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The Uses of Ecological Principles

Another View of Environmental Research

Management of fishery industries and conservation of fishery resources should have one common goal, namely, full use of marine environments. Research and thinking about environments, particularly in relation to philosophies of conservation, should be directed toward finding principles of ecology that will be helpful, if not essential, to achieving that goal. In this chapter a few principles that seem valid and pertinent to our subject are examined in comparison with some common misconceptions that are often responsible for the wasteful misuse of environments. The development of true ecological principles depends on long-continued systematic studies of environments. In general, ecological research in the past has not been continuous. Such progress as has been made in this field has resulted from spurts of transient, sometimes enthusiastic support usually ending with fits of impatience or starts of economy. Consequently, much of marine ecology is characterized by a quality of aimlessness, as though people concerned with it, lacking direction, devoted themselves to collecting odds and ends of unrelated data. What is needed for this field is a clear goal and a great deal of attention to the integration of *results with the formulation and rigorous testing of natural laws. Two general lines of work are indicated: (1) systematic, well-planned field observation, which would come within the purview of the laboratory of environment proposed in the previous chapter, and (2) assembling and analyzing information from all available sources to see how it can be applied to the direction of fisheries.*

The argument of the previous chapter was directed toward making environment the subject of research for the sake of learning the how's and the why's of the occurrence of the various kinds of marine organisms, regardless of their commercial value. Such research would enlarge knowledge of the mechanics of ecological systems and would be used as a basis of dynamic fishery management. This chapter will examine environmental research once again, this time from the viewpoint of application of its results to the development of a science of fisheries.

A few definitions will be useful: by a system, we mean an assemblage of natural elements which affect each other in various ways and are thus united by interaction or interdependence. "Ecosystem" is another way of saying environment (as I use the term in this book), but it connotes something more, namely, the environment in action.

Dynamic fishery management, an ideal to be striven for, is continuous direction of fisheries so as to take full advantage of the action of ecological principles in relation to current conditions of availability, density, abundance, and distribution of all the various usable species. That is to say, an industrial or governmental fishery manager having current knowledge about an area over which his fishery operates—the characteristics of the environment and the physiological requirements, and abundance, and distribution of the several species—would deploy the fishermen's efforts over time, over fishing grounds, and among species, so as to spread the harvests to promote on the average the most economical use of fishing time and equipment, and to encourage a desired balance of the populations.

The idea of dynamic fishery management differs from the concept of management which has long been orthodox among people concerned with exploiting the sea, in emphasizing the environment as a whole rather than a few popular species within it. It is based on the principle that the composition of every environmental system exists naturally in a state of constant flux, whether man is part of the system or not. Individual populations flow and ebb as shifts in the environment favor or do not favor their specific requirements. Any action disturbing one part of the system necessitates some reaction, however slight, in all the other parts. Thus readjustment toward a steady state goes on constantly.

Nevertheless, ecological systems seem never actually to reach a steady-state condition because the environment changes continually, within limits, just as do elements in large-scale geophysical systems such as the weather. The assemblage of species responds variously to these environmental changes as well as to each other's response to them, and there are time lags in these adjustments. Thus at best the species of a system are in a state of continual oscillation. The alternating waves of abundance of predator and prey species is one example. The lag between failure of one fishery and development of a new one is another.

As soon as fishermen begin exploiting a virgin stock of a species, they introduce a new factor into the system of which it is a member, disturbing thereby the pattern of oscillations in which they found it. Gradually thereafter, while the fishery grows, they reduce the stock to lower levels until a new pattern becomes established in the system, which now includes man among the predators. From then on it is difficult to study "the environment" or "ecology" without taking human affairs into account. Man's weight in the equilibrium is determined by such things as the number of fishermen, the efficiency of their gear, the wages that a fisherman is willing to work for, the price the public is willing to pay for the fish, and so forth.

