STATE OF CALIFORNIA

FISH AND GAME COMMISSION

FISH BULLETIN No. 2

The Scientific Investigation of Marine Fisheries, as Related to the Work of the Fish and Game Commission in Southern California

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CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO
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THE SCIENTIFIC INVESTIGATION OF MARINE FISHERIES, AS RELATED TO THE WORK OF THE FISH AND GAME COMMISSION IN SOUTHERN CALIFORNIA.*

By WILL F. THOMPSON.

In June, 1917, the California Fish and Game Commission inaugurated scientific investigations of commercially important fishes of southern California. The writer, who is at present in charge of the investigations, has been asked many questions regarding the purpose of the work, and he has come to realize the necessity of an outline to which the various lines of research may be referred and thus understood. However, it is difficult to tell into what fields the pursuit of truth will lead in the case of each investigation, and it will be found that in this paper resort has been had to the statement of aims in terms which are perhaps applicable to fisheries research in general, rather than to that of the albacore in particular, the fish now being studied. The formulation is frankly tentative, due to the chaotic state of the branch of fisheries research concerned, and it is hoped that further experience will correct errors and enable clearer conceptions to arise.

The Need for the Investigation.

There is a fundamental need for the knowledge we are seeking, information regarding the life histories of, and the fisheries for, certain species. The comparatively recent and enormous development of our fisheries, the prospect of a far more extensive utilization of their products, and the perfection of the machinery of exploitation, has brought sharply to focus the question of the capacity of the species of fish to withstand the strain. Instances of overfishing are already well known, both on our own coast and in the Atlantic, and the stability of the supply is a real question everywhere.

Those men intimately concerned with the fisheries, having as a rule decided opinions regarding the species in which they are particularly interested, frequently ask why the world should not accept at once and act upon their belief that the fish are becoming less in number, or their contradiction of such an assertion. However, proof that seeks to modify the ways of commerce or of sport must be overwhelming—and unfortunately the statements of those who know the truth are too readily contradicted by the assured arguments of those who regard the resources of the sea as inexhaustible, or of those who see in everything evidence of depletion. The same is true of opinions concerning the habits of fish, and of the measures which must be taken for conservation or for the aid of the fisheries. Not only do research and careful study along scientific lines produce the required weight of evidence, but they are far more likely to bring to light important considerations than even the combined powers of observation of the fishermen and dealers. It would seem, in brief, that if any attention, local or international,

*These investigations are being made under the supervision of Norman B. Scofield, head of the Commercial Fisheries Department of the Commission. His advice in the formulation of the paper is thankfully acknowledged. Thanks are also due Dr. C. H. Gilbert for criticism and the use of the library in his department at Stanford University. Mrs. W. F. Thompson has assisted throughout the preparation of the paper.

is to be paid to fisheries by a government, some means of accurately ascertaining the correct grounds upon which to act is indispensable; and that is the animus of the work of the commission.

In stating the general aims of the work, a start must be made from the basis that governmental interest in marine fisheries is defined and limited almost entirely by the use we are able to make of the products as food, leaving aside the consideration of recreation. It is the universal aim to make the greatest possible use of a resource, formerly without considering the future, but now more and more with the clear idea of rendering the yield from it permanent, not only for the present generation, but for those in the future. Moreover, it has become the function of government, not only to aid in procuring the greatest possible use, but to insure its continuance, because it is the only agency uniting all factions and successive generations. The task which is being undertaken devolves upon the state because of its jurisdiction over commercial fisheries, and it is incumbent upon that government to adequately inform itself regarding the conditions of the fisheries which it controls. No private agency could be given the authority to collect the proper statistics of the fishery, nor be trusted to bear consistently in mind the objects sought. The preservation and care of the fisheries, and the ascertainment of the proper methods for doing so, are therefore imperative duties of the state, and the recognition of these facts renders it possible to formulate a definite procedure for that agency which the state has expressly created for the care of the fisheries.

Permanent Use the First Consideration.

This procedure should be undoubtedly that which is necessary to the perpetuation and prosperity of the fishery, and should not include at present those questions of general biological interest which deal with all life in the sea and the formulation of natural laws—questions as yet remote from solution, and not to be solved without long continued research. Governmental work must necessarily lack much of clearness and definiteness until such problems are solved, but the direct necessity of caring for the fisheries makes it advisable to rely upon other public and private agencies for the placing of emphasis on such questions. It is not, to use an illustration, as incumbent upon a governmental agency, directly concerned with animal husbandry, to discover the processes of fœtal growth in cattle, as it is to insure such conditions as will result in the birth of an adequate number of calves, however closely related the two subjects may be in the last analysis.

Problems of Immediate Interest First Considered.

The cause of a successful spawning season matters less to us than the fact of success, from which may be foretold the effect on the fishery. Not the manner of a fish in obtaining food, or in producing descendants, is the first consideration, but its success or failure in obtaining or producing these things in sufficiency. Although it is necessary, without doubt, to a full understanding of a fishery, that a complete knowledge of the growth and habits of the particular species of fish concerned be at hand, yet the broader and more significant features of its life and their relationship to the fishery must form the first subject of governmental inquiry. Depletion of our fisheries must be recognized; their fluctuations must be known and foretold or prevented, that a maximum yield may be obtained economically; and features, such as the importance of the individual to the species at each stage of life, must be known that human aid in protection or propagation may be efficient and that encouragement may be given to the fishery without harm.

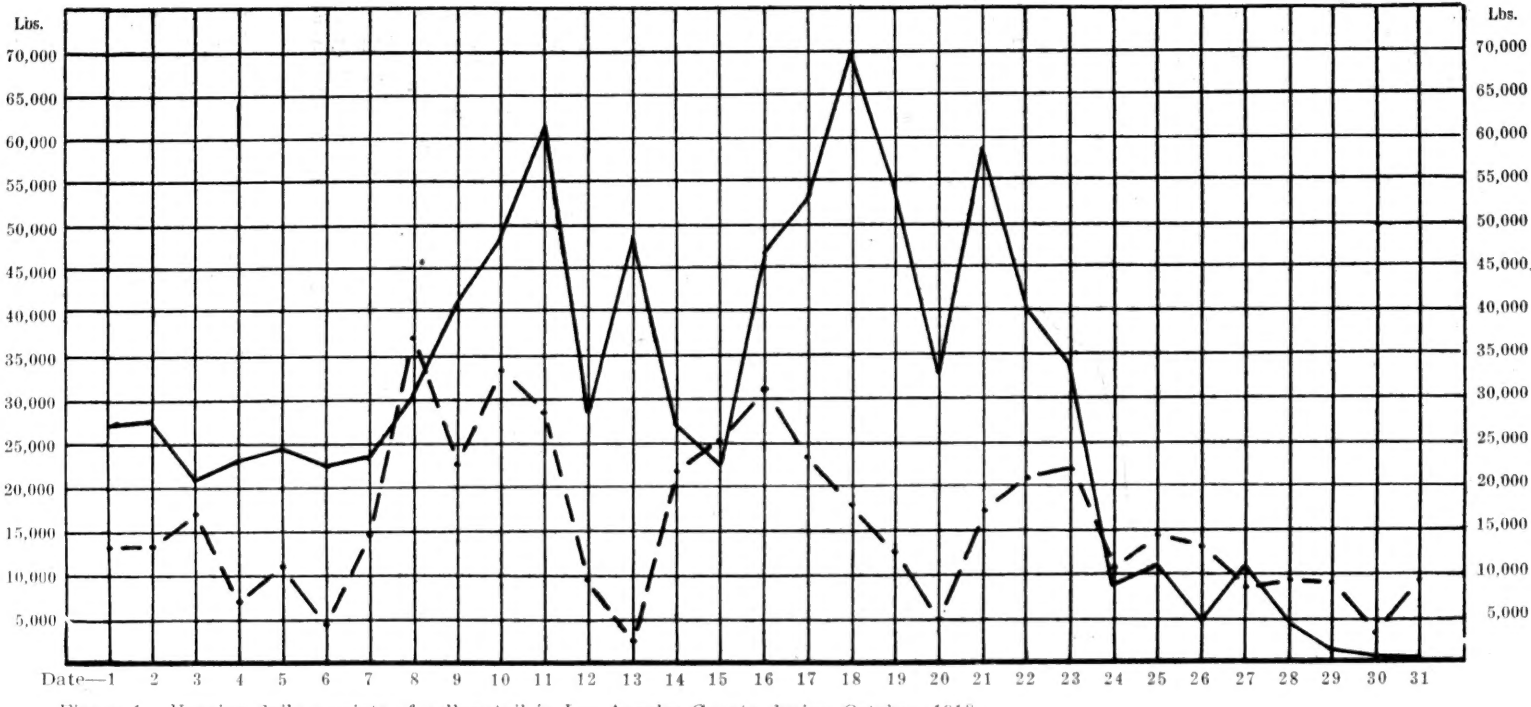

Figure 1. Varying daily receipts of yellow-tail in Los Angeles County during October, 1918.
— — — Broken line: In fresh fish markets.
——— Unbroken line: In the canneries.

