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# Changing Concepts In Fishery Research On the Great Lakes

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It must seem illogical to approach the subject of accomplishments of fishery biology on the Great Lakes by detailing certain weaknesses of earlier researchers and points of view. Yet the paradox may not be as grievous as would appear. Surely we may count it an accomplishment to have become aware of defects both in our way of doing and of thinking and to have made a start toward the development of new lines of attack which we feel will make our future efforts more productive.

Before undertaking the painful specification of past shortcomings, let us digress momentarily to give a minimal background on the Great Lakes and their fisheries.[1] The five lakes have a combined surface area of 95,000 square miles—61,000 within U. S. boundaries and 34,000 under Canadian jurisdiction. The U. S. waters of the Great Lakes are shared among eight states, each of which has full jurisdiction over the fisheries within its boundaries. Thus we have altogether nine fishery codes.

Ecological conditions vary widely both between and within lakes — often in contiguous waters. We know, for example, that within the relatively limited confines of an area as small as Green Bay — only 118 miles long and at most 23 miles wide — the life histories of certain shallow-water species differ greatly between the northern and southern ends. It is these highly variable shallow waters that are most productive. This same Green Bay, for example, has contributed 60 to 70 per cent of Lake Michigan's total production in recent years. Only the deeper waters of the three upper lakes and Lake Ontario offer anything even approaching the degree of uniformity and stability of habitat encountered in the open sea.

Commercial production of fish in the Great Lakes is relatively small — characteristically 70 to 80 million pounds in U. S. waters in recent decades — but is economically important. As an illustration, the dollar value of Great Lakes production equalled that of the Pacific sardine when that fishery was at its height. The lakes are without large fishing ports; the catches are

1 For accounts of the Great Lakes fisheries at various periods see: Milner (1874); Smith and Snell (1891); Rathbun and Wakeham (1897); Koelz (1926). Gallagher and Van Oosten (1943) gave considerable historical information on the fisheries, offered detailed discussions of problems of regulation, and published all available records of production through 1940. Van Oosten (1938) wrote a historical sketch with special references to State of Michigan waters.

landed at hundreds of points scattered along the nearly 5,000 miles of U. S. shoreline.

Principal gears are gill nets (almost always fished on the bottom and never drifted) and various types of impounding nets. Most fisheries are composite, in that several species are taken simultaneously and most species are taken in quantity by several kinds of gear; this circumstance has forced the development of special procedures for the estimation of availability and fishing pressure.[2]

The complexity of situation indicated by these sketchy comments played an important role in the framing of past biological investigations of the Fish and Wildlife Service and inevitably must loom large in the development of future research plans. Confronted by scanty and fluctuating budgets the Service took the only approach really open — studies of individual commercially important species and fisheries based on them in single lakes or sections of lakes. Even here the selection was more by circumstance than by plan, for materials were collected as opportunity presented itself during the course of practical studies — mostly on gear selectivity[3] — of sufficient urgency to attract outside support from State and other agencies.

This haphazard approach was not as unproductive as might have been anticipated. Numerous sound, and a few substantial, pieces of work were completed and a large amount of fundamental information was accumulated. Yet we are in the anomalous situation of the property owner who has considerable building material scattered about his lot—has even made a start on construction—but still is living in a tent.[4]

It is to be suspected also that the necessity of placing first one fish and then another under our scientific scrutiny may have betrayed us into oversimplification of the problem of productivity. The typical history of production in the Great Lakes has included an initial period of relatively high output dominated by first-choice species as lake trout and whitefish, followed by a progressive deterioration in which the production of the valuable species declined and less and less desirable varieties as freshwater drum, suckers, and carp became more prominent in the catch. At times this deterioration reaches the point that total production is controlled by the market for "rough" fish.

The sequence—reduced production of one after another choice species followed by increased take of less desirable varieties—was given the interpretation both common and generally acceptable at the time. It was depletion through overfishing in the simplest classical sense—removal of the stock at a rate faster than it could replace itself. First one species or group of species was depleted; then the fishermen turned to another and the process was repeated until, as a result of the successive, largely independent declines, the cupboard was bare except for the neglected varieties of lowest quality.

