TEXTBOOK OF POND CULTURE

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TEXTBOOK OF POND CULTURE

REARING AND KEEPING OF CARP, TROUT AND ALLIED FISHES

by

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Translated from the German

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Preface

Pond culture during the last decade has been developed more and more into an independent and important industrial branch of national economy. Its development at the same time led to a sharper division into two main fields: carp pond culture and trout culture. In spite of this the science of the entire pond industry, inclusive of artificial fish-culture as contained in this book, has remained equally important for the instruction of both the carp pond culturist and the trout grower. It will be useful for each of them to use the experiences of the other and to draw comparisons. General principles in both industrial branches are largely the same, also transitions in practice repeatedly erase the division to again form a whole: the pond industry in a larger sense. It has become self-evident today that the small pond culturist, who is concerned only with the maintenance of fish, informs himself about the breeding of his fish, and that the lake and stream fishermen will repeatedly learn from the pond culture industry.

All expedients for the advancement of the pond industry and for lowering production costs, such as the care and treatment of ponds, fish feeding, precautions for avoiding fish losses and fish diseases are more effectively and successfully applied by the careful consideration of the given environmental requirements of the pond fish, their nutritional demands, the regulations of natural food production in the pond, and the peculiarity of the fish diseases. I have therefore placed at the beginning of this textbook, the "Biological Principles of Production" which influence more than anything else the industrial procedures of the pond industry. The opposite pole is formed by the treatises on fish enemies and fish diseases which not less strongly oppose industrial success and management. In spite of this, each division of the book is complete and comprehensive in itself and independent of the others.

The beginner will at once obtain a deeper insight into the practical aims and methods by this manner of presentation. The marginal chapters with their discussions on pond management and fish feeding will provide especially valuable and entirely reliable principles for new improvement methods for experienced directors of pond culture industries.

The sections dealing with the actual rearing and behavior of carp, trout and their relatives have been adapted to the natural arrangement of the subject, by which a very definite form of textbook-like presentation was obtained. I have set myself the task of always placing the importance of recent pond culture practice in the foreground. The accomplishment of this task was therefore made easier for me because in the last decade several industrial methods have crystallized out of an abundance and have become generally accepted. The illustrations of the book, since they are intended to illustrate the modern status of pond industry, have been for the greater part newly drawn by me and adopted in practice.

Naturally no textbook can be complete or final. Although I have repeatedly entered into the regional differentiations, there certainly will be cases in which the previous rule of the locality requires departure from the established basic industrial principles and the introduction of other industrial procedures not described here.

Berlin-Friedrichshagen, in the Spring of 1933.

W. Schaeperclaus.

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CHAPTER I

THE BIOLOGICAL PRINCIPLES OF POND CULTURE

A. Introduction

The teachings of commercial pond-culture deal with the problems of feeding and existence and the biological factors of production of the pond itself.

Together with Thienemann (1931), I understand production--in a general sense--to mean total quantity of all organisms and their excretions within a certain space of time.

These fundamental principles will have to be considered in all questions, concerning fish breeding in general, feeding, and rationalization of pond culture.

B. Metabolism of Pond Fish

The metabolic functions of fish can be divided into the two categories of:

(1). Basal metabolism, (catabolism)

(2). Anabolism

According to Schaeperclaus (1928, the latter may be subdivided again into:

(1). Supplementary anabolism

(2). Reproductive anabolism

(3). Sedimentary anabolism

Summary of components of the metabolism of fish from the viewpoints of physiology and pond culture.

	Physiological classification		Pond-cultural classification
General Metabolism	Basal Metabolism (catabolism)		Body Sustenance
	Anabolism	Supplementary anabolism	
		Reproductive anabolism	Body growth
		Sedimentary anabolism	

The fishbreeder should know that basal metabolism as well as supplementary anabolism operate for body sustenance.

It is through basal metabolism that certain parts of the food are converted for the performance of bodily functions, while through supplementary anabolism is compensated the loss of used-up body material. The latter also provides for gland secretions, such as loss of cutaneous mucus, gastric juices, etc.

To reproductive and sedimentary anabolism is due bodily growth; weight increase from the fishbreeders viewpoint.

Reproductive anabolism expedites the growth proper of the body by increasing the number of protein cells and other vital cells, capable of development.

Through the function of sedimentary anabolism, bodily reserve materials, especially fat and glycogen are deposited in certain well defined places (especially in the connective tissues between muscle sections, between the abdominal organs and also under the skin and in the liver).

All metabolic functions—general as well as of the different components—depend upon certain factors which are—from their functional results—of highest importance to the fishbreeder.

