organisms are not only plentiful but are most varied. It is the environment where most of the sedimentary rocks have been laid down. In order to understand the geologic history of the earth, it is essential that far more complete data be compiled upon the interrelations between the organisms, particularly potential fossil-forming types, and the physical characteristics of their environment.

It is obvious that the physical characteristics are the keys to both biological and geological problems. These factors can be used to characterize and compare the different environments, so that similarities and differences can be recognized and through the key organisms the terms that must be employed to describe the features of the oceans that existed in past eras.

THE PHYSICAL CHARACTERISTICS

It is not the purpose of this discussion to enumerate all the individual characteristics that make up the physical environment. However, a few of the more significant ones must be mentioned. First of all, because we are dealing with a marine environment, it is implied that the water contains dissolved salts in the relative proportions that characterize sea water. In regions of great dilution this relationship will obviously not hold in a strict sense, and there will be significant differences depending upon the origin of the diluting water. In this connection it should be pointed out that under certain circumstances runoff can be beneficial in that it will carry to the sea nutrient materials required by plant growth. At the other extreme, industrial wastes and sewage can be extremely harmful. The fresh water introduced by rivers and runoff from the land produces a variety of effects characteristic of the nearshore regions. Besides diluting the water, in the sense of concentration of dissolved materials, it carries with it sus-

pended material of both organic and inorganic origin. This not only tends to reduce the transparency of the water but is, of course, the origin of much of the sediment accumulating on the bottom or being transported across the shelf to deeper water. The fact that the fresh water is lighter than the sea water tends to the formation of a dilute surface layer that overlies the more saline water. This may produce a variety of conditions. During spring in midlatitudes, the surface layer may be much colder than the underlying water. During the summer, the turbid surface layer may become very warm with an almost discontinuous decrease in temperature at the lower boundary of the dilute layer.

Motion of the water is generally more violent in the coastal regions than in the open sea. Currents that are so important in the transportation of organisms and their food are generally more rapid in the shallow water and in the proximity of land boundaries. Four types of water movement must be evaluated in describing an environment: permanent currents, wind-driven currents, tidal currents, and those currents associated with surface waves and river outflow. The rise and fall of the tide and the violent action of the surf on the shore are dominating features in the shape and character of the beach and shallow water zone. The transport of water, either along the beach or away from shore, caused by the onshore movement maintained by the waves, is also significant. All the various chemical constituents, particularly those affected by biological processes, such as the nutrient substances (nitrogen, phosphorus, and silicon), dissolved oxygen, and the carbon dioxide-calcium carbonate equilibrium, are also valuable parameters.

CHARACTERISTICS OF THE INSHORE ENVIRONMENT

Some of the physical characteristics have just been outlined. If it is possible to talk about "inshore" or "nearshore" environments as opposed to offshore or oceanic environments, there must be certain features that set them apart. The most obvious of these is the much greater range and variability of conditions near shore. First let us consider the regional variability. The highest temperatures found in the sea exist in land-locked waters in arid regions in low latitudes. In the Red Sea temperatures exceeding 40° C are common during the summer months, whereas temperatures exceeding 30° C are rare in the open ocean. Temperatures in tide pools and shallow water during the daylight hours rise rapidly and at night may fall considerably below those in adjacent deeper water. The opposite case of low temperatures does not apply so well, because when the temperature falls below - 2°, ice is formed and sets the lower limit for temperature of

the water. However, it is obvious that sea ice in shallow water will have more far-reaching effects upon the biological environment than sea-ice in deep water.

Salinity also shows a far greater range in coastal regions than in the open sea. To refer to the Red Sea once more, it is found that there salinities often exceed 40‰ , whereas in the open ocean they rarely are found to be higher than 37‰ . In land-locked areas and tide pools, of course, evaporation sometimes proceeds to the point where the salts are precipitated. The effects of dilution have already been mentioned, but it should be pointed out that in the open sea the salinities rarely drop below 33‰ .

The character of the bottom is also more variable, ranging all the way from solid rock to rapidly accumulating fine sediments off the mouths of such rivers as the Mississippi. The combined effects of waves and currents upon the organisms of the nearshore regions are certainly more violent than in the deep sea.

It is frequently stressed that the marine environment is extremely stable. From what I have just mentioned, it is obvious that inshore environments are in direct contrast by being extremely varied. Shallow coastal regions are also subject to a much greater range of conditions than the open sea. The rise and fall of the tide has little effect upon the deep sea environment, but it is certainly one of the important features in shallow water. This is true not only because of its effect upon the intertidal zone but also because of the tidal currents that sweep back and forth across the shelf. To thrive in the nearshore zone, organisms must be able to withstand a variable environment. They must be adapted to meet fluctuating temperatures, wide ranges in salinity, turbid water, shifting bottom sediments, and violent motions set up by waves and swell. At first glance, this picture looks rather dark for the organism, but it raises some very interesting questions. If the inshore environment is so variable, why does it appear to be so productive? Is it the proximity to land or is it the shoaler depths that make this great production possible? Answers to these questions and many others could undoubtedly be found in studies of carefully selected areas. How do areas with extensive shelves compare with coastal regions where there is deep water near shore? How does the productivity of an offshore area overlying an isolated bank compare with that of a shallow area near land? The recent discovery of the phantom bottom or deep scattering layer tends to indicate that in deep water the organisms may be relatively dilute but dispersed through a deep water column. The fact that shallow regions are essentially two-dimensional rather than three-dimensional may be very significant in their bioeconomy.

