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PRODUCTION IN BODIES OF WATER

by

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F I S H E R I E S R E S E A R C H B O A R D

O F C A N A D A

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The subject of production is of particular interest to fishery biologists and it has seemed advisable to define certain terms and to outline some of the factors affecting production.

While the material presented applies to all bodies of water, reference is made only to lakes as a matter of convenience.

Production and Productivity

These two words are best used synonymously. They are so thoroughly confused in popular usage that an attempt to assign them different and exact meanings would be more or less useless.

I. TERMS AND THEIR DEFINITIONS

A. Gross Production and Net Production

The gross production of a lake is the total amount produced of organisms or organic materials per unit of time. More particularly, it is the increase in weight of all such materials during such time, up to the point where they change their form. Thus, if the gross production of fish during a year be under consideration, it includes all increase in weight of any fish living in the lake, at any time during the year, regardless of whether they survive to its end or not. Or again, if the lake's yearly gross production of protein be under consideration, it would be the total quantity of proteins of all kinds elaborated during the year, regardless of whether these were subsequently digested or oxidized during the same year; the same actual materials (phosphorous, carbon, etc.) might in fact appear several times in adding up the total of protein produced.

The net production of a lake per unit of time may be defined as the excess of elaboration over destruction (or more generally, of gain over loss) of specified organisms or organic materials during the time in question. In the examples above, it would be the difference between the total weight of living fish at the beginning and at the end of the year; or the difference between the total amount of protein at the same times. It is easy to see that the concept of net production

is much more susceptible to quantitative evaluation than is that of gross production. To estimate net production for a given period, it is necessary only to measure the standing crop at the beginning and the end of the period, and take the difference. It follows that net production so measured must often be negative, and in such case could be called net decrease, whereas gross production, as defined, can fall to zero but cannot ever be negative.

Net production is most useful when the time under consideration is short. For example, the net vernal production (increase) of phytoplankton can be measured, and may be a large quantity. There may be a net increase in a certain species of fish over a period of years, as recently with the yellow pickerel of lake Huron, or of sockeye in Cultus lake. But in general, as the time interval is increased, the net productions, both positive and negative, for both single species and groups of species or materials, tend to be stabilized at some small positive or negative value. This value will be governed only by the magnitude of current physiographic and climatic changes in the lake's physical nature and environment. Exception to this statement must be made, however, in the case of the introduction, whether by natural or artificial means, of new species into the lake.

It is important not to confuse the concept of net production with that of utilized production, to be described later. Fish, etc. destroyed by predators, including man, will affect the net production in so far as they affect the standing crop at the end of the period under discussion; but "net" production as here defined does not suggest utilization of the product, but rather its accumulation.

B. Total Production and Specific Production

Total productivity of a lake refers to its total production of organic matter of all kinds per unit of time. Total net production of organic materials,

considered over periods longer than a year, must usually be close to zero; must be, in fact, the slow accumulation of organic matter associated with changes in the "trophic" or food character of the lake, as in increasing entrophy or dystrophy.

The specific productivity of a lake is its production of certain specified kind of organisms or organic materials. Such materials may be chosen on any conceivable basis; e.g. chemical: carbohydrates, amino-acids etc.; or phylogenetic: plants, animals, bacteria, insects, fish etc.; or according to their situation in the lake: plankton, benthos etc.; or according to their usefulness to man: game fish, coarse fish, big fish etc.

C. Actual Production and Potential Production

Actual production refers to conditions as they are now. Potential production is a useful concept to indicate the probable effect of proposed changes, and shouldbe used in conjunction with a clause indicating the nature of such changes, e.g., "this lake has a potential production of 1000 lbs. of bass per year if the pike were to be destroyed"; or "lake Erie has a potential (utilized) productivity of 5 times as many classes as at present, were its fisheries to be properly regulated." A great variety of changes may be proposed or anticipated: adding new species of plants or animals, removing others already present, improving spawning beds for fish, warming the water by deforestation of the shores, changing the volume of flow, etc., etc. There is, however, an upper indefinite limit to permissible changes, as for example, if the lake were dammed to double its area, it would in effect be a new lake. Potential productivity, like the actual, may be thought of as gross or net, total or specific, but in practice the term is usually confined to the sense of specific utilizable production.

B. Utilized Production

1. Actual Utilized production may be defined as that part of a lake's organic products which is used by man.

2. Possible Utilized Production may be defined as that part of a lake's organic product which may be used by man without endangering future supplies (i.e. causing depletion). When the Actual Utilized Production exceeds the Possible Utilized Production depletion is taking place.