Analogous to the metabolic functions in warm-blooded animals, the rate of metabolic actions in fish is in ratio to the performed labor of locomotion, to organic activities (conform to the doctrine of: "Needs regulate rate") and to the measurements of the surface of the body.

Evidence for the existing relation between metabolic rate and performed labor will be found in the increased consumption of oxygen after physical disturbances and agitated swimming around (fish in transport, drainage of ponds, "rising" in wintry ponds). Kirschstein found that the consumption of oxygen in tench, for instance, right after transfer to a barrel was three times as high as 15 to 20 minutes later.

Another proof may be found in the fact that voracious feeders among fish require more oxygen than others, on account of their harder task of digestion.

According to Lindstedt and Schaeperclaus (1925), the factor of surface measurements applies to all fish, in fact to all water fauna, for that matter.

It is for this reason that the metabolic rate of a small sized carp of 12 grams (in 24 hours and per kilogram body weight) is 24.48 kilogram-calories, as against 7.97 kilogram-calories of a fish of 600 grams weight but of less proportional body surface.

Upon a basis of 1 square decimeter of body surface and at a water temperature of 15 degrees centigrade, we find that the caloric needs of the small-sized carp amount to 27 gram-colories, as against 23 gram-colories in the larger fish.

Therefore, we must not lose sight of the fact that in fish small differences in length mean nevertheless great differences in caloric requirements.

Evidence for the relatively greater caloric needs of smaller fish--per weight unit--is their greater oxygen consumption per like weight.

Therefore, if the holding capacity of containers for transportation is figured upon the basis of weight, such containers must carry less fish weight in smaller fish than in full-sized ones.

Far too little attention is paid to the fact that other essential metabolic functions--reproductive anabolism, for instance, are relative to the size of fish.

The rate of growth, by sufficient feeding, is the more rapid the smaller the fish. The age of the fish, in this respect is apparently of little importance.

Making an experiment with some carp, 4 summers old, impeded in their growth, at the hatcheries of the Forest Academy in Eberswalde, I observed a weight increase from 277 grams to 1300 grams. Two years previous to this, carp, 2 summers old from the same spawn, in the same pond and under identical conditions merely increased from 285 grams to 940 grams.

The beginning of full maturity (puberty) seems also to depend upon size, rather, and not upon age alone. Buschkiel reports that carp in India reach the stage of full maturity (ability to propagate) at as early an age as 1 to 1½ years, as against the age of 3 or 4 years in Germany. Nevertheless, the faculty of propagation is strongly influenced by age.

I have observed, myself, tench females of only 7 centimeters length--retarded in growth through malnutrition--fully mature and able to spawn. As a rule, such females will begin to spawn only after having reached a length of from 18 to 20 centimeters.

The existing relations between the demands for growth increase and the demands for mere sustenance are very important from the practical viewpoint, especially among the different full-sized fish. The rate of the food-quotient is based upon it.

But the favorable food-quotient of yearling carp in comparison with full-sized carp cannot be used for the solution of this problem. The lower quotient in this case is chiefly due to greater utilization of natural means of subsistence on account of increased density of population.

Quite recent observations by Cornelius, upon rainbow trout, of from 100 milligrams to 100 grams in weight, did not show any differences in the food-quotient.

Schaeperclaus (1928) calculated the ratio between demands for growth and demands for sustenance--in young rainbow trout in proportion to their weight. He arrived at the figures of from 1:1.5 to 1:3.2, which may be regarded as an average for most pond fish.

It is generally known that the total caloric needs, and consequently the oxygen requirements depend upon the kind of fish. The following figures by Lindstedt, calculated upon 1 square decimeter body surface, per hour, and for a temperature of 15 degrees centigrade may be considered as more or less correct:

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Tench	approximately	10	gram-calories
Carp	"	25	" "
Rainbow trout	"	60	" "

It follows that rainbow trout require 2 to 3 times more oxygen than carp and 6 times as much as tench under like conditions as to temperature and body surface measurements, of course.

The "normal" rate of growth of these three species also varies greatly, which in turn affects the demands, made by them upon the most important components of their anabolism.

The rate of growth differs individually, also, of course, quite apart from racial differences within the respective categories. This also is of greatest importance from the practical viewpoint.

Schnigenberg and Willer speak of an "Intelligence Factor" in order to explain the differences in individual growth. After all, this is merely another name for the inherited degree of skill in the hunting for food. But without doubt, this is only one factor within a wider complex of individual factors.

Aside from other factors, one can assume, at least, the existence of a "Food-conversion Factor", by which is meant the individually inherited faculty of food-conversion.

The "Intelligence Factor" can only play a role after free feeding has begun, while the "Food-conversion Factor" may be effective already during the period of existence in the vitelline sac.