In order to characterize nearshore environments it will be necessary to set up certain questions that must be answered for each region. In many cases these will involve a comparison with the oceanic conditions in the adjacent areas. The boundaries will not be clear-cut but it will certainly reveal that the inshore environment, wherever it may be, is more variable than the nearby oceanic regions.

COMPARISON OF INSHORE ENVIRONMENTS

Since the physical environment is a complex of many variable factors, the only way in which different areas can be compared is by describing them according to some standard procedure. The list of characteristics should be held to a minimum and as our experience develops they should be arranged in some type of generic system that will permit classification. It appears that four general features might serve as the basis for such a classification of nearshore environments. These are:

- a. The degree of isolation.
- b. The type of coastline.
- c. The latitude.
- d. The relationship to adjacent land masses.

The degree of isolation is a qualitative expression indicating the extent to which the area under consideration is cut off from the adjacent sea areas. It is important because it reflects the amount by which conditions will differ from those in the open ocean. This can be illustrated by a single example. An area such as a fjord with a narrow and shallow entrance will be a very different environment than that in the adjacent open water.

The type of coast is believed to be a useful parameter because the topography of the sea floor near the coast is in general very similar to that of the land near the coast. This is the equivalent of saying that the location of the water line is irrelevant and that if sea level were lowered we would find essentially the same terrain extending outward to the edge of the shelf. The number of different types of coastline is a subject of debate, but one author recognizes eleven major types ranging from steep mountainous areas to river deltas and coral reefs. The reason for emphasizing the type of coastline is that it makes it possible to estimate many of the physical features of the regions from land maps and charts. These will be not only the general subsurface terrain but also the type of bottom, the amount of local runoff, the probable amount of suspended material and its character, exposure to storms, and the types of current.

Latitude is obviously a useful index to a number of features. Not only is it an index to the seasonal range and value of temperatures, but

also it fixes the duration of seasons, intensity of illumination, and length of day.

Proximity to adjacent land masses is another qualitative indicator. Whether we are concerned with an area adjacent to a continent, a lone island, or part of an archipelago is obviously important. We must also know whether the area is on the east or west side of a continent because only then will we be able to predict the general type of circulation, the importance of upwelling, the type of tides, and certain other features.

Any system of classification is not of particular value without detailed information on conditions in the individual areas. Because extremely valuable conclusions could be drawn from detailed comparisons of different areas, it is believed that a program for systematic compilation of such studies should be undertaken. To be most useful they should consist of three general parts:

1. General average conditions.
2. Historical compilation.
3. Factors controlling the environment.

The first section should present as briefly as possible by means of graphs, charts, and tables the average "climatic" picture that would serve as the basis for comparison with similar analyses for other areas. All studies should be based upon the same outline and should employ standardized means of presentation so that comparisons may be made rapidly and easily. The historical compilation should contain all available types of records pertinent to the area for which they have been accumulated over a period of years. In most locations these data will be scanty and will be limited to such items as sea level data from tidal records, surface temperatures, surface salinities, river discharge values, and such records as may be available from meteorological offices. This information would be most useful in establishing empirical correlations between catch records, success of year classes, abnormal biological conditions, and certain physical features. The third section should be a discussion of the area, pointing out the factors that seem most important in controlling the local environment and indicating possible means by which variable factors might be predicted in advance.

In the foregoing no mention has been made of the biological information that might be included in such systematic studies. It is clear that compilations of the type just outlined would be of the greatest help to biologists and fisheries experts and would provide the type of information that is urgently needed by those concerned with paleoecology. There is another use, however, that may not be quite so obvious. The physical environment, in very large part, determines the feasi-

bility of fishing, the types of equipment to be employed, and the size of vessel necessary to operate under a given set of conditions. From the systematic analyses just outlined, it is easy to see how such information could be used to great advantage in planning fishery development in hitherto unexploited regions and in improving techniques in regions where fisheries have developed by traditional trial and error methods.

SUMMARY AND CONCLUSIONS

As the inshore environment is always so variable, it is important that methods of investigation be devised that make field investigations as rapid and simple as possible. Because of the importance of comparative studies it is likewise important that methods of study and reporting be standardized. This requires careful planning and coordination. By classification and systematized descriptions of inshore environments information would be available that would serve not only the biologist, paleontologist, geologist, and fisheries investigator but would be of value in fishery development and the expansion into new types of fisheries and into new areas.