3. Potential Utilized Production may be defined as that part of a lake's organic product which might be used by man, without endangering future supplies, providing certain changes were made in the environment, whereby production is increased. Potential Utilized Production is a useful concept to indicate the probable effect of proposed changes, and should be used in conjunction with a clause indicating the nature of such changes, E. G., "This lake has a Potential Utilized Production of 1000 pounds of bass per year if the pike were to be destroyed.

Definitions in Brief

The actual organic production of a lake may be subsumed under the following heads:

	Total Production	Specific Production
Gross Production	Total elaboration of organic materials, plus organic stuffs from other sources.	All increases in weigh (or numbers) of a species; or total new additions to the stock of an organic substanc
Net Production	Excess (or defect) of organic income over loss; which is a	Increase or decrease in abundance of a

	Total Production	Specific Production
Net Production (cont'd)	measure of the change in a lake's trophic character, over long periods.	species, or in its total weight. Same for given classes of organic stuffs.
Utilized Production		The "catch" of a species of fish; the amount taken of any other utilized organic object.

II. METHODS OF DETERMINING THE PRODUCTION OF LAKES

1. Utilized Production

1. The Actual Utilized Production can be determined by keeping "catch" records. This is fairly easy in the case where a commercial fishery is prosecuted but is frequently difficult in the case of a sport fishery.

2. The Possible Utilized Production is difficult to determine accurately, however a study of it is essential to the intelligent regulation of a fishery. If the catch, or take, is constant for a period of time and evidence is at hand to indicate that depletion is not taking place then the Possible Utilized Production may be fairly close to the Actual Utilized Production. This does not necessarily follow for if the fishery is not intensively prosecuted the Actual Utilized Production may be considerably below the Possible Utilized Production. However a fishery which has much value is usually actively prosecuted and the population is either being depleted or is in danger of depletion. If depletion is just beginning to occur some information on the size of the Possible Utilized Production may be ascertained from the data. If depletion has taken place it is obvious that the Actual Utilized Production has exceeded the Possible Utilized Production and conservation measures must be inaugurated to save the resource. To determine the Possible Utilized Production the catch and the standing crop, or population, at fairly short

intervals of time must be known. The standing crop has been determined sometimes by (1) poisoning and then collecting all dead fish or by (2) draining the lake and then collecting the fish. Either of these methods have the disadvantage of bringing to an end the prevailing relationships and can only be used in small lakes in any event. The standing crop can in some cases (plankton) be determined by quantitative sampling. However, this method is not very satisfactory for most species due to the difficulty of obtaining representative samples. The determination of the standing crop has been attempted by marking a number of a species, releasing them, later recapturing them and from the data on number marked and percentage occurrence of marked individuals in the catches, the number of individuals in the population can be calculated. While theoretically the method is valuable difficulty is usually experienced due to differential mortality of marked and unmarked fish, loss of tags if the fish are marked by tagging, and difficulty of collecting representative samples of the population. A relative measure of the population can sometimes be obtained by a statistical study of the catch per unit of gear.

A knowledge of the standing crop does not, in itself, furnish any information on the productivity of a lake except that in general the larger the standing crop the greater the productivity is apt to be. If the standing crop is the same at the end of an interval of time (the interval being one or more cycles) as it was at the beginning (net production being zero) the Possible Utilized Production is equal to the Actual Utilized Production.

3. The Potential Production of a lake is always a hypothetical figure as it is difficult or impossible to evaluate accurately the effect of changes in the environmental character of a lake. This concept of productivit is, however, of great importance as in addition to maintaining a fishery the aim

of fishery management should be, if possible, to increase the Possible Utilized Production.

III. FACTORS AFFECTING THE PRODUCTIVITY OF LAKES

1. Physical Properties

A. In general, the size, shape, and depth of the lake affect the size of the populations of the various species therein. These factors to some extent control the temperature of the water, shallow lakes being warmer in summer and colder in winter (other factors being constant) than deep lakes and hence have an affect on the type and growth of the population.

B. The nature of the surrounding country affects the biotic condition of a lake in many ways, abundance of terrestrial organisms, the amount of sunlight, and the run-off into the lake.

C. The turbidity of the water which is controlled by numerous factors directly affects the amount of photosynthesis and the character of the flora and fauna.

D. The flow of water through the lake is important from a variety of standpoints such as temperature, effect on the thermocline, introduction and removal of chemicals, and effect on turbidity.

E. The latitude and elevation of a lake affects its temperature and the nature of the surrounding flora.

2. Climatic Conditions

A. The temperature controls the character of the population and its growth rate.

B. The amount of precipitation is important from a number of viewpoints, in a measure it determines the inflow, outflow, and level of the lake, and has a pronounced affect on the surrounding flora.

