

What is Over-fishing?*

By

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(With one Diagram.)

FOR the sake of argument I will suppose :

I. That in a biologically self-contained area, *e.g.* in the North Sea, statistics show that the value of the total yearly catch of a certain species of fish is decreasing year by year ;

II. That the catching power and the prices are not reduced ;

III. That the physical conditions have not changed in an unfavourable manner.

The decrease must then be ascribed to organic factors, either to man or to other organisms.

If the decrease must be ascribed to man solely, or in some degree, over-fishing has taken place.

It will be understood that over-fishing cannot easily be proved with regard to many species of fishes, *e.g.* for true migratory fishes. For example, in the case of the herring and the cod statistics have always shown great fluctuations. For this reason it is necessary that statistics in the case of such fishes should extend over a very long time to prove any decrease beyond the ordinary fluctuations. In dealing with other fishes, *e.g.* the plaice, the statistics do not fluctuate so much because the plaice is not so migratory. However, if we had statistics alone to depend upon, the problem concerning the influence of man would never be solved. Any decrease might always be ascribed to some or other imagined reasons. Fortunately we can get more than statistical data to rely upon.

It is not my intention here to discuss all problems about over-fishing, this being impossible. I only wish to give an example in

* This analysis of the problems of over-fishing was prepared to meet a desire expressed by several members of the International Committee on Over-fishing during the last meeting of the International Council at Copenhagen.—W. G.

order to throw light upon some of the principal ideas concerning this matter.

Accordingly I take the case of an imaginary fish, species "P," which exhibits the following features :—

1. It does not migrate out of the North Sea.
2. It takes three years to grow up to maturity (see Diagram).
3. It is nearly in every respect closely allied to the plaice.

The stock of this fish "P" has, during recent years, been reduced in the Kattegat and in the North Sea to such an extent that statistics prove that the weight of "P" annually caught is not at present so great as formerly, in spite of the catching power being highly augmented. Had not the prices per kilo increased during the same period, nearly all "P" fishing would have been stopped, at least in the Kattegat.

Now somebody may say, "Well, you have had to do with a stock of 'P' accumulated during many years. The III Group (Diagram, IIIa) was accumulated and included all 'P' of three years and above, possibly up to twenty years, the maximum possible age of a 'P.' In the very beginning you were catching these old III individuals, but this cannot be done every year, since a larger stock will grow up in twenty years than in one. This fact is the explanation of your decreasing statistics."

This *status quo* may occur in Norwegian fjords, where the areas in which the I or II Groups live are very limited, and where the number of individuals in these groups is consequently small compared with those in the III Group. The individuals of the I and II Groups are very fond of shallow, sandy beaches, but those of the III Group live in much deeper water. Fishery investigations in such fjords have proved that the III Group is really much easier to catch in numbers than are the I and II Groups, and that the average size of the individuals of the III Group is thirteen to fourteen inches (Diagram, IIIa). This example of an annually decreasing catch is not strictly an example of over-fishing, at any rate it is only an exceptional kind of over-fishing, which is inevitable, and to some degree desirable.

An explanation of this kind, however, cannot be used to account for what has happened in the North Sea and in the Kattegat during recent years, since the fishery of "P" in this area is no longer based upon the III Group, but upon the II Group. If we consider numbers instead of weight, the greater part of the total annual catch is now, and has been for many years, made up of individuals of the II Group with comparatively few of the III Group. The average size of the III "P" has, moreover, during the same time gone down from thirteen or

fourteen to ten inches (Diagram, IIIb), and statistics show a decreasing value year by year in the North Sea taken as a whole, the North Sea being a biologically well-defined area for the "P." *

This being the fact, what can be the reason or the reasons for the declining statistics and for the reduced average size of the "P" in this area? The catching power has been much enlarged, the prices have risen, and the physical conditions have not undergone any unfavourable change; so the decrease in value of the total yearly catch must be ascribed to organic factors, *i.e.* to man or to other organisms.

Has the bottom been injured by trawling in such a way that the food of the "P" has been destroyed?