People of fishery industries are often passive to these biological and economic mechanisms and tend to strike a let-nature-take-its-course attitude about its action. Taylor expresses this attitude perfectly in the following passage:

> [There is] a characteristic behavior of the fisheries under heavy exploitation that is often overlooked, namely, that as any one species of fish is pursued and its abundance diminishes (as a result of fishing or any other cause), the cost of producing it rises relative to the cost of catching other species; if the price does not increase to compensate, the fishermen discover the diminution of returns from this fishery and some of them take up some other, so that part of the pressure is taken off the "over-fished" species, a process which amounts to an automatic economic regulation of the intensity and distribution of fishing. The principle applies also to the fisheries collectively of a region operating in competition with other regions. If the fisheries reach a point of diminishing returns in one region, economic compulsion operates to relieve the pressure in favor of another.
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> *It appears to be impossible to exterminate a species or a fishery for profit,* since the profit disappears before the fish is exterminated. Within the fisherman's freedom of choice to catch, and selectivity or nonselectivity of gear, each species or fishery tends to be fished to a point at which it just yields a wage to those engaged equal to what they could earn by fishing other species, or by working at some other trade ashore. Equilibrium would undoubtedly be estab-

lished at this wage level for each species if natural fluctuations did not occur in the supply of various species and if market conditions remained constant. *This operation of economic law is such as to distribute the total fishing effort over the total fishery resources of a region and to deliver a total of yield into the consuming market just sufficient to meet total of demand.*[1]

Even if this description were correct, the automatic mechanism, such as it is, is so far from smooth-acting as to be of little benefit to society. For a reduced fishery is rarely replaced by another in the same region—the same country, perhaps, but not the same region. Moreover, after a fishery has fallen to unprofitable levels, there is often a considerable time lag while the public cultivates new tastes, and while fishermen and others in the industry adjust their habits, apparatus, and techniques to new types of fishing. Thus the collapse of the Pacific pilchard fishery in 1947 has not yet been compensated for by the growth of another Pacific coast fishery of similar magnitude. During the lag period, men lose their investments and their savings, some of which are never recovered. Some fishermen change to other occupations, and their country loses them as links in a chain of tradition and becomes the poorer thereby. Burkenroad writes on Taylor's argument thus:

The phrase . . . *"it is impossible to exhaust a fishery for profit because the profit disappears before the fish does,"* is speciously employed. A fishery may continue profitable to fishermen even though exhausted to such an extent that effort is being wasted with the sole effect of reducing the catch. Such waste may be contrary to the public interest. . . . The quoted maxim is used as if it meant that self-regulating factors ensure use of fish-stocks in the manner most advantageous to society; whereas its only real meaning is that changes caused by most commercial fishing are likely to be reversible under appropriate conditions.[2]

A fishing industry can be strengthened by flexibility and diversification. One which depends wholly on a single stock is at the mercy of the vagaries of its abundance and availability. If the stock vanishes, the fishermen spend a few seasons hopefully searching for it—"surely this season they will be back." After that, they consider what other kind of fish to exploit. This is bad management. A conservation agency might consider only the vanishing stock, seek restrictive laws to reclaim it, and not consider how to redirect the fishery to other species. That, too, would be bad management. In both instances, people are unduly restricting their use of the environment's total produce. In other words, fisheries could be greatly improved if the people concerned with the business enlarged their idea of the sea's potentialities and came to think of their resource not so much in terms of a few well known species as in terms of the environmental systems in which those species live.

Environmental systems have mechanisms which operate according to principles, and these principles must be understood before a system can be manipulated scientifically. Textbooks of ecology often attempt to state principles controlling the relations of environments to their resident populations. It is hard to be precise about such statements. Hardly are they set down on paper before it becomes necessary to add a weakening, qualifying word; and hardly is that added before exceptions come to mind. Still there are a few statements of principles which seem approximately true and pertinent to our subject. It is probably true that:

The populations of organisms inhabiting a common habitat are in constant flux and react upon each other dynamically.

For each species there is a unique combination of environmental conditions which is optimal for its well-being.

A population tends to fill all the space in its system that meets its peculiar physiological and behavioral requirements, up to limits set by the abundance of food, predators, and competitors and by diseases and physical barriers.

With changes in the combination of environmental conditions in an ecological system, such as a fluctuation in climate, a shift in ocean currents, invasion by a new predator (man, for instance) or the sudden infestation of the dominant species by a disease, the species composition of the system changes.

The members of a population compete with each other for food and space.