Although in thus laying emphasis upon certain aspects of scientific investigation, the detection and prevention of depletion is regarded as of predominating importance, yet the general question of fluctuations in supply is undoubtedly next in seriousness. The alternating abundance and scarcity of fresh fish in the markets of California is a serious obstacle to the widespread use of fish and to the handling of fish at reasonable prices. The machinery of the industry must be geared to care for periods of great abundance and the profits of such periods must be such as will pay for the maintenance of the machinery during slack periods. The same is true of the canning of fish. Thus the salmon canneries must be idle the larger part of the year, as the tuna canneries were compelled to be until the sardine filled the vacant months. Even during the run of fish, when everything must be in readiness to handle the maximum, there are long periods of idleness and unproductiveness. To give point to this statement we may cite the case of the canneries of southern California during the three good months of January, February and March of 1918. The combined daily capacity of the canneries was eight hundred tons of large sardines or three hundred and twenty tons of small (not both), but the actual pack was one hundred and eighty tons per day, on the average. In other words, there was either more than half the time wasted, or less than half the machinery used. Nor does this economic waste end with these fluctuations within the season. The years vary as widely in their productiveness as do the days or the weeks, and a year may go by with a pack but a portion of the normal size. We are, therefore, faced with a major problem of waste capital, labor and machinery, which renders the price of fish high and the returns to those engaged in the business precarious. As will be seen later, the study of these natural fluctuations is linked inseparably with the study of depletion or overfishing, and a program of investigation can not separate these two.

In contrast to this care of the source of the supply by governments, there may be considered another phase, upon which considerable emphasis is at times placed: namely, the handling and marketing of the supply. Thus, direct governmental aid to the fisheries may take the shape of a furtherance of efficiency and an improvement of methods, as by the establishment of federal fishery schools. But to the state, such things as these are certainly subordinate to the primary duty of the maintenance of the supply at its height. Also, as in the case of the great meat packing corporations, the public is demanding an actual regulation of the whole fishing industry, from fisherman to retail dealer. The question of economic control is, however, not at present placed in the hands of the Fish and Game Commission. It is the commission's concern to insure a supply, then to aid in its proper and efficient use, and not—at present—to exercise any legal control over the economic phases of the industries.

Therefore, we are dealing, in the first place, with the problem of the *abundance of fish in the ocean* as it is related to the fisheries. This is included in our first two sections as given below. Then secondarily—although certainly considering it a duty—we are dealing with the use of the supply, as included in the third section. Naturally, the sections are interdependent and related; but the extent of this will be seen.

Hence, in formulating plans for research on various fisheries, it has seemed necessary that the Fish and Game Commission seek a knowledge of those things which will:

Outline of Work.

Section 1. Indicate the presence or absence and extent of overfishing, explain it, and provide proper corrective measures.

Section 2. Give an understanding of fluctuations in supply other than those of depletion and provide if possible a basis for their elimination and anticipation in order that the yield may be constantly at its maximum.

Section 3. Aid the fishermen, dealers, and canners in the use and increase of the available supply with the greatest good to the industry and the public, and with the least danger of incurring depletion.

It will be readily seen, and as frankly acknowledged, that our research must begin with the fishery itself. Its nature and peculiarities are prime factors in any conclusions reached, and its records are invaluable in answering questions which may arise. In the records of the catch must lie evidence of depletion and of fluctuation, if such be present. Therefore, if our studies are really studies of the fishery, as well as of the fish, the work is no less scientific in character, indeed more so, than if the fish alone were regarded. Such studies are practically the only means to the ends assigned.

Necessity for Study of Fishery as Well as of Fish.

They are possible only to a government; for it alone has the power to gather adequate data, throughout periods of years; and it, alone, is the best judge of what knowledge it seeks, responsible as it is for the prosperity and continuance of the fisheries.

First Section.

OVERFISHING, ITS CRITERIA AND METHODS OF PREVENTION.

By depletion, which is included under this first heading, is usually understood a decreasing yield for the effort involved. There have been few attempts, with the exception of those of Great Britain, to keep adequate records of the fisheries to show specifically whether depletion is in progress or not, although that must undoubtedly be one of the main purposes of fishery statistics. The furnishing of data which may show the volume of business in a district is not of full value unless it gives some means of comparison with other data to prove its condition, or promise of continuity. It is undoubtedly most unfortunate that this has not been more generally recognized, for at the present time there is usually but little definite ground upon which our fisheries may be judged, despite the sometimes elaborate statistics of the total catch.

It is possible, however, to show that depletion, or overfishing, may be proved by adequate statistics, and an examination of the basis of these adequate statistics should illuminate the requirements we must meet.

The experiences of fishery investigators in the North Sea have conclusively shown that man has it in his power to profoundly affect the stability of marine species, but this conclusion has been reached only after much painful experience with ordinary fishery statistics. The opinions of Huxley are of little value in this regard, as he antedated the great expansion of the fisheries, but even he stated that certain fisheries such as the cod, herring, and mackerel were inexhaustible "in

Criteria of Depletion in the Fishery Statistics.

relation to our present modes of fishing'' (page 14, Inaugural Address, 1883). The early conclusions of the Fishery Board for Scotland (previous to 1900) seemed to them to justify the closure of the territorial waters in certain regions because of the exhaustion of the supplies of plaice and other species. Unfortunately, their conclusions were based on inadequate data, as for instance the experimental hauls of the

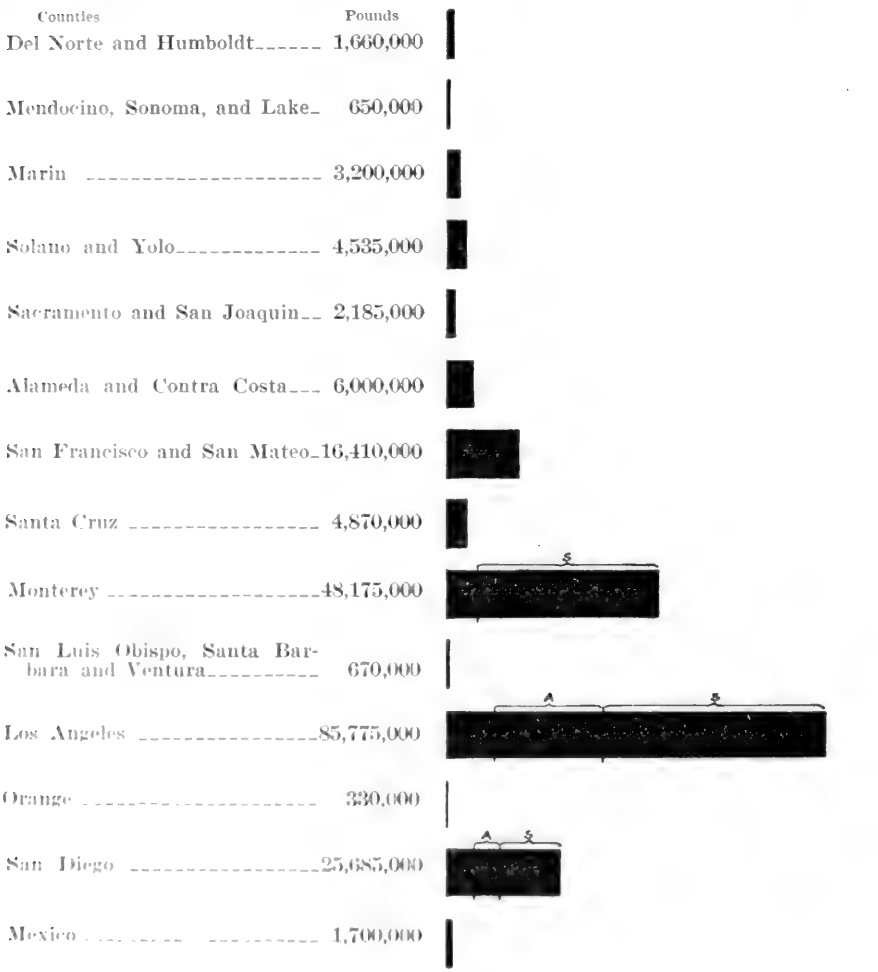

Figure 2. Total receipts of all fish in California during 1917, by statistical districts, in order from North to South. Also relative importance of albacore and sardine fisheries. A—Albacore. S—Sardine.