This view was held in former times, but has never been proved or set forth in such a way as to make it probable. If the "P's" food was destroyed, we might suppose that the "P" in consequence would look very lean, or not be able to grow, as the case is in the Baltic. Marking experiments, nevertheless, prove that the "P" grows fast when not too abundant in a narrow space. Overcrowding may perhaps be found on certain grounds, this being actually the case in the Western Lim Fjord; but in other parts of the Lim Fjord the "P" grows very fast where it is scarce. Experiments of mine specially directed to this point have shown that the small invertebrates are still as numerous per square foot in the western part as in many other places in the Lim Fjord. Speaking generally, we cannot consider that food is wanting in the North Sea, at any rate not to a greater extent than formerly; but in the present state of our knowledge is it possible to suppose that other invertebrates, *e.g.* the star-fish *Asterias rubens*, eat the small bivalves which are the best "P" food, and that *Asterias* is more numerous at the present time because the large "P" individuals have disappeared from many fishing grounds? Investigations on the actual rate of growth of the "P" in such localities may solve this problem—at any rate, they may prove how fast that "P" is growing, which is the

* I am extremely familiar with this kind of fishing upon the II Group, since the plaice lives in the Lim Fjord, but does not propagate there, perhaps because all plaice are fished out there every autumn when they have grown some few inches during the spring and the summer. The young ones immigrate in numbers every year from the North Sea. In the Lim Fjord we have no true stock at all. What must, then, be thought of the Lim Fjord fishery? Is it "destruction of immature fish," since all are fished out before they reach maturity, and almost entirely fished out every year? The Lim Fjord, however, is not a biologically self-contained area for the plaice, and this question accordingly forms only a part of the whole over-fishing problem. The fjord gets its young plaice from the North Sea every spring, and we in Denmark have only the two things to do: (1) To help into the fjord as many as there is room for, and this is limited, and (2) to leave them in peace during the summer to grow up to a saleable size, like carps in a carp pond. As we get our young plaice every spring for nothing, or almost for nothing, and as they reach a good size for sale during the six to eight months, they ought to be fished out every autumn and winter.

essential point in the matter. I do not think it necessary further to discuss it here.

When the "P" grows fast, we might take predatory animals into consideration as a cause of the reduction in the average size of the "P." It will then have to be investigated which predatory animals attack the big "P" more severely than smaller ones. I think it is not very probable that such animals exist. At all events, I do not know of such animals, and have never heard of any.

Other organic factors (diseases) may, perhaps, be mentioned as capable of reducing the average size of the "P." We do not, however, know anything about this; but from our investigations (1) we know the quick rate of growth of the marked "P," and (2) we see that their mortality, except by fishing, is not great in the North Sea. And this is sufficient.

The first immediate influence of fishing is beyond doubt the reduction in number of the "P."* The second influence of fishing is that it prevents the "P" from being as old, and therefore as big, as in places where no fishing is going on. It is in this latter fact, I think, that we have to look for the reduction of the average size of the "P" in the North Sea and in the Kattegat. When admitted that we have not to do with an accumulated stock of "P" in the North Sea, but only with a stock of the II, and a small part of the III Group of "P" highly reduced by fishing and growing up again every year nearly, but not quite, to the same point as the year before, it will be understood that the average size has been slowly reduced year by year. Somebody might already regard this reduction of the average size as over-fishing, yet it is not absolutely so. We suppose that the mature fish, Group III, have been greatly reduced in numbers, but are still capable of yielding sufficient eggs to keep the stock up to date. According to the custom of nature, it is probable that in former times eggs and young fishes were produced in overcrowding multitudes, and that a very high percentage consequently died out. The mature "P" may undoubtedly become so scarce that they cannot supply the stock sufficiently with eggs. If this be so, we have to do with one kind of over-fishing of the mature "P" which reduces the number of "P." I do not, however, suppose this to be the case, but rather that there is a sufficient supply

* It is possible to imagine that reduction of the III Group by fishing may afterwards allow the II Group to spread over a larger area, and consequently procure more favourable conditions for the individuals of this group: (1) they will grow quicker, and (2) the mortality will perhaps be reduced, and the total number of all "P" will thereby in a twelvemonth be larger than before the fishing was carried out. This would be a peculiar result of over-fishing. Whether it really is over-fishing depends upon two things: (1) the amount of reduction of the average size, and the price of the fish at this reduced size; (2) the extent of the increase of the numbers and rate of growth of the II Group. Statistics must solve this problem.

of eggs, and that it is only Group III which has been reduced in average size, and is less numerous than before.

Then there is the possibility that the two other groups, I and II, are growing faster now than before because they have more room, and each of them consequently more food. Group II still consists of saleable fish, and they grow up a year quicker than Group III; not so many of them die or are eaten by animals, because they are only two years old. For these reasons it is very likely that it would pay better to base the fishery for the greater part on this group and not on the III Group.

This problem depends upon the value of the fish in Group II compared with that of the fish in Group III, and upon the mortality in the third year. If we only knew the rate of growth, the mortality during this year, and the price of the fish, the question might be exactly solved by mathematics. In the third year we know that the "P" increases its value four times by growing. If the mortality is as high as one-half during this year, which is not probable, it would pay to prevent all fishing for the II Group. Failure to prevent all fishing for this group would then involve the "destruction of under-sized fish." A size limit for the fish would, under these circumstances, be desirable. Studies on the rate of growth, and of predatory animals feeding on the "P," would greatly add to our knowledge on this point.