The bulk of living organic matter is greatest in the plants which synthesize organic food, least in the supreme carnivorous animals which live off other carnivores. Among species between these extremes it decreases rapidly as dependence on animal food increases. Consequently, the farther away from the bottom of this "food pyramid" a fishery operates, the smaller is the maximum possible harvest.

The supply of food varies from time to time and place to place.

Generalizations more or less like these are taught in college courses in ecology. They are widely accepted as truth, or at the very least as rough approximations of truth, for there is a good deal of reason and some evidence to support them. These generalizations have been reached from studies on land and in fresh water rather than in the sea. If such principles do hold true in the sea as well, they ought to influence people's attitudes toward the exploitation of sea environments. As it is, they have rather little influence, for there are in existence some quite commonly held opposing ideas which have evolved by deduction from reasonable-sounding premises, and which are kept alive by tradition and sentiment. These principles are not often expressed; nevertheless they are clearly implied in many proposals of laws advanced for conservation purposes. They go about like this:

The number of offspring fish surviving to useful size is closely related to the number of spawners.

This idea seems so logical that the man in the street usually assumes it to be true without even questioning it. Yet no study of a marine fish has yet demonstrated a clear, consistent correlation. This point is discussed more fully on page 43.

It is more destructive to catch fish during the spawning season than at any other time of year.

This conclusion grows out of the belief that as long as the sex products are ripe they should be utilized. But the quantity of sex products is so vast that the proportion destroyed by taking spawning fish is negligible. Moreover, a fish caught in December instead of in the following June is thereby prevented from spawning in June and the effect is the same. Under some circumstances, however, the proposition may be true. If all the adults of a stock collect in one place to spawn, they will be particularly vulnerable to a fishery that converges on them at that time.

A species has but little effect on others that share the same environment. If one species declines, the space which it had occupied remains vacant until the abundance is restored to its former level.

This is an assumption which is often implied in policies of those concerned with commercial fisheries. Yet it is contrary to principles of ecology. If a valuable species declines, its space may be occupied by a species quite worthless from the commercial point of view, but it does become occupied. When a food species fills this space, fishermen should be encouraged to change their operations accordingly.

The only important cause of diminution or disappearance of a stock of fish is man. All other causes are, on the average, constant and relatively inconsequential. Being natural causes, "they have always been that way" and should not be altered. Indeed, they cannot be altered. Therefore there is little practical value in studying them.

This idea is becoming less prevalent among people interested in fishery problems than it was a few years ago. Its persistence in some quarters adds to the difficulty of gaining support for ecological research.

An unregulated intense fishery will always exterminate a stock eventually.

This is one extreme view and probably unsound. It can reduce the volume and value of the annual yield, but is not likely to extinguish the stock.

Direction (i.e., regulation) of a fishery is useless for various reasons, for example, because natural factors alone control abundance or because economic factors alone control fishing rates.

This is another extreme view, and probably also unsound.

If there is not enough knowledge about a stock to provide a basis of scientific regulation, it is better to regulate by judgment or common sense than not to regulate at all.

This is a dangerous idea because it *seems* right and is hard to refute. Actually such a regulation might be of no benefit to the stock and harmful to the fishery. Where an unsupported regulation is absolutely necessary, it should be carried on as an experiment, its biological effects carefully measured.

For the most part these statements are inconsistent with principles where facts are available to support principles, and they are inimical to the most profitable management of the resources. How backward agriculture would be if it were conducted with such a restricted viewpoint! An educated cattle rancher seeks to run his business in accordance not only with sound economics but also with principles of scientific land use and of animal husbandry. He recognizes that the two sides of his job, the one having to do with human affairs and the other with the ecology of his property, are inseparable. Fishery entrepreneurs on the other hand, though attentive to business, are often passive to husbandry, leaving the job of fishery management wholly to government. Since they expect this management to take the form of restriction to prevent overfishing, they often oppose it automatically. Government interest in this kind of management usually does not begin until a fishery gets into a distressing situation. I have written elsewhere on this as follows:

> A species may appear to be in danger of extermination through overfishing; or fishermen operating two types of gear may dispute as to whether one of them is unduly destructive; a population of shellfish may suddenly vanish without trace; an epidemic may break out or masses of dead fishes may wash up on the beaches, the stench of their rotting bodies driving tourists away. But whatever the occasion, it is generally the disturbing condition, preferably a disaster, that arouses people's interest. They hope the Government will solve the problem quickly by acting, say, to stop dumping ammunition at sea, or by passing legislation providing a size limit, or by enacting a law to stop

all commercial fishing for a species, or to abolish purse seining, or to abate pollution. The Government usually holds hearings over such questions, which usually bring out such diverse and conflicting opinions on the issues that it becomes necessary to gather some pertinent, objectively gathered facts before reaching a decision. Thus the Government starts an investigation of a species, or a fishery, or a particular situation.[8]

This is a pattern which has been repeated in various localities to solve special problems during the whole history of our biological fishery research. There develops an anomalous condition (often diminution of fish stocks which people remember as having once been much greater). An interested special group of people requests that the condition be investigated, and after due legislative procedure, scientists are assigned to the problem. To understand the cause of the undesirable condition, the scientists first try to establish facts about the time when the condition was satisfactory (i.e., the normal pattern), but because records are nearly always fragmentary or lacking, this effort usually proves fruitless. Then, because they are expected to devise a remedy for the condition in a reasonable time, they make deductions and recommendations from the data they can assemble. Such an investigation may not be conducive to learning much about the normal, being bound by too many limitations, for the anomalous condition is usually sharply delimited in scope. It is limited in time to the memory of the current generation, often even to such a short period as a season or two. It is limited ecologically to the affected species which are of most economic value.

The net effect of our preoccupation with problems of this kind is that we neither cover enough ground in our research programs nor make fast enough progress toward the ideal goal of full utilization of marine environments. What can we do to speed up the rate of progress? We can be sure that the most dramatic events—the undesirable situations, the anomalies—will continue to generate public support for special investigations and we will have to continue conducting them. But at the same time, we must try by every means to get better support for the systematic, less spectacular studies of normal conditions, which in the long run will provide us more systematically with what we need to know about the anomalous situations.

Very little systematic marine biological research has been devoted to the dynamics of ecological systems. There is a plenitude of descriptions of communities and catalogues of animals and plants collected in surveys. Although these have reference value to zoogeographers, taxonomists, and others interested in what is often called natural history, they tell very little about the history of nature. A list of species resulting from a survey, even one made with proper statistical technique, shows only what composed a community at one moment in its history. It is like a single frame of a motion picture in its relation to the continuity of a drama. A second survey made of the community ten years after reveals that the flora and fauna have changed. Nothing more. What caused the change? Did an intensive fishery remove an important predator, permitting species lower in the food pyramid to accumulate? Or did it remove a key fodder fish, causing predators to starve to death or to leave for richer grounds? Had a change of climate resulted in a rearrangement of distribution? Had epidemics destroyed some of the populations? Had cycles, resulting perhaps from the numerical relations of predator and prey, arrived at a different part of their periods? It is not possible to understand causes of changes in the composition of an ecological system without watching them happen, and that requires the drudgery of systematic, long-continued observations of the system in its natural setting. The following is an example to illustrate that changes do occur:

F. M. Davis surveyed the Dogger Bank area of the North Sea during 1921–1923 to measure the relative quantities of the various bottom-living organisms that his gear (Petersen grab) collected.[4] Twenty-seven years later Erik Ursin of the Danish Commission for Fishery and Sea Investigations made a similar survey in the same grounds. In comparing the numbers of animals in the samples which he took in the central and western parts of the Dogger Bank with those which Davis had taken, Ursin found that a remarkable change in faunal composition had occurred in the intervening time,[5] as shown in the following table:

	Number per Square Meter	
	Davis (Oct. 1922)	Ursin (May 1951)
Spisula subtruncata	272	5
Mactra corallina	11	1
Other species of bivalves	4	43
Polychaets	4	70
Echinoderms	4	28
Other groups	8	65
Total	303	212

Among miscellaneous species not listed above, the most numerous was *Tellina fabula* of which there were 22 specimens per square meter in 1951 as compared with 0.5 per square meter in 1922. Ursin also found fairly large quantities of a few species which apparently had been absent in 1922. Notable among these were *Echi-*

nocyamus pusillus, Myriochele heeri, and *Cerianthus lloydii.* Ursin writes on this:

> What brought about the changed composition of the fauna is still an unsolved question because we know very little of the stability of marine animal communities. In fact, it is not known whether the difference observed between the composition of the fauna during the two periods of investigation is indicative of a fairly constant change from one state of balance to another, or whether it merely indicates the degree of fluctuation in the said area under relatively stable conditions of environment.