steamer ''Garland,'' which were shown to be too few and not comparable because made at times of the year which differed in the early and late periods of investigation. Careful examination of commercial hauls—the only practical way to get a sufficient number of records—led Fulton (1902) to state that although there were (1) a decrease in the quantity of good grade fish and an increase in poor, with a net increase;

(2) a great shift in fishing grounds to deeper water and more distant seas; (3) a great increase in the quantity and efficiency of fishing gear; and (4) a conviction on the part of the fishermen that depletion was occurring, yet there was required in order to show the actual abundance, comparable data from a single area during a period of years. He desired (1) the quantities of various species landed, by (2) each method of fishing, in (3) a definite region, by (4) a certain duration of fishing, and (5) in seasons which were comparable from year to year. McIntosh, in a book (The Resources of the Sea, 1900), dominated by two ideas: namely, the extraordinary powers of reproduction of animals and plants in the sea, and the criticism of the trawling experiments as well as the closed areas of the Scottish Fishery Board, pointed out the faults in the data at hand and boldly asserted the inability of man to affect the species in the sea. He was adequately answered by Garstang (The Impoverishment of the Sea, 1900), and it need only be regretted that those who read the book by McIntosh frequently look no further into the subject. Moreover, from what was discovered by fish-marking experiments, it became plain that from 20 to 40 per cent of the marketable plaice were removed from the banks yearly. The work of Garstang in the report quoted, the investigations of the Scottish Fishery Board as reported by Fulton and D'Arcy W. Thompson—based on the accurate statistical requirements specified by Fulton—and the work of men of other nationalities has since 1900 proved the effect of man on the fisheries and disposed of the contentions of McIntosh. Heincke, for the International Commission for the Investigation of the Sea (Investigations on the Plaice, 1913) stated that "It has perhaps come so far already, that the fishery is annually taking not only the highest possible interest of plaice food, produced by the natural productivity of the sea, from the capital represented by the stock of plaice, *but is also attacking this very capital.*" [Italics Heincke's.] So also Allen (Food From the Sea): "We should not forget, however, that the evidence is now almost conclusive that human agency has been powerful enough to exert a marked adverse influence upon many of the best and most productive fishing grounds. . . ."* We need not quote others, such as Fulton and Thompson, who are even more positive in their conclusions to careful statistical work, the point being evident enough. Not until adequate statistical methods were employed, and proper units for comparison obtained, was it possible to prove to the world what was accepted by the fishermen themselves, the effect of the fishery on the abundance of the more valuable food-fishes, notably the plaice, in the North Sea.

With regard to the Pacific coast, it may be briefly said that in the two cases in which a statistical and biological study has been made of the trend of the fishery, the conservation of these forms is admitted necessary and is now under consideration: namely, the halibut of the North Pacific, and the salmon of the Frazer River. In the former of these cases the statistics were obtained merely by a fortunate circumstance in the methods of fishing for them; in the other, through the peculiarities of the life history of the species considered in connection with the statistics of the catch.

*Compare Ritter, Bulletin of the Scripps Institution, No. 5, 1918, p. 16. Also Alexander, Moore, and Kendall, Bureau of Fisheries Document No. 816, Report U. S. Commissioner of Fisheries for 1914 (1915), pp. 68, 69, 92, and 97.

In all of these cases it is obvious that the figures of the total catch are not available as a basis of judgment because they do not discount factors which may be present other than the productivity of the fishing grounds. As has been shown in the case of the North Sea fisheries and the Pacific halibut fisheries, an important part of the growth of a fishery consists in the increase in fishing apparatus, and its radical betterment, with more men employed; of the utilization of new grounds; and of the prolongation of the fishing season because of an increase in the profit in fishing. The introduction of power vessels, the enormous improvement in transportation facilities, the use of ice and refrigerating plants, the introduction of the otter trawl, and the great increase in population have taken place within the last thirty-five years. The effectiveness of these economic factors in obscuring the facts may be illustrated by the change in the classes of fish sold in the markets now, as compared with those sold a number of years ago. Small fish, formerly discarded, are now taken eagerly, and varieties formerly unsalable are now greatly in demand. Such things may increase the total yield despite an extensive depletion of the fishing grounds. On the other hand, the total for any one species may be actually decreased by a change in gear used, taking more of some other species and less of the one considered, while there might be no reason in reality to be alarmed at the condition of the fishery for that species. Even though the total yield were divided by the number of fishing boats and men, this would not eliminate the remaining considerations, which would often suffice to totally mask the extensive exhaustion of the whole or part of the grounds, and would certainly render of doubtful value any conclusions which might be reached. The discovery and use of standards for comparison which will give an ideal indication of the abundance of fish, must, therefore, be one of the principal aims of scientific work on commercial fisheries.

From what has been said above, it is obvious that it is possible to obtain from statistical records, if such are properly kept, criteria of depletion which, if not ideal, are trustworthy. It has undoubtedly become, or will soon become, a first duty of the government in control to see that a failure of statistics in this regard does not take place, and that the usual program of doubt and controversy be not repeated here. The objects sought are, on this coast, even more vital to the prosperity of the fisheries than is the case in the North Sea, for the available area of coastal banks is far less in proportion to adjacent land areas and prospective populations. Yet it should be possible to obtain more adequate statistics, with acceptable criteria of the condition of the fisheries, because of the radical differences in modes of fishing and the youth of the industries involved. The constantly increasing inclination to hold governments responsible for the care of natural resources, even to the extent of a demand for their national ownership, will ultimately force the adoption of adequate programs everywhere, such as Fulton desired as a result of his experiences with North Sea fisheries. Systems of statistical records based on the best obtainable units of comparison will undoubtedly prove indispensable.

It must therefore become one of the primary aims in work done for the Fish and Game Commission to adopt adequate statistical records, wherever a close study of the fishery concerned shows it to be possible. The study of the varying abundance of fish in each region, the recording

of changes in the fishing fleet, and of the shifting of the fishing grounds are phases of this purpose.

Criteria of Depletion in the Biology of the Species.

Notwithstanding the apparent value of such statistical records, the validity of each of the various criteria of depletion must be tested and weighed carefully in the case of each species. In such cases as that of the herring, or the sardine, for instance, where densely schooling fish are concerned, and are caught by nets, it may well be that depletion does not evince itself in increased labor or expense to the fishermen until the practical destruction of the schools is at hand. Difficulty in finding the schools may not increase proportionately with the decrease in their size, and once found, small schools may conceivably yield half their numbers as readily as large schools a twentieth. Moreover, it is not known whether the catches of herrings or sardines represent the fluctuating abundance, or simply the varying accessibility of the schools. A further biological study of the behavior of schools under varying physical conditions is in such a case imperative, and until such is made, it should not be assumed that the resources of the sea are inexhaustible even in regard to these two species, nor should assertions of overfishing be made.

In the case of the mackerel of the western Atlantic, which became very scarce for many years, its disappearance has never been analyzed, and to the present day it is unknown just what phenomena accompanied its departure. And the same is true of other species. Such instances are simply illustrations of the fact that our ignorance of the biological conditions accompanying overfishing or obscuring the relative abundance of fish is profound. Yet certain facts are known, if not generally recognized, and an attempt will be made to deal with them in the following pages.