So far I have dealt with the following three cases:—

- I. Over-fishing of an accumulated stock.
- II. Over-fishing of the mature fish to so great an extent that they cannot render a sufficient number of eggs to supply the stock with young fishes.
- III. Reduction of the average size of the fish to such an extent that they are not sufficiently saleable. This case we may name the "relative destruction of immature fish."

It is, nevertheless, possible to imagine another kind of over-fishing, viz.:—

IV. The Group I of the "P" is living in certain very restricted areas close to the shore where shrimp-trawling is going on. It is possible that shrimp-trawling can destroy too many young ones. This I Group has no value in the market at all, and if such individuals are killed by fishing for shrimps or by other methods, it may, in the true sense of the word, be called "destruction of immature fish."

It is again possible, *e.g.* in the Kattegat, that the stock of "P" is reduced a good deal by fishing, while other allied species, *e.g.* the dab (*Pleuronectes limanda*), are less affected. If this be the case, the last-

named fish may then increase its stock and take its food in areas where the "P" was formerly the dominant fish. This only means that the equilibrium of nature has been disturbed by man. We may in many cases expect other organisms to augment the disturbance by retarding the rate of growth of the "P" and by augmenting its mortality, but this has nothing immediately to do with over-fishing.

How is it possible to recognise in nature which of the four kinds of over-fishing we have to deal with in a particular case?

We suppose the "P" to be the most important fish in the North Sea, and the fishing on the whole to be based upon it. We know that the value of the total catch is going down year by year, and that the prices per kilo of the various sizes have been constant or perhaps rising. We know still further that the average size of "P" in the market has gone down. We know the "P" of Group I to be living close to the shore in shallow water, while Group II is living at greater depths, and Group III in the greatest depths of the North Sea. We, furthermore, are acquainted with the facts that no accumulated stock of "P" exists here, that the weight of a II Group "P" on an average is one-quarter kilo, and the price of each fish ten öre (three halfpence), while the "P" of the relatively scarce III Group has a weight of one-half kilo, and the price of it is forty öre (sixpence).

Perhaps we shall never be able to prove in a purely scientific and statistical manner, without experiments by preventive laws, which kind of over-fishing, as set forth in II, III, and IV, actually has damaged the stock of the "P" most seriously in the North Sea—whether over-fishing of the mature III "P," relative destruction of the immature II "P," or the destruction of the I Group. However, we cannot ignore the fact that over-fishing is taking place, and that we must do something if the fisherman is not to starve and the North Sea become a barren "P" fishing ground. What must be done? We must do something that at the same time will help us in all the three kinds of over-fishing. The remedy may be a suitable size limit for saleable "P." If the size limit be sufficiently high, it will, in the markets as well as in the sea, augment the average length of the "P," and, therefore, the number of eggs. It must be high enough to prevent saleable fish of too small a size being admitted to the market. It must further be provided that shrimp-trawling does not destroy too many young "P," as we have perhaps here an essential factor in the problem of over-fishing. In applying this method, all three kinds of over-fishing will be dealt with at the same time.

How to legislate here I do not wish to discuss, nor shall I propose any particular size limit, since the most economical size limit can only be shown by investigations all over the North Sea.

A suitable size limit will be able, in some cases, (1) to augment the average size of the II and especially of the III Groups; (2) to increase the numbers of the III Group, and thereby the number of eggs.

A low size limit may be without any effect at all, while a too high limit may cause an excessive number of "P" to die out or to be eaten before they are fished. I imagine the best size limit will be found in the neighbourhood of the upper part of the II Group, or perhaps in the lowest part of the III Group, since the "P" at this point is growing fast, and increases its value four to five times in one year's growth, and since the "P" at this size obtains the highest price per kilo which on the whole is paid for this species of fish at any size.

The North Sea is, with regard to the "P," a well-limited area from a biological point of view, but this is not so from all fishermen's points of view. The interests of the shore-fishing vessels are not the same as of the sea-going; and over-fishing is, perhaps, not carried out in all parts of the North Sea, but only in this area taken as a whole. I feel inclined to think that the decrease of the total yearly catch of "P" is essentially due to reduction of the III Group, and, consequently, that the process of over-fishing takes place in the areas inhabited by the fishes of this group, viz. in the open sea. If the shore-fishing vessels do not affect the yield of the large open areas in the North Sea by killing the young "P" on the shore, they should still be left in peace; but if they are now interfering with greater interests, it may be necessary that they, at least to some degree, should give way to the interests of the commonwealth.