Now, none of us engaged in the earlier research on the Great Lakes is so poor a biologist as to believe that different species of fish do not affect

2 For descriptions of procedures employed for the analysis of Great Lakes fishery statistics see: Hile (1937); Hile and Jobes (1941); Van Oosten, Hile, and Jobes (1946).

3 Van Oosten (1932, 1933, and 1935) described and gave summaries of findings for some of these pioneering studies of savings gear.

4 See Hile (1952a) for a historical review of Federal research on the Great Lakes fisheries.

each other. Yet the conviction that the importance of these interactions among species was negligible in comparison with the direct depleting effects of unwise fishing was implicit, if not always stated, in the pronouncements of the period. Warnings as to the impending collapse of the fisheries stressed always the growing scarcity of individual species through the simple mechanics of too rapid removal. The mere fact of declining take came to be accepted as *prima facie* evidence of overfishing to be corrected only through restrictions.

The regulatory measures recommended were designed to correct a simple unbalance between rate of recruitment and rate of exploitation—reduction of fishing intensity through higher size limits, closed seasons and grounds, restrictive specifications on gear (principally in the form of larger meshes). Given sufficiently drastic restrictions, it was argued, the fishery surely could be saved from almost certain doom, and most probably much of its former productivity restored.

We arrive now at the matter of changing concepts. Briefly stated, the accumulation of new information and the re-appraisal of old are forcing on us the realization that the cause of deteriorated fisheries in the Great Lakes, and hence the means for their improvement, do not offer a problem as simple as has been supposed. It is not suggested that over-fishing in the strict sense has not taken place, or that regulations past and present have been useless. As recently as the early and middle 1930's we saw the destruction of stocks of whitefish in Lake Huron that almost surely could have been prevented or lessened by the adoption of relatively simple restrictions (Van Oosten, Hile, and Jobes 1946), and bad as conditions are now they might be far worse in some fisheries but for restrictive measures in effect. On the other hand, we do know that the imposition of restrictions has not been generally effective in restoring productivity and that on occasion overzealous protection has all but put an end to potentially productive fisheries.[5]

Our principal departure from earlier thought concerns not so much the cause of the deterioration of the fisheries as the process whereby the change has come about. Although we concede readily the importance of such factors as the deposition at various periods of sawdust, bark, and silt, the pollution from varied industrial and domestic wastes, the fertilizing effects of sewage effluents and drainage from agricultural lands, and disruptions from introductions of exotic species of fish, we must still consider fishing activity a principal cause of the decline of the fisheries. There is a good reason to suspect, however, that in the mixed stocks of our shallow-water areas, ". . . a major effect of fishing lies in the disturbance of ecological relations among the fishes. Thus, fishing pressure to which the species are subject in common may give one a competitive advantage and place another at a disadvantage. Differences of fecundity, growth, and longevity, . . . that lead to a particular species composition at one level of intensity may bring about a greatly different composition at another. Changes of this origin can be accentuated if fishing pressures, relative to the actual stock, differ from species to species. Furthermore, the generally lower level of commercial

5 A good illustration of this point is provided by studies still in progress on the yellow perch of southern Green Bay (Hile 1953). Here, the evidence indicated that production was limited by the inability of most individuals in the slowly growing stock to survive the more than five years required to attain the minimum legal length of eight inches. The effects of a reduction of the size limit to 7½ inches are now being studied.

production in the modern period suggests the possibility that fishing pressure on commercially exploited species may have operated so much to the advantage of the smaller, non-commercial species that the latter now make up an increased percentage of the total biological production."[6] In brief, we hold that fishermen did not turn from declining first-choice fish to exploitation of a pre-existing stock of cheaper fish but rather that through ecological changes the poorer fish became more plentiful as the better ones grew scarce. We question whether the biological production of fish ever has declined significantly in the Great Lakes; on the contrary the fertility of the lakes probably has increased with the rise of human population.