The existence of wide variation in the accessibility of fish, especially species found on the surface, shows that statistical evidence drawn from commercial catches may not in itself mean decreasing abundance unless allowance is made for the factors which cause this wide variation. Because of this, it seems overwhelmingly important to examine the various fisheries from a biological viewpoint, in order that other supplementary indices to the condition of the fishery be discovered. In fact, so important is the subject, that even were the statistical criteria satisfactory in themselves, the conclusions drawn from them should be corroborated by additional evidence, naturally biological in character.

In the ordinary sense of the term, it might be said that a species is undergoing depletion when the total number of fish existent is being constantly diminished. This is what the comparison of statistics from year to year is intended to show. But this definition can not be said to be strictly correct, as it is possible that there is a surplus of adult fish which are not necessary to spawning. If such were not present, exhaustion of the available supply of fish would be very rapid in those cases where great fisheries are carried on. A series of unfavorable years might completely banish the species, if it were not provided by nature that there should be a reserve sufficient to overcome setbacks. It is this reserve upon which men must depend if they wish to use the fisheries, and at the same time preserve them. It is possible, then, as far as the present purposes are concerned, to find a better definition than that

given above, by concluding that overfishing is the result of any fishery which lessens the number of mature or spawning fish below what is necessary to maintain the species commercially under such changed conditions of survival as are the result of intensive fisheries. (See Peterson, 1903, for further definitions of overfishing.)

The depletion of the mature will follow naturally from extensive fishing because the great increase in rate of mortality among the commercial sizes will lessen the average length of life; and must mean the decline in size of the older classes. This is the more true as in most modern fisheries, particularly those carried on with hook and line, the larger fish alone are taken, thus concentrating the strain on the mature and near mature. The extent to which this lessening of the average length of life may proceed without danger to the species is logically dependent on the number of mature fish which exist in excess of those necessary to produce sufficient offspring. The greater the mortality, the fewer the fish which reach maturity, and the smaller the surplus existent.

There never has been, it should be obvious, an accurate measurement of the number of surplus adults in a species, save in such rare cases as the enumeration of the surplus fur seals of the Pacific. Nevertheless, in certain cases, it is possible to judge of the proportions of mature and immature present in the commercial catches, and thus arrive at some means of recording the fluctuations in number of mature. Any lessening of the proportion of mature would mean necessarily the lessening of the surplus present, and the total exhaustion of the surplus would mean the commencement of depletion, because of the incursions on the number of necessary spawners.* If the surplus were exhausted, a state of relative stability would be reached only if the fishery were to depend entirely on the yearly increment to this surplus, in other words become restricted in extent (as may happen after the decline of a fishery because it no longer pays). But, as a rule, the total amount taken does not decrease, simply becoming a larger and larger proportion of the available supply, increasing the rate of the mortality and decreasing the chances of reaching maturity. We may, therefore, adopt as an indication of the tendency of a fishery, the variation in the proportion of mature fish present from year to year, when compared to the immature. Hence, a continuous, progressive decline in the numbers of mature fish, coincident with a decrease in the abundance of all fish, must mean an approach to, and the ultimate commencement of, depletion, and must, when very extensive, indicate its presence. There is in this fact what may be termed a biological criterion of overfishing.

There are, however, circumstances which must modify this conclusion. The decline in number of necessary spawners must finally result in a decreased number of young, and the marked decrease in proportion of mature from year to year will then of course become obscured because the two classes will tend to decline in numbers together. The first interval of sharply falling proportion of mature must include the time taken to exhaust the surplus of mature as well as the interval which must elapse before a class depleted by lack of spawners can appear among the commercial sizes. At the same time, if the *total* catch taken

*To what extent the surplus owes its size to the commercial use of the enemies of the species, or to their increase, is a moot question, which can not be approached on any adequate basis at present, and at all events need not affect our present conclusions.

remains the same or increases, it must consume a larger and larger percentage of the constantly depleted remainder, thus increasing the rate of mortality among the commercial sizes; and this is what seems to have happened in those few cases which have been analyzed. Moreover, the lessened numbers of immature naturally decrease, ultimately, the numbers of mature produced from them. The result must be a continuation in the fall of the proportion of mature despite the commencement of a decline in numbers of both mature and immature classes. Although no such exact analysis has been made of any fishery, yet it is evident that the usefulness of such a biological criterion as the falling proportion of mature may be much greater during the earlier stages of overfishing, before it can be reinforced by additional statistical evidence.

A logical consequence of the decline in proportion of mature mentioned above must be the much exaggerated decrease in numbers of fish caught in regions which are replenished from other grounds or banks and do not normally possess young. Such regions will be the first to show the depletion which later becomes evident in even the habitat of the very immature. Almost similar in significance, and if anything more promising in prospective value, would be the discovery that one part of a fishing season is dependent in whole or in part on mature fish, so that it may be contrasted with that part depending more on the immature. Some measure of the depletion of the mature classes could be obtained in these ways, but, if they should prove practical, use could not be made of them without adequate systems of statistics applied to the regions concerned.

The change in the proportion of mature is naturally the accompaniment of overfishing, and experience indicates that it can be used to distinguish fluctuations due to natural causes from the decline produced by overfishing. Natural fluctuations in abundance are supposed generally to arise from the success or failure of spawning seasons, aside from epidemics or hydrographic catastrophes.* But the failure of a spawning season would not diminish the proportion of mature or of older classes, but should have an action the reverse, as well as a temporary effect. The distinction of a *lack* of mature fish due to overfishing from a *superabundance* of immature, due to a good spawning season, implying on the one hand a decrease in total numbers, on the other an increase, necessitates statistics which will correctly indicate the abundance of all fish—something not always met with, of course. Such reasoning has been found to apply to the bottom fishes of the North Sea, for instance; and it is the effect of successful spawning in increasing the abundance of fish upon which Hjort (1914) lays great emphasis in his explanation of the fluctuations in the great herring fisheries of Europe. In these cases, the facts seem clear, and the conclusions legitimate; and there seems to be no reason why the sequence of events should not be the same in other species—for instance, the mackerels.

There is, then, a criterion of overfishing at hand in the biology of the species, when some method of arriving at the relative numbers of mature fish is adopted. During the investigations by the Fish and Game Com-

*We have omitted from consideration such things as hydrographic catastrophes, or greatly increased attacks by enemies, which might only rarely affect those classes taken by man in commercial fishing, and hence produce similar effects. Actual observation must be relied upon in such cases, or sufficient time allowed to lapse for such temporary effects to vanish.

mission, this must be borne in mind, although the application to each species must be governed by the circumstances of the fishery.

It will be worth while to examine the manner of knowledge which the use of the statistical and biological criteria of depletion mentioned above implies. It should be borne in mind also that the same knowledge will be necessary for the study of fluctuations other than depletion. There must be known, besides other things of lesser importance:

Wide Knowledge Necessary to Use Criteria of Overfishing.

1. The accuracy of the measure of abundance used—in other words, the correctness of the statistical unit employed.
2. The relative percentage of mature and immature in the commercial catch at various times and various localities. This involves the age and rate of growth and the time of maturity.
3. The degree of independence of the various banks or regions, or the extent of intermigration and interdependence.

(1) The relative accuracy of the measure of abundance used is of course of great importance when the comparisons are made from year to year. By accuracy is meant, primarily, the freedom from fluctuation in the value of the measure employed, and secondarily, the correctness of the idea which it conveys of the absolute numbers of the species. The most that can reasonably be expected is probably an approximate knowledge of the variations which occur in the unit of measure, and the limits of error to be expected. Thus when the catch of the same vessel year after year is used as a measure, the variation in the efficiency of gear, or the seaworthiness of the vessel, can not be examined with exactness, but the results obtained may at least be discounted for the possible error. A knowledge of the economic conditions governing the fishery is of course of primary importance in this regard.

(2) The relative percentage of mature and immature in the products of the fisheries must in most cases be discovered largely through a study of the frequency of various sized fishes in the light of a knowledge of age and rate of growth. In some cases, as with the plaice, it has been possible to determine from commercial statistics the meaning of the categories of size into which the fish have been classified. In others, as in the herring, it has been proved necessary to maintain a careful biological examination of age, or of the frequency of occurrence of sizes.