In marked difference to warm-blooded animals, the rate of all metabolic functions in fish is strongly influenced by temperatures. Van't Hoff's rule in this respect may be considered as fairly correct.

At lower temperatures, a rise of 10 degrees nearly doubles the rate of metabolic activities. As the temperature rises, this rate steadily declines. Incidentally, the rise in temperature is likewise proportional until the optimum (most suitable temperature) is reached.

The optimum for brook trout hovers around 20 degrees centigrade, while carp seem to require a much higher temperature, i. e. optimum, an opinion based upon the studies by Buschkiel, anent the rapid growth of carp under tropical conditions.

He found that carp in Java--under a yearly average of 27 degrees centigrade--grew 3 to 5 times as fast as carp in Central Europe (9 degrees average).

All this leads us to very important results.

In Germany, on account of the changes in temperature, the demands for food vary greatly with all pond fish. All feeding must of necessity be reckoned with these factors.

Staff and Demoll (1931) found that feeding as well as all digestive labor ceases, in carp, at a temperature of from 9 down to 8 degrees centigrade. At a temperature of 7.5 degrees, the carp goes to bottom where it lies upon its belly in a state of hibernation. This tallies with earlier statements by German physiologists.

In conflict with these statements are the findings of F. Schiemenz (1907-1931), who states that one and two-summers-old carp--above all others--will feed even during the winter, i. e. at the lowest temperatures, and that in the case of yearlings such feeding is even necessary for their well-being. He found the intestines of two-summers-old carp, in a wintry pond of 0.5 degrees centigrade full of <u>Trichoptera</u> larvae. Since the larvae in the stomodaeum were still alive, it was evident that the carp had fed shortly before being caught.

Quite recently it was discovered by Demoll that yearling carp, in February and at a prevailing temperature of 3 degrees centigrade were still feeding on larvae and bosmina, while two and three-summers-old carp would feed upon decayed vegetable matter at a temperature of 4.8 degrees centigrade.

Therefore, while metabolic functions as well as demand for food decrease greatly during the winter months, the fishbreeder must not overlook the fact that even carp, at lowest temperatures, still require some kind of sustenance.

Few researches have been made as to the influence of temperatures anent the <u>relations between basal metabolism</u> and <u>reproductive anabolism</u>, although it is quite important from the viewpoint of food-conversion, especially in trout where natural alimentation plays no role.

From practical experiences, I conclude that in the case of rainbow trout a temperature of about 10 to 15 degrees centigrade will give best feeding results.

A certain periodicity is also of regulative influence up all metabolic functions, in fishes. This "periodicity" is influenced by spawning, by the "habitual" rest period during the winter months, but is independent of temperature changes. It is the belief of some investigators that this "periodicity" plays a certain role in the perfection of the year-rings upon the scales.

Finally, <u>all metabolic functions</u> are dependent upon the <u>general conditions of existence</u>.

In this respect we have to consider the chemical components of the pond water (oxygen content, contents of salt or of possible poisonous substances), also the factor of space (size of the pond), the composition and digestibility of the supplied food--insofar as it reacts upon the metabolic functions--the state of general well-being etc.

The influence of the food supply will be dealt with in the next article. Be it said, here, that on account of the enumerated regulative factors and in compliance with the law of "needs regulate rate", the life-sustaining functions of basal metabolism must be fully assured. In case of undernourishment these requirements will be maintained at the expense of bodily substance.

C. Growth of Pond Fish

Growth--even in carp--depends upon cell multiplication and enlargement of cells (researches made by Scheuring, 1921).

In comparison with the quickly growing "noble carp" (Edelkarpfen), the cell elements in the "peasant carp" (Bauernkarpfen) and also in undernourished fish are smaller and the process of cell differentiation is retarded.

One may assume that the complicated mechanism of growth in fish--similar as in the case of warm-blooded animals--operates, with regard to rapidity in growth, along the lines of species and race and depends upon the components of form development, weight increase, multiplication of cells, enlargement of cells, differentiation of cells, general conditions and disposition.

In the preceding article it was shown that reproductive anabolism, i.e. growth, is dependant upon such factors as heredity, bodily size, temperature of water and general environment.

All of these factors--like all other character-forming factors--can be brought under the two headings of:

(1). Genotypical (internal) growth factors, determined by hereditary "disposition". These may be characteristic for:

(a). The species of fish.

(b). The race of fish.

(c). The individual fish.

(2). Paratypical (external) growth factors, i.e. environmental factors. These will influence growth within the field of heredity and constitutional possibilities.

With regard to the part played by nutrition, one is entitled to