C. The amount of light is of importance in controlling photosynthesis and is itself affected by latitude, weather conditions, vegetation in the lake, and the nature of the surrounding country.

D. The amount of wind is frequently important in affecting the temperature, depth of the thermocline, and exchange of gases between the air and the water.

3. Chemical Properties

A. The chemical properties of a lake are naturally important as they are really the building stones on which all life is dependent. There are certain chemicals found in lakes which are not used for growth and their presence is unimportant. However, the concentration of chemicals in a lake may be such as to inhibit the growth of certain organisms. A given concentration of chemicals may be harmful for some organisms and may be beneficial to others, hence we have a variation in the flora and fauna of lakes in accordance with the variation in concentration of the various chemicals. It is usually the case that any chemicals added to a lake in relatively large amounts are injurious even though small amounts may be harmless. In this respect the pollution of streams and lakes by sewage, industrial wastes, salt water from oil wells, etc., needs careful consideration. Sometimes a small amount of a pollutant may be beneficial, but the usual picture is to find the chemical composition of the stream or lake being radically changed with resultant changes in the flora and fauna.

B. The total chemical composition of a lake is constantly changing due to various causes. Chemicals are added to lakes by the inflow of streams, by pollution, by the wind (O_2), by terrestrial insects dying or being eaten by fish, and by anadromous fish. Chemicals are lost from lakes

by outflowing streams, catch of fish, migrations of fish, predatory birds, etc.

4. Density of Population of Utilized Species

A. The effect of the density of the population of a utilized species is, of course, of vital importance in determining the productivity of a lake of that particular species. Obviously if a species is not present in a lake, its production of that species can only be zero regardless of its capacity to produce. The ease of accessibility of a lake to anadromous fishes may affect its production of those species. To get the greatest possible production of a given species the density of the population of that species must be kept at an optimum value. Keeping the population of the species at a figure above or below the optimum values can only result in a smaller Possible Utilized Production than might be possible. The determination of this optimum value and keeping the population at that value is one of the most important functions of the fishery administrator.

5. Abundance and Kinds of other Flora and Fauna in a lake

A. The utilized species are (except in the case of plants) dependent on other forms of life for their food and all factors affecting the food supply, indirectly affect the lakes production of the utilized species.

B. Disease producing organisms may play an important role though their effect under strictly natural conditions is thought to be slight.

C. Predators are, of course, important in that they are in a measure in competition with man in reaping the crop and consequently a reduction in the toll taken by the predators usually results in an increased utilized production. As is the case when any changes in the environment are made by man extreme caution should be exercised to determine the full effects of removing predators as the predators may, in part, be controlling some other

undesirable species.

D. Population pressure caused by extreme abundance of some other species may have an effect on the production of the utilized species though such cases are rare.

E. The area and condition of the spawning grounds may be influenced by the kind and abundance of the flora.

IV. AIMS OF FISHERIES MANAGEMENT

1. To so regulate the "catch" or "take" that the Actual Utilized Production is neither less than, nor greater than, the Possible Utilized Production. If the Actual Utilized Production is less than the Possible Utilized Production the yield of the lake is only being partially exploited. If the Actual Utilized Production is greater than the Possible Utilized Production depletion is taking place.

2. To endeavor to make the Possible Utilized Production equal the Potential Utilized Production. This can be attempted in a number of ways, among the most common of which are, to bring the density of the population of the utilized species to its optimum value by proper regulation of amount and kind of fishing, control or extermination of predators, control of undesirable species which are competitors for food with the desirable ones, control of diseases, improving spawning beds, introducing new species, indirectly increasing the food supply by the addition of chemicals, etc. Considerable care needs to be taken in any steps to increase the Possible Utilized Production in that it is usually extremely difficult to determine beforehand the full effects of some proposed change before the change is made. For example, a new species may be introduced which in itself may be valuable but which may have a very deleterious effect on some other still more valuable species already resident in the lake. Again some

species which may prey on some valuable species may be killed off without taking into consideration the possible value of that species in controlling a third species which may be a predator or competitor for food with the first one. The introduction of new species may and frequently does result in the introduction of disease producing organisms which are sometimes very destructive.

3. To regulate the catch or take so as to produce the greatest possible economic benefit. This is one phase of fisheries management that has not always received as much attention as it should. If there is one season of a year when a species is in poor condition the "take" during that season should be curtailed or prohibited so that the "take" at some other season may be increased. Thus without a material increase in the quantity of the "take" its value might be materially raised. Regulation of the use to which a fishery product is put may be important and in some cases this has been done. Each individual case requires separate consideration and hard and fast rules cannot be laid down as to the best methods for controlling a fishery so as to produce the greatest good, however, this aspect of the situation should always be considered in formulating fishery regulations.