The age and rate of growth are discoverable, principally, through the structure of the scales, otoliths, and bones, which show annual rings much as do trees. The results from such work are corroborated by studies on the frequency of occurrence of different sizes of fish. Especially in the earlier years, there are well defined classes of various sized fish, each of them representing a year's spawning, and an understanding of their significance awaits the formation of a complete series of these well-defined classes, unless an index of age agreeing with them is found in the scales or otoliths, thus indicating the various ages to which the series of sizes actually present may be assigned.

The great significance of the rate of growth is seen in every phase of the work undertaken. Fluctuations in abundance due to the variations in success of spawning seasons, or the mortality of the larvæ, become evident *only after the fish have had time to reach the age at which they are taken by the fishermen*, and in distinguishing the natural fluctuations from those due to depletion, this must be taken into account.

In order to know the homogeneous nature of the data obtained it is necessary to know the comparative rate of growth of the males and females, and the relative proportion of the various ages and sizes of fish included. The age at maturity is of the greatest importance because of the relation it holds to the age when the fish are first caught, and the number of years it is capable of spawning. If maturity supervenes before the fish becomes of a size large enough to take the hook, there will naturally be a supply of breeding fish untouched by the fishery. On the other hand, if the age at maturity is late, exposing the fish to several years of the fishery before the first spawning, the danger of entirely eliminating the mature is proportionately greater. It has, in short, been universally recognized that it is indispensable to know the various ages of the fish caught, that being the logical basis upon which to study them.

(3) Naturally, the value of a demonstration of overfishing is largely dependent on whether it is shown for merely a limited area or an extensive one. This brings to mind questions as to the movements of fish, such as the albacore, from region to region, and between schools of the same species. To solve this adequately means the following of several lines of inquiry: namely, the morphological features which may differentiate such schools and prove them independent, the migratory and spawning habits, and the movements of individuals. Any one of these implies a great deal of work. In the case of the albacore, it might at present be taken for granted that it intermingles and moves freely everywhere within its bounds, but the absolute truth of such an hypothesis remains to be seen. Failing knowledge concerning this matter, it is of course necessary to prove overfishing for the whole region involved.

Knowing these things—namely, the accuracy of the measures of abundance; the percentage of mature present, with the facts as to growth and age at maturity; and the migration between, or interdependence of, the populations of various regions—there should be no question of the validity of the evidence adduced for or against overfishing. Attainment of absolutely comprehensive knowledge concerning these things is undoubtedly out of reach, but sufficient progress toward that end can without doubt be made so that no question exists regarding the main conclusion. The observation of the condition of the fisheries implies the adoption of an adequate program of investigation of these phases of the life history. This has of course been done in the case of the albacore fishery, in so far as we have been able to judge of what is adequate.

Methods for Prevention of Depletion Are Dependent on Nature of Species.

The matter of corrective or preventive measures to be applied to a species which may be threatened with depletion is, it seems from what is known on the subject, largely dependent on the nature of the species. Certain general measures seem probably acceptable, but serious doubt must exist as to others.

If the species be one which moves about very little, as shown by studies on migration, or on the differences shown between populations of different localities, then particular regions may be alternately protected and opened to use for longer or shorter periods. On the other hand, if it be an actively moving form, roaming freely as individuals, then measures must be applied to the whole.

Again, a sufficient number of eggs could perhaps be secured and be hatched artificially to substantially increase the numbers of young and hence the numbers of fish reaching a size fit for market. It would not be true in all cases, however, that the number of young produced would be worth the expense undergone, even if great numbers were hatched, because of the greatly varying worth of a larval fish as a prospective adult in the different species.

What would seem to be a more logical method than the latter, would be to aid the survival of the young by encouraging the use of their enemies—other fishes, for example—as food, just as the use of the predatory ray or skate should increase the supplies of shell fish in San Francisco Bay. It may well be possible that extensive exploitation of individual fisheries will prove ruinous without a corresponding general utilization of all fisheries. For instance, the slowness of the decline in the tremendous and comparatively well-balanced fisheries of the North Sea may be a logical consequence of well-distributed strain—although to be sure they show overfishing because of their great intensity—and the much more rapid depletion of the highly concentrated halibut fisheries of the Pacific, the result of badly-distributed strain. The matter of interdependence of species of fish, at least the influence of the numbers of one on the welfare of the other, is highly speculative. It is, however, definitely worth while to adopt the principle of protecting various ages and the species as a whole from their enemies as far as possible.

These measures seem sound in principle, but regarding others there is some obscurity. Thus it may be noted here that the supposition generally advanced that fish be protected during their spawning season or when immature should be subject to grave question as to its justice in all cases. It should be obvious without the saying that the ova or their fundaments are present in the gonads throughout the year and throughout life, undergoing a continuous process of development, so that the death of an individual eleven months previous to spawning in reality destroys as many ova as does death a day previous to spawning. The laying of the greatest possible number of ova implies the presence of the greatest possible number of individuals during the spawning season, and to hold its own a species must carry *throughout the year* as many ova as it is in need of.

Varying Worth of Protection at Different Periods.

And in the pursuit of this end it should be very obvious that it is impossible to reduce the numbers of either immature or unripe individuals below a certain level without reducing the eventual numbers of mature or ripe as a consequence, and *vice versa*. The question is simply one of where it is best to take toll of the supply, considering first the survival of the species and then the age or time at which the available surplus may best be taken. Is it best to take the immature before the natural perils of the sea have reduced their numbers, or to take the mature after they have increased greatly in average size? Should adults be taken before the spawning season when they are unripe, or when they are ready to spawn and have increased in size but have decreased in numbers? In other words, which has the least value to the species, weight for weight?

As the chance of death before spawning daily decreases with dangers passed, the proportionate value of an individual as steadily rises. But, because of growth, it will take more individuals to make up a

hundred pounds of fish early in the year or in the life of a generation, than it will late, with a corresponding decreased value of a hundred pounds as spawners (without considering mortality). The value to the species of the hundred pounds, therefore, tends to steadily decrease through the season. There is, then, because of the natural mortality, an *increase* in the value of—and the value of protection to—individual fish in their spawning year or during their life; this counterbalanced to an unknown extent by a *decrease* in the value to the species of a given weight of fish because of the normal growth of the individual, the spawning unit. The normal increase in weight during the third year is in some species, as the Pacific herring, over sixty-five per cent of its weight at the end of the second year, and it would seem doubtful whether the natural mortality balances this. If not, it would surely be best to center the strain on the older fish, providing an equal weight would be taken in any case. But without evidence to the contrary, is it not best to assume that equal toll should be taken of old and young? It is obviously impossible to provide an answer to such questions with our present knowledge.

We have supposed, however, that the mortality and the growth in a species are distributed in a regular fashion throughout the life and the year, but as a matter of fact this is probably true of no species. In almost all forms there must be certain times of the year or certain growth stages at which the mortality is very great and during which the value to the species of the individual increases suddenly without a proportionate increase in value as food. But at other times the mortality must be lower and the value to the species does not increase while the weight of the individual and the value to the fisherman does. It should be obvious that these changes might give a clue to the best time for taking toll of the species. Thus the catch should be greatest at those times just preceding a period of high mortality before the value of the individual to the species has risen, and at the end of times of low. It should be greatest, other things being equal, at the end of a period of rapid growth, when the value to the fisherman is greatest. These things follow from the facts that the fewer the number of individuals the greater the relative importance of each to the species, and that considerable reductions in numbers must take place at times.

In connection with this, it may be noted that a species which normally lives to an age of fifteen years, for example, must have a considerably lower annual mortality than does one living but three years, with a correspondingly less abrupt increase in its value per individual after survival of each crisis. But naturally until we have sufficient knowledge upon which to base judgment any such conclusion must be subject to question.

There are, certainly, but few species regarding which we have such detailed knowledge as to enable us to form competent conclusions regarding these matters. The salmon, in their passage up the rivers, may have a period of high mortality before spawning, and if so, concentration of the catch just before their entry into the river is doubtless fortunate. The marine species may undergo their greatest growth during the summer months, inclining one to believe that the late summer months are the best within which to concentrate the fishery—providing the mortality does not also increase in proportion to the growth.

But aside from such instances as these, doubtful as they sometimes are, we are certainly at a loss for those facts which will logically guide us in the protection of fishes by closed seasons.