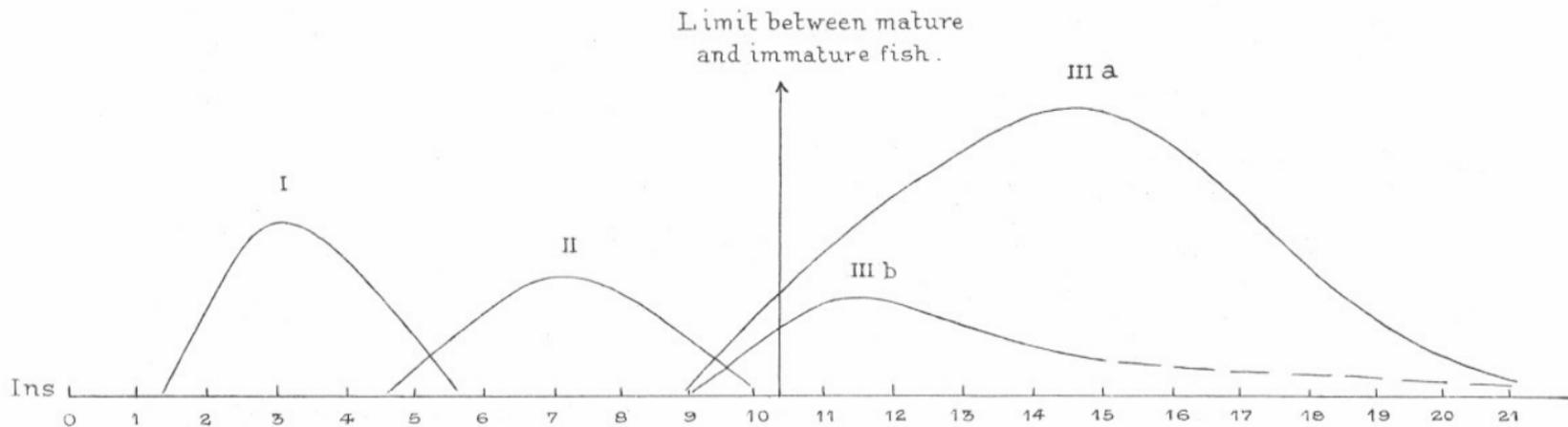
It has been proposed by means of artificial hatching, and by artificial fertilisation of eggs, to increase the stock of "P." At present we know, however, that this remedy can only meet one kind of over-fishing. It has also been suggested to fix a size limit simply from a biological point of view, viz. one which should allow fish to spawn once before being caught. This also does not deal with more than one part of the problem; but we have to consider all parts of the problem at the same time as far as we are able. Which of these parts is the most essential can only be ascertained through experience. Artificial hatching would, *e.g.* probably in the Lim Fjord, be of no consequence because the water is so dirty. I also consider all natural hatching here impossible for the "P." In this place a new stock of "P" can only be produced every year by immigration from the North Sea. We know, however, that this immigration does not reach all parts of the fjord to the extent that is desirable, so we help it artificially by transplanting. Such transplantation would, I think, also be useful in larger seas, *e.g.* in the North Sea. It would be a profit to the whole stock if multitudes of small "P" were taken from the overcrowded shallow grounds where

they are slowly growing, and transplanted to areas where the III "P" is fished out, and where there is, consequently, enough room and food,—just as young cabbages are planted out every spring. I, for my part, have much more belief in such work than in artificial hatching. By marking the transplanted "P," it is possible to get an idea about their growth, mortality, and augmented value, while we do not know what becomes of the newly-hatched young larval fishes when liberated in the sea.

It has been set forth in former years that "the question of immature fish" was itself an immature question. This charge may have been a just one. Possibly the question when first urged was an immature one; but in a few more years we may hope that the fishes, as well as the questions, will approach maturity more and more, *i.e.* if the fishes are not caught too soon and the questions not forgotten. It is my wish that the question, What is over-fishing? should not be forgotten, but discussed and investigated in every possible way.

Postscript.—To prevent misunderstanding, Dr. Petersen wishes to repeat here that the diagram is not intended to represent the stock of *plaice*, but the stock of a hypothetical species of fish approaching the *plaice* in habits and conditions of existence. A small number of "annual groups" has been purposely assigned to the hypothetical fish, in order to facilitate simplicity of treatment of the general problem.

Diagram representing the stock of "P" in the North Sea in spring.



- Group I. = the one-year-old "P," from c. 1-6 ins.
,, II. = the two-year-old "P," from c. 4-10 ins.
,, IIIa. = the original stock of all "P" three years old and upwards.
,, IIIb. = the reduced stock of the same (for the most part only three years old).