Although the general increase in the percentage of cheaper fish in the commercial take leaves little doubt that fishing has been on the whole prejudicial to the welfare of first-choice varieties, certain outstanding exceptions preclude the assumption that we have a simple case of selective fishing against the better species. In some areas the changes in ecological conditions seem to have operated for the betterment, not to the detriment, of first-choice fish. A striking example comes from the Michigan waters of Green Bay where the 1929-1949 average annual production of whitefish, a high-priced species always in market demand and fished intensively, was 4½ times the average take in the early fishery of 1891-1908 (Hile, Lunger, and Buettner 1953). Similarly, in Lake Erie the catch of the highly prized walleye, fished intensively without benefit of a closed season during spawning and at a size limit a full two inches below that recommended 20 years ago, has shown a strong upward trend of production during nearly all of these same 20 years—a trend that has carried the take to unprecedented high levels.[7]

Thus, our problem is complex indeed. It is one that calls for study of populations of fish rather than of individual species. We need most to understand interactions among species and how they are affected by changing environmental conditions. In this situation we see little prospect for an approach toward sounder management for higher productivity through the application of fishing theory as developed among others by Baranov, Russell, Graham, and Beverton in Europe, by Thompson, Ricker, and Schaefer in North America, and as applied so brilliantly by some of them toward the solution of fishery problems. This is not to imply that our particular fish are exempt from the laws of nature—that rates of growth, natural mortality, recruitment, and exploitation are not primary determinants of yield. Rather, these factors do not behave in our fish stocks in a fashion which must be assumed in a model population if one is to arrive at equations for which there is any chance of obtaining even approximate solutions. True, fishing theory has grown to accept the idea of a certain fluctuation of rates other than rates of exploitation, has recognized possible interactions among these rates, and to some extent has made adjustments for them. Also, the importance of hydrographic and other environmental conditions in the

6 From Hile, Lunger, and Buettner (1953).

7 Gallagher and Van Oosten (1943) considered the 1885-1908 average annual production of 1,949,000 pounds of walleyes to be the "normal" take for U. S. waters of Lake Erie. After the catch declined and averaged only 1,418 pounds or 73 per cent of normal in 1912-1935. How sharply the trend has been upward during the last 20 years is demonstrated by the following 5-year averages: 1933-1937—2,001,000 pounds; 1938-1942—3,531,000 pounds; 1943-1947—4,434,000 pounds; 1948-1952—5,126,000 pounds.

determination of abundance has long been generally recognized. Nevertheless, the validity of mean rates—perhaps more properly typical rates—and the concept of factors operating within a largely independent, self-contained stock is implicit in and essential to the theory.

Our stocks of fish in the Great Lakes clearly do not meet the conditions that must hold if fishing theory is to be the basis of management.[8] Not only do we have constantly growing evidence that extrinsic factors by far overshadow intrinsic factors in the determination of availability of a particular stock; it is apparent also that in some stocks the fluctuations are of such a magnitude as to make management on the basis of mean or typical rates out of the question. Time does not permit a detailing of evidence in support of these statements. From historical records we do know that species once plentiful are now scarce and species once scarce are now dominant.[9] During the periods of our own researches we have seen enormous and sudden changes of availability and species composition which, though they may possibly be related to previous fishing activities are not to be explained sensibly, at least in quantitative terms, by any theory as yet formulated.[10] Although we have used and propose to use the most exacting analytical procedures available to us and within our capabilities, our central problem is not one of vital statistics. Rather, it is a problem of biological understanding. We must learn the causes of or at least the conditions that permit or accompany the great fluctuations that occur; we must understand better how fluctuations

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8 But for the fact that the stocks of lake trout have all but disappeared from Lake Huron and Lake Michigan and are dwindling so rapidly in Lake Superior that early collapse of the fishery threatens (Lakes Ontario and Erie have never been important centers of lake trout production), we should need to make a possible exception for that species. Ecological conditions in the deeper waters inhabited by the lake trout are far simpler and more stable than those in the shallower areas. Here the lake trout has existed as the principal predator on large stocks of small species of coregonids (ciscoes or chubs) and of cottids and sticklebacks. The only other species of similar predatory habits (and one equally vulnerable to the sea lamprey), the burbot, has been much less abundant. This relatively steady environment and simplicity of interspecies relationships, together with the long life of the lake trout and the normal dependence of the fishery on a considerable range of age groups, led to a high degree of stability. Although the production and availability of lake trout have exhibited both long-term and cyclic trends (Hile 1949; Hile, Eschmeyer, and Lunger 1951a, b), the fishery has in general lacked the sudden, wide fluctuations characteristic of the fisheries for so many Great Lakes species. Despite the fact that the point has not been tested, we suspect that the application of fishing theory to the lake trout fishery would have been profitable.