At the same time, there are certain contingencies in which it would seem that our action may be clearly indicated. Thus it is well known that in certain cases, such as those of the sturgeon and the halibut, excessive fishing has depleted all classes beyond the limit of safety, and that protection for the young must be of the greatest importance simply because there must be young to produce adults at all. Again, it might be asked whether fishing during the spawning season is destructive of eggs which have been deposited, or whether the spawning schools may be broken up in such a way as to prevent spawning—if the chances of such damage were not so remote in the majority of deep sea species, which lay freely floating eggs, fertilized after extrusion, and if it were not so probable that fish are so indifferent to death and destruction that they are not easily or profoundly affected by what man may do.

It is therefore evident that very difficult questions must be answered to prove that in a given species spawning fish are of greater value than those which are not, or that additional value has been suddenly acquired at the commencement of the spawning seasons. It is certain that in a great many of our species the greatest mortality is not necessarily just before nor during the spawning season, and it is extremely probable that in some species at least the value to the species of a certain weight of fish is actually less the nearer the spawning season approaches.

Knowledge Necessary for Rational Protective Measures.

It must be seriously queried, then, whether, in a given species, the protection of fish in the spawning season rather than two months previous to spawning is of appreciable value, and whether the time of protection is not the subject of other considerations; namely, the very unequal distribution throughout the seasons and the years of life of the dangers to the species and of the relative rate of growth. It would seem that there are a number of subjects to be investigated: Is a certain weight of immature fish of a greater ultimate value to the species than a similar weight of mature? Is there any season of the year in which the most valuable class is especially exposed to the fishery? If the mature congregate to spawn, are they not less valuable than the immature, pound for pound, and hence fittingly subject to exploitation? Are the inroads on immature or any other class so great, on the part of the fishery, as to preclude the maintenance of a sufficient number of mature spawning fish? Is there any period of great mortality during the year which would greatly increase the value of the survivors, and justify the concentration of the fishery previous to the period of excessive mortality? The difficulty of reaching accurate results in such cases is plain, but there may be at least an indication of the probabilities in most instances which would suffice to guide action more intelligently than is often the case.

In case such results are not obtainable, there are frequently grounds for action which would at least be in the right direction. It might be asked, in the case of a depleted fishery, why protection should not be applied to those classes which are most affected by the fishery; and if grounds for the protection of any particular season or size are not visible, certainly protection applied to any class, at any season, would

be advisable—providing it did not shift the strain of the fishery rather than eliminate a portion.

We may content ourselves with these suggestions as to the possibilities, with the conclusion that they indicate unmistakably the necessity for much greater knowledge than is usually available regarding the life histories. The assertion that fish should be protected during their spawning seasons, however, is obviously in need of proof when it is made; and unfortunately it is usually the first reason advanced for the protection of the fish. It is one which is made without the careful study of the biology of the species concerned, and without the adequate statistical knowledge of the real intensity of the fishery at different times, or of its relative pressure on different classes, which is necessary to a competent discussion of the question.

It is very apparent that without a statistical knowledge of the fishery, and a biological study of the habits of the fish concerned and of its life history, we are not in reality equipped to discuss measures designed to avert depletion.

Second Section.

Fluctuations in supply other than the results of overfishing.

Next in importance to a study of the fisheries for signs of overfishing is that of the fluctuations which occur from other causes. It is of course necessary to know that the effects of overfishing are not confused with natural changes in the fishery; and, in fact, an adequate study of the condition of the fisheries implies a study of the fluctuations. The fact of overfishing can be relied upon to show itself by the persistent and gradual appearance of a scarcity of fish; but the more it is possible to eliminate changes due to other factors, the sooner is it possible to conclude on such grounds that a given tendency is or is not due to depletion. Hardly secondary to this phase of the study is the possibility of distinguishing, foreseeing, or preventing variations in abundance, quality, and classes of fish in the catch, thereby tending to make the fishing industries more stable and the supply constant, as well as more economically conducted. It is, therefore, of the greatest importance that fluctuations be analyzed, and thoroughly understood.

Necessity for Demonstration and Study of Fluctuations.

It is necessary in the first place to show that there are major or minor fluctuations in abundance. There are no great fisheries known which do not have variations in the abundance of the fish concerned, but it is a serious question in the case of each species as to whether there are well-developed great, or major, fluctuations. In such species as the herring, sardine, and cod, as studied in Norway, there are undoubtedly great fluctuations covering many years; but in others, such as the lemon sole and the plaice, such have not been observed to be as striking and well marked. We have still to study our species of the Pacific in order to discover the existence of anything comparable in the way of such fluctuations.

Such great changes have been attributed provisionally to the variations in the Atlantic current which enters the North Sea (Helland-Hansen and Nansen, 1909). But even were there no prominent hydrographic phenomena on this coast to which such changes could be assigned, it would still be possible that there were such variations in abundance, both of total and of separate classes of fish; and were there

phenomena which might explain their presence, it would still be necessary to demonstrate their existence. In other words, we are dealing with a new problem, with which nothing but actual observation can help us.

The salmon and the halibut are the only two species for which great fisheries exist and for which we have statistics lending themselves to investigation, and in neither of these cases are we able to judge concerning the present problem save in a limited degree. The salmon is a highly localized anadromous species, for which artificial propagation is carried on very extensively, and its fresh water life is perhaps more critical than its marine. It is therefore not comparable to purely marine species. The halibut has undergone too rapid a shifting of the fishing grounds to allow of comparison, from the standpoint of fluctuations other than depletion, of the limited data extant. The accurate analysis of the yearly abundance of fish therefore requires much better statistics than have been supplied for any marine forms on this coast thus far.

To illustrate and emphasize the importance of such a study of fluctuations other than depletion, the different types supposedly to be met with are here briefly considered. No pretense is made at completeness in treatment or enumeration, it being desired simply to indicate the importance of such features of the fishery.

Perhaps one of the most important causes of changes in the catch is the change in economic conditions. The improvement of the gear and the vessels, the increase or decrease in their number, transportation conditions, the extension of the grounds or of the season, the changes in classes of fish utilized, and the varying market are factors in altering the total catch whose influence is acknowledged to be overwhelming. It does not need to be emphasized again that the elimination of their effects in so far as possible is the first requisite in any study of the abundance of the fish. Not only do they affect the catch from year to year, but even within the year there may be changes in the demand for fish, in the price obtained, and the cost of materials which will modify the manner and amount of fishing, the length of the season, etc. Until such features are known and discounted, or methods used which eliminate their effects in the data, our knowledge of what is happening is defective.

Granted that a comparable unit of catching power is obtained which does eliminate such economic factors, and gives a real indication of the abundance of the fish as the fisherman sees them, we have several types of fluctuations which interest us. The irregularity in the annual yields from year to year, the minor irregularities within the fishing season, and the regularly occurring seasonal variations in abundance, will serve as heads under which to discuss them.

Irregular Annual Yields.

It is, very probably, the unexpected variations in annual yield which are most important, because of the more permanent effects on the fishery and associated industries, and the greater effect on the supply to the public. They are also more apt to be confused with the decline due to overfishing.

The effects of epidemics or disasters would be considered, ordinarily, easily differentiated from depletion. There comes to mind the near elimination of the tilefish, and the epidemic of sporozoans in the herring of the Gulf of St. Lawrence during 1914. It is of course impossible

to say how often such occurrences cause serious trouble, but the recorded cases are relatively few. Where of any magnitude, their effects must be sudden, and distinctly shown in the fishery statistics, whereas depletion manifests itself gradually and over a period of years. It would seem that any widespread mortality would be detected by observation, as was the case with the epidemic of sporozoans mentioned above.

Hydrographic or meteorological changes would not, so far as experience has gone, directly affect the abundance of fish available for the fisheries, save in so far as they modify the habits of migration and the accessibility of the schools. This is a matter worthy of separate study, indeed, and seems to have been manifested in many local variations in catch where marked hydrographic changes have occurred. Thus the extent of the water of low salinity along the Norwegian coast—due to the rains of the previous year—and the great submarine "waves" of high density water which periodically enter the fjords, affect the catch of herring greatly. Such cases are entirely similar in nature to the prevalence of adverse temperature or weather conditions and the consequent inaccessibility of the schools of albacore. The recognition and elimination of such direct effects is certainly of importance if for no other reason than the correction of the measurement of actual abundance of fish. But the immediate results of such changes can not be said to be lasting in nature any more than the hydrographic changes which caused them, and are characteristically more local in extent in so far as changes in physical conditions which have a radical effect, are local.