There is still another possibility. Ursin made his survey in the spring, Davis in the fall; and the differences in faunal composition might reflect seasonal rather than annual differences, since the mollusks in question are short-lived.[6] This points up the importance of carrying on surveys like this all the year round, as well as year after year.

It would be appropriate now to give an example to illustrate changes in fish fauna, but as far as we know, no one has yet followed the history of an entire ecological system completely enough or long enough to observe how the various species of fishes oscillate and interact. This is partly because of the difficulties of sampling several species of motile organisms of differing habits, and partly because such a study requires continued financing and persistent work over many years before results can emerge. Fortunately, at least one example is available to show how one species *may* affect another. Scientists of the Danish Biological Station made periodic surveys of the Limfjord from 1903 to 1927, fishing with a fine-meshed otter trawl throughout the fjord.[7] This trawl consistently took at least one kind of fish in proportion to its abundance, the eelpout (*Zoarces viviparous*). Presumably the other species were variably elusive. The eelpout fluctuated during the twenty-year period in three waves. At the same time, the commercial catch statistics of the area show that the stock of codfish also fluctuated. Periods of scarcity were followed by periods of abundance when good year broods appeared in the fjord, as they do at rather rare intervals. When that happened, the young cod fed voraciously on the accumulated stock of eelpout and gobies, which they quickly reduced to levels that remained low until fishermen had caught off the cod.

Here is another suggestive example:

Within the short span of eight years, the total southern New England catch of yellow-tail flounder plummeted from 60 million pounds to only 10 million pounds. This evidently reflected a decline in actual abundance. Fishermen say that all the while this was happening the quantity of miscellaneous species of lesser commercial value which they call "industrial fish" was steadily increasing. (Fishermen originally called them "trash fish," but later agreed to change the name because these miscellaneous species do have value as raw material for fish meal.) They had always returned these unmarketable odds and ends to the sea, but beginning about 1947 they brought them into port to supply the growing demand of animal feed producers. Thus in five years, the landings of "industrial fish" from the area that had formerly been flounder grounds, rose from zero to over 55 million pounds. More than 90 per cent of it was composed of red hake, eelpout, skates, whiting, sculpin, goosefish, toadfish, sea robin, sea raven, and dogfish.[8] Did overfishing reduce the stock of flounders to low ebb, or were other causes responsible? Did the reduction in flounders itself bring about the alleged increase in "industrial fish," or was it changes in the climate of the environment that did it? No one knows. Scientists were studying the yellow-tail flounder, but before they could get to its ecology the work was discontinued. Consequently no one knows what, if anything, happened to the environment, or how, or to what extent the fauna changed; and there was nothing by which to advise fishermen how they might have taken most profitable advantage of the changes that were occurring, or how they might even have directed their fishing so as to control the faunal composition. As it is now, flounder fishermen, on purely circumstantial evidence, blame the industrial fishery for the decline of the flounder resource.

Enough has been said about environment as a whole—the ecological system—to emphasize the scientific and practical value of making it the focal subject of special research. Enough has been said, too, to show that environment is a peculiarly amorphous and elusive subject to study as well as to discuss. It is far beyond the range of any one man's education, for it involves many fields: among the biological sciences—zoology, plant and animal physiology, histology, cytology, taxonomy, anatomy, comparative physiology, bioassay and biochemistry; and among the physical sciences—organic, inorganic and physical chemistry, soil analysis, trace element analysis, geology, hydrography.

The greatest danger of environmental research is that it will fail to track. Each of the people engaged in it can easily find some detail of environment overwhelmingly diverting, and pursue it "for the sake of science." Of course an environmental laboratory needs such people. It also needs others who have the patience to conduct the necessary systematic observations year after year. And above all it needs scientists who are devoted to integrating all sorts of information in order to find such principles as it may disclose.