9 Smith and Snell's (1891) comprehensive port-by-port account of the Great Lakes fisheries in 1885 makes possible many instructive comparisons of early with present-day conditions. Valuable also are their descriptions of changes in species composition that had recently occurred or were taking place at the time of their survey. Their following comment (p. 116) on the fishery of Oconto County, Wisconsin, for example, gives evidence that the present strong dominance of the yellow perch in southern Green Bay was in the process of establishment in the 1880's: "While the whitefish and the pike have been disappearing the perch have become enormously more abundant. Before 1882 only a few scattered ones were obtained, averaging about six to each lift of the pound net. Since then they have become more and more numerous each year, until in the spring of 1885 never less than 50 pounds and sometimes as much as a ton of them were taken at a lift."

10 A recent example of these tremendous fluctuations is provided by the 1943 year classes of three species in northern Green Bay, Lake Michigan (Hile 1950; Hile, Lunger, and Buettner 1953) so strong as to lead to a modern high in the production of lake herring and to all-time records in the output of whitefish and walleyes. Although the analysis of data on the walleye remains to be completed, the preliminary estimate that the contribution of the 1943 year class to the commercial fishery will be 50 to 60 times the average of year classes for the preceding 10-15 years is in no way excessive.

of one species affect another; we must learn more of the role of meteorological and hydrographic factors; and, of course, even though the application may not be by equation and formula, we must study carefully the effects of fishing.

In situations as intricate as those in most of our Great Lakes fisheries, we must approach understanding through a series of approximations. Precision in our statements relative to changes in populations will come slowly. We count it unlikely that in our time we shall be in position to recommend changes of management procedures with full confidence as to the extent or even the direction of their effects. We expect nevertheless to recommend changes of regulation which, according to our best knowledge, give promise of being beneficial and to check carefully to determine their actual effects. Improvements in the regulation and management of the Great Lakes fisheries long must come through experimentation rather than deduction. The function of the biologist will be that of furthering maximum efficiency in this experimental process.[11]

The principal accomplishment of fishery biology in the Great Lakes, then, has been to teach us that for more effective understanding we must focus our attention on how fish live together in a constantly changing environment. Circumstances may require that we study species individually, and we may never achieve the goal of simultaneous research on every variety in a population; but we must never think in terms of one species alone, for it does not live alone.

This statement of changing outlook carries no admission that our past efforts have been futile: rather it is an expression of hope that our future programs will be more effective. We envision no great change in our methods of research. We shall continue to count and measure fish, read scales, examine stomachs, analyze statistics of production, intensity, and catch per unit effort. We trust only that we can schedule our operations more sensibly and piece together our information to form a more comprehensible picture.

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## Half a Century of Fishery Biology In Europe

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At the invitation of the King of Sweden, representatives of several Governments met on 15th June, 1899, in Stockholm. The countries represented were Denmark, Norway, Sweden, Germany, Great Britain, the Netherlands and Russia. They wished to join in studying the seas: the hydrography especially in relation to fisheries, the fisheries themselves, and the biology of the various species of fish.

During the century that was just ending there had been some half dozen pioneers into these subjects. Victor Hensen had conceived the possibility of evaluating the production of the sea by sampling with plankton nets (Hensen, 1911). Frank Buckland had devoted a life's work to the conception of managing fresh water fisheries according to their natural history.* T. W. Fulton (1897) had started to relate hydrographical studies to the facts of the commercial fisheries. E. W. L. Holt (1893) had done the same for biological studies, and had advocated remedial measures for the North Sea plaice. Particularly eminent among these pioneers was C. G. J. Petersen (1894) who had correctly appraised the problem of rational exploitation of a fishery, and had also demonstrated the possibilities of transplantation to areas with a rich bottom fauna. On the hydrographical side, Otto Pettersson had sketched the possibility of relating fluctuations in fisheries to astronomical phenomena through hydrographical effects, and so of foretelling them (1899). Frijof Nansen (Helland-Hansen and Nansen, 1909) had begun the study of water masses, and Martin Knudsen (1899) the chemical and physical characteristics

*See, eg., Graham, 1948