Perhaps the greatest effect of such changes has been shown in the curtailment or enlargement of the number of young which complete their first year, probably through favorable conditions or the injury done to larvæ or eggs. Thus Hjort (1913) shows the effect of the very successful spawning season of 1904 on the Norwegian herring fisheries throughout a period of ten years. The fish born in that year predominated in the catch of every year from 1907 to 1914, the last mentioned year having 54.3 per cent of its fish of that class. The importance of this phenomenon in forecasting the yield in quantity and quality should be manifest, providing Hjort's results are corroborated, and are shown to apply to other districts as well as to the Norwegian coast. He also attempted to show that this predominance of certain year classes was characteristic of the cod, the haddock, and the salmon. It is still a question whether such phenomena are to be expected in the Pacific—or other districts of the Atlantic for that matter.

The case of the run of sockeye salmon in the Frazer River is in all probability the best known instance of well-defined year classes on the Pacific coast, and the dominating characteristic of that species is (or was) certainly the permanence of the "big year" run, occurring every fourth year in regular rotation, a striking illustration of the fact that the chief factor has been the numbers of spawners on the beds, not the success or failure of their spawning, or survival during immature years in the ocean. It is nevertheless true that there may be, in this case, distinct variations in the relative success of the spawning on the beds which are too small to be appreciated when compared with the four year cycle.

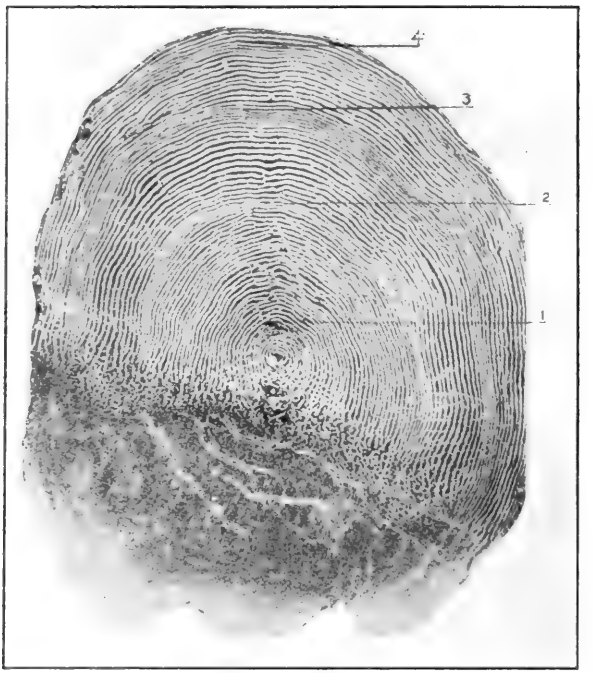

Fig. 3. Scale of a female Frazer River sockeye salmon, Bellingham, Wash., June 18, 1917, 23 inches long and in its fifth year. The scale shows approximated circuli marking the winter growth, the end of which is indicated by a line in each case. (After Gilbert, Rpt. B. C. Comm. of Fisheries, 1917.)

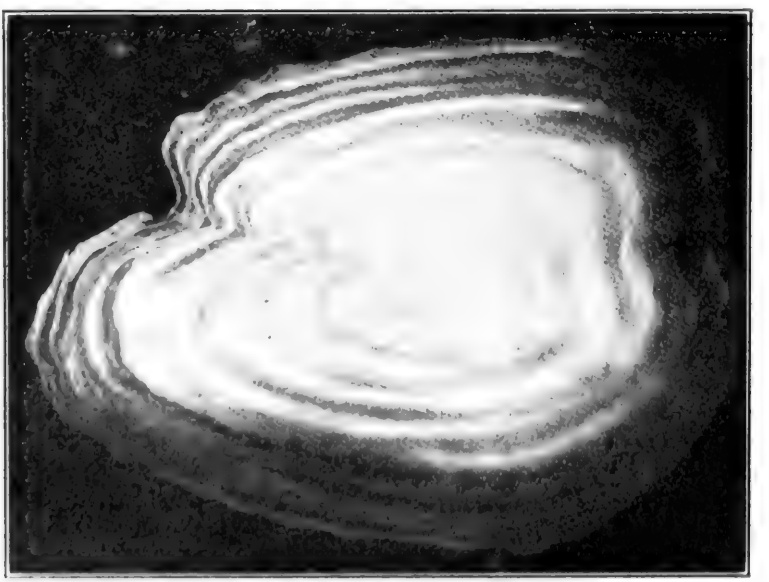

Fig. 4. Otolith, or ear bone, of halibut, in tenth year, showing dark "winter" zones and light "summer" zones. (After Thompson, Seventh Ann. Rpt. Commission of Conservation, Canada.)

Regarding the fluctuations of the type shown by Hjort in the herring, there is one thing which should be pointed out: namely, that an increase due to the success of a year's spawning should show itself in a great proportionate increase of the younger fishes, coincident with an increase in the abundance of the species. A predominance of mature should subsequently be evident if average or poorer seasons followed. In fact, the state of affairs is reversed to what would be evident in the case of depletion, where a predominance of immature is coincident with a decrease in abundance. There should, theoretically at least, be no difficulty in distinguishing the two features of the fisheries. It is hardly conceivable that the decline in the abundance of plaice in the North Sea, coincident with an increase in the proportion of young, can be anything but the effect of overfishing, just as the same sequence characterized the overfishing of the halibut in the North Pacific.

It is important to note that we do not have, at the present time, sufficient knowledge of any Pacific species to say, for instance, that a definite result will follow a certain hydrographic phenomenon. But if Hjort's results hold true in other species, the spawning and the growth of the larvæ must be affected to a greater extent than the growth of the young and mature, and the fluctuations due to changes in their abundance become of predominating importance. It follows from this that a knowledge of rate of growth is necessary before hydrographic results may be linked with the fisheries. This is because there must elapse a certain time between the first year, which is that of birth, and the attainment of a size sufficient for commercial use, when mankind finds it possible for the first time to judge of their abundance by the success of the commercial catch. It being as yet impossible to assign definite results to certain hydrographic or meteorological phenomena, the most that can be done to prophesy the coming fluctuation in catch, or probability of fluctuation, is to observe the abundance of the various year classes in the catch, and become aware of changed proportions of young and old as soon as possible. This is in accordance with the work of Hjort on the herring. It implies, of course, research on the rate of growth, and adequate statistics of the fishery.

The investigation of the effects of changes in the physical environment of the species is that portion of fishery science which is perhaps the most complex, and in which, at least as concerns the indirect effects on the abundance mentioned in the preceding paragraph, extensive research is most needed. This would be obvious from the fact that accurate knowledge of the life history is required before changes in such conditions may be assigned definite consequences. The fact that most of the economically important species lay pelagic eggs (floating free in the water) immediately opens the great question of the influence of varying currents on the drift and ultimate destination of the young, that of the influence of altering temperature on the rate of development and time consumed during the pelagic life, and the necessary migrations of the mature fish. An instance which is unusually clear, if well founded, is seen in the influence of predominating off-shore winds in driving the pelagic eggs away from the coast of eastern Australia, to the detriment of the inshore fisheries a certain number of years subsequently. (Dannevig, 1907.) Certainly, the path to an exact knowledge of the fluctuations in abundance of a species of fish lies over a perfect knowledge of

the life history, as subsequently linked to an adequate knowledge of hydrographic or meteorological changes. It is undoubtedly a long and hard path, and requires a devotion to the more abstract and less immediately practical side of the subject which is worth the while of anyone with the ultimate good of the fisheries at heart.

Minor Fluctuations Within the Season.

