total of 16,586. At the same time only about 1,066 trout fry were found alive out of 4,020 distributed in this same area in July, 1925.

Does not a loss like this (73 per cent.) take place in accordance with the generally accepted biological principle that animals in a state of nature tend to breed up to the limit of subsistence? Even men breed in conformity with this law in thickly populated parts of India and China and in the slum parts of all big cities. Forbes Brook, like most others, produces food enough to feed only a limited number of fish, just as 50 acres of pasture land can feed only a limited number of cattle.

Now a majority of the 319 trout, 82 fundulus, and 16, 152 stickleback during the spring and summer of 1925 bred up to the limit of subsistence, and therefore there would be no extra food for the 4,020 weak and helpless fry which were dumped among the 16,586 enemies and competitors. The result was that some of the 4,020 were devoured by the larger and more active enemies, while others of them, weakened by scarcity of natural food, either died, or, it may possibly be, succumbed to the combined attacks of their numerous competitors, such as the stickleback.

May I suggest, therefore, that we have been trying to build up our fish culture results upon too narrow a foundation, namely, hatchery work alone for over 50 years. We have been limiting our protection of the fry and our feeding of fry to the comparatively short time which they pass in the hatchery. The hatchery, it must be remembered, is only one factor in the artificial production of commercial or game fish. Besides the hatchery there are the streams, ponds, etc., in which the fry are distributed and which must be studied quite as diligently as hatchery operations if fish culture is to be made successful. We must find out (1) the kind and numbers of enemy and competitor fish; (2) the available food supply, and (3) the limiting factors, forces or conditions which nature imposes upon the continuance of life, such as temperature of the water, oxygen supply, carbon dioxide, salinity, hydrogen ion concentration, intensity of light, pressure, desiccation and pollution.

Of the three factors just mentioned—enemies, food supply and physical condition—undoubtedly the most difficult and most important one to determine is the food supply in the streams and lakes in which the fry are distributed.

REMEDIAL MEASURES

1. The ordinary hatchery employee who possesses no scientific knowledge may nevertheless become an expert seiner and procure information as to the different kinds and numbers of enemy and competitor fish. How many of such fish should be removed and destroyed can only be determined by experiment. In order to promote efficiency in seining, surplus cover in the shape of shrubs, large stones, and submerged logs should be removed by the hatchery employees during off time in spring, summer and autumn.

2. Many enemy fish and competitor fish should be seined and destroyed for the same reason that weeds are destroyed in a garden, or wolves on a sheep farm. In this way more food would become available if not immediately for the fry, at least for yearlings or older ones. The food supply and limiting factors on the other hand can be determnied only by well-trained biologists. Until fish culturists extend their knowledge along the following lines so as to form a proper foundation for their science it will be idle to expect the best results.

3. A quantitative estimate to be made of the microscopic and macroscopic animal food upon which both fry and adults live.

4. A quantitative estimate to be made of the plant food upon which the microscopic and smaller macroscopic animals live.

5. An approximate quantitative determination to be made of the substances in solution in the water and which constitute the nutritive material upon which minute aquatic plants grow. These plants in turn form the food of minute aquatic animals.

So then we have this chain of nutritive relations to be studied: adult fish: minnows and fry: minute animals (entomostraca, etc.): minute plants: soluble material or food for the plants.

It may be objected that this broad study of the foundations of the science of fish culture will be an expensive affair. Yes, at first, and until the animals, plants, mineral matter and limiting factors have been determined. But once they are determined we shall have the satisfaction of knowing more or less accurately the approximate numbers of adult fish which we are getting for our legislative appropriations, instead of the guesses which pass current to-day.

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SEX DIFFERENCES IN MORTALITY AND METABOLIC ACTIVITY IN DAPHNIA MAGNA

FROM studies of the relative mortality of the sexes in *Daphnia magna* throughout their life span a mortality curve has been constructed for this species based on deaths of several thousand individuals all derived parthenogenetically in a pure line from a single original female. The organisms were reared, some singly, mostly in groups of varying size in battery jars containing at least 40 cc of ordinary manure-soil culture solution per individual. A census of survivors in the populations was taken at each seven-day period.

The mortality curves from this data show that under the laboratory conditions defined the males survived far better than the females during early and middle life, but that in later life (past the point of downward inflection of the curve) the males die off much more rapidly per unit of time than the females.

Experiments instituted to explain these differences revealed several points of interest in connection with physiological sex differentiation in its relation to duration of life:

(1) The males possess a characteristic higher rate of metabolism than the females throughout life until the decline during senescence sets in, when the female rate approaches and finally comes even to exceed that of the males. The observed greater locomotor activity of young males in comparison with young females led to an investigation of their relative heart-beat rates as a measurable criterion of metabolic activity. From Robertson's work the frequency of beating of the daphnid heart is known to be a function of temperature, the temperature coefficient being slightly greater than 2. As counted against a stop-watch at laboratory temperatures the frequency of heart beat of our young males was found to exceed that of young females by approximately 20 per cent. On the contrary, the rate for very old (always more sluggish) males proved to be some 5 per cent. lower than that for females of the same age.[1] As further evidence of the relatively more intense metabolism of males among the young and of females among the old, they were found to pass more quickly into a state of anesthesia with 3 per cent. alcohol, and then to recover sooner from its effects, and again, when tested with rapidly acting killing agents they showed correspondingly higher direct susceptibility and succumbed more quickly. In general, the curves for heart rate, direct susceptibility, anesthesia and for survival under ordinary culture conditions are quite precisely parallel at all ages.

1 Rapidity of heart beat also varies with special conditions of culture. "Crowding" females for male production promptly slows down the heart beat to only four fifths that of "single" females, which produce mostly female young. This observation agrees well with the current view that a state of depressed metabolism during maturation of the ova is associated with the onset of the sexual phase.

(2) The mortality curve for Daphnia represents a curve of deaths by indirect susceptibility, according to the method of Child. The metabolically more active sex at any given age tends to have a higher average survival frequency, as though vigorous physiological functioning were regularly associated with comparative resistance to ordinary untoward conditions of the environment. Conversely, that sex succumbs more rapidly under the usual laboratory living conditions, which shows least resistance to ordinary slow-acting killing agents or to excessive crowding conditions (twenty-five to fifty specimens in as many cc of medium), these being lethal only after acting for several days.

(3) The relative longevity of the sexes may be expressed as varying inversely with their average rates of metabolic activity. The average age at death for males was 37.8 days and for females 43.53 days, the duration of life for females exceeding that for males by 14.6 per cent. Now in metabolism, as estimated by heart rate, the males surpass the females by nearly the same percentage, and the product: heart beats per second (weighted average through life) × average age in days at death = a constant, *e.g.*

Males: 4.3 beats × 37.8 days = 161.54
Females: 3.7 beats × 43.8 days = 162.06

The experimental data thus tend to support the view that a definite endowment of vital energy, potential in the protoplasm of the species and line, may be transformed and expended rapidly, as in the short-lived males, or more slowly, as in the longer-lived females. The evidence so far available indicates also that length of life in *Daphnia magna* has the usual temperature coefficient for a chemical reaction. Other factors being equal, it would seem that, at least in this species, longevity is a function of metabolic rate.

If a workable method can be devised the metabolic rate will be measured from quantitative determinations of oxygen consumption and CO_2 production.

A more extended report, including details of data on the various phases of this work, will be published elsewhere.

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