There are, as has been mentioned, fluctuations of supply within the season, which it is desirable to eliminate or forecast, in order that the fishery may be carried on efficiently and economically. Here again, it is most obvious that an adequate method of following the trend and fluctuations in apparent abundance is imperative, and proves the necessity of a close detailed examination of fishery statistics and records. Such changes are more characteristic of some species and some fisheries than others, and the existence of these minor fluctuations should be proved. They, it is hoped, will help to explain the causes of the greater fluctuations in the fisheries, on the grounds that the parts of each year must be affected to a greater or less extent by the irregular strength of the factor concerned. There are so many possible causes of these minor fluctuations that it is futile to consider them in detail—either climatic, economic, or biological. It can be said simply that the study of them may not be merely of general importance, but may indicate directions in which the fisheries might be improved, as by the elimination of scarcity due to weather conditions and inferior boats. Although it is true that few governments have made any progress along this line, it may well be worthy of attention. From the standpoint of fishery research in general, the elimination of these irregularities from data used to study the abundance of fish becomes of importance, because of the necessity for accuracy in the measure of abundance of the various species.

Seasonal Fluctuations in Yield.

In considering seasonal and entirely regular changes due to scarcity during the winter, migration, or variation in the classes of fish caught, there is entered a field of vital interest to the fisheries in general. The proper knowledge of such changes is necessary to the use of statistics of the catch to indicate abundance from year to year, and data must be used which are taken during the same season, and in the same locality, from year to year. The variation in classes of fish caught is of the greatest importance to an understanding of the restrictive measures necessary, and to the use of those criteria of depletion which depend on the varying proportion of mature present. The possibility of error in this regard may be illustrated by the great change which takes place in the halibut fishery in regard to the average size of the fish caught, the winter fish being at their maximum sometimes an average thrice that of the fish caught during the summer month with the smallest average.

The possibility of introducing proper methods of fishing during off seasons, or the shifting of the location of the fishery to follow migratory fish, may be of great importance in furthering the ideal condition of a constant and steady supply of the best quality fish. Thus for a long time the sardine fishery at Monterey was irregular, seemingly because of the habits of the fish; but improved methods of fishing demonstrated their presence and the possibility of taking them throughout the year, giving a steady supply to the canneries. So, also, the

mackerel on the coast of France was a summer fish, caught on the surface, whereas it is now caught on the bottom in winter by means of trawls. Although these things were developed independently of government aid, yet there is no reason why an efficient system of experimental fishing and a study of fluctuations might not be of great importance. Research along these lines is proceeding in the case of the albacore in southern California by means of gear brought from Japan, and there is no reason why gear brought from foreign countries should not be applied to other fisheries.

The study of the seasonal fluctuations must ultimately be of the greatest importance to the theory of fishery science. It is a very common thing among scientific men, and fishermen as well, to make use of varying times of greatest abundance of fish in different regions to prove migration. Numerous attempts have been made in the North Sea, for instance, on the demersal fishes and the mackerel. It is at all events not at all certain but what investigation will show, through studies from different angles, that there are not, in many of these cases, such extensive winter migrations as are supposed, but rather a change in habit of the fishes themselves resulting from seasonal changes in surrounding conditions. Reasoning from the winter and summer abundance of small plaice has led several scientists to accept the hypothesis that the young plaice of the North Sea hibernate in winter, taking no bait, and not being active enough to be caught by the trawl. A similar conclusion has been reached concerning the mackerel, whereas previously an extensive migration was supposed for it. Also in the case of the halibut of the North Pacific, an explanation of the seasonal change in size would seem possible on this basis. There undoubtedly is, it must be admitted, a problem of great importance regarding the relative habits and activity of fishes during the various seasons. An accepted general law concerning these would profoundly modify all reasoning as to migrations, the theory used to explain all disappearances at present. The effect of this upon current theories of fishery research and upon methods of regulation proposed would be very great indeed. It is, therefore, a subject of immediate practical importance and also one of more purely scientific significance.

In summarizing this section, we see that the study of fluctuations in supply other than those of depletion is of the greatest importance, that it is necessary to prove their presence or absence, and to distinguish them from the effects of overfishing. The different types must be studied, and those caused by economic factors must be isolated and discounted by the use of proper units for comparison. In the discussion of the various types we have seen that the effects of relative success in spawning, of hydrographic or meteorological changes need study in all their details, presenting as they do fascinating possibilities of prophesy. The causes of minor fluctuations, multifarious as they are, may give explanations of the greater annual ones, and an understanding of regular seasonal variations in yield may lead to improved methods of fishing and fundamental changes in the theory of fishery science. Throughout the whole section is seen the need for proper statistical and biological studies of the fisheries as well as of the fish themselves.

Third Section.

MEASURES TO AID THE USE OF THE FISHERIES.

Regarding measures which have been taken by governments for the aid and furtherance of the fisheries, it can be said that they have depended upon the nature of the fishery and of the species considered. The subject is too great a one for treatment here. It would appear that there is no beneficial activity of society which governments should not encourage and aid, so that in reality every phase of the fishing industry which can be improved should receive attention. The discovery and adoption of methods of breeding fish, of increasing the percentage reaching maturity, the extension of the known fishing areas, and the encouragement of the use of unexploited marine products, are both of value as direct aids to the fisheries, and of use in preventing or remedying overfishing of any species. The improvement of methods of preparing canned and salted products, and the use of improved gear in fishing and marketing, have received considerable attention at the hands of governments. The greatly increased use of fishery products has rendered it feasible to introduce new products, and has directed attention toward the necessity of proper methods, new and well known alike, in those new and expanding fields which lack standardized products. Less attention has, perhaps, been paid to the practical assistance required by fishermen in the way of improved boats, gear, and methods, than should be the case. The establishment of fishery schools by the federal government should be a step toward this end, for instance. But, however insistent these things are because of their direct economic importance, it should be borne in mind that they are not vital to the fisheries and their associated industries, but rather incidental to them. They have not the indispensable character which the observation of the condition of the fisheries has, and however much attention is given economic phases, those dealt with in the first two sections of this paper should not be neglected, especially by the state.

In thus briefly treating this division, it is not intended to question its importance, nor advocate its neglect by the state. It is beyond the scope of the present paper, and a part of the great subject of governmental control or aid of economic conditions, rather than of the conservation of resources.

CONCLUSION.

It is distinctly to be seen that the basis for any study of the fishery and its variations must be primarily some accurate means of following the actual changes in abundance of the fish. It is true that much of the life history and the hydrographic surveys as well, may be dealt with independently of the commercial fisheries, but the application of results from these studies presupposes an accurate knowledge of the abundance of fish. There is no means of studying this which is comparable to the study of the actual commercial operations, because of the wide scope in time and area covered by the latter. It is in fact the investigation of the commercial fisheries which is under discussion, their condition being the cause of our interest in the life history and the physical surroundings of the species, and it should be obvious that an accurate means of observing the fisheries is the most indispensable thing. That accurate means must be a statistical record, the lack of

which will nullify biological or hydrographical results; and by this we do not mean the ordinary statistical summaries, but the *obtaining of, and competent analysis of, records of relative abundance of fish.*

It is also true that knowledge of the biology of the species is absolutely necessary. In fact, it must guide the collection of statistical facts, corroborate them, suggest remedial measures for overfishing, and explain the fluctuations present in the fisheries. *A biological study of the species concerned is, therefore, inseparable from the statistical studies,* and must be concentrated on those features of the fisheries which bear an immediate relationship to the questions at issue in the preservation of the fisheries.

It seems obvious that the program of investigation is a large one, becoming merged with questions of a more abstract nature which bear on the ultimate principles of fishery science.

The state must feel itself responsible for the immediate care of the fisheries, and this implies primarily the direct observation of the condition of the fisheries. It can not afford to neglect this, nor to give over to institutions subject to vacillating policy, what is plainly committed to its care. At the same time, it is plain that there are no boundaries between the immediate interests and the science of the subject, that competence in the one implies ultimately competence in the other, and that the perfection of the one is bound up in the perfection of the other. Foresight, therefore, should seek avoidance of the mechanical functioning of a statistical staff, and should require that the work be done in the light of the most complete possible knowledge of the subject.

This conception is at the basis of the work on the albacore in southern California. Plans are in progress for the keeping of adequate records for the fisheries of the entire state. It is hoped that this attention to the phase of the problem with which the state is directly concerned, and, indeed, over which it has legal jurisdiction, will meet with the support of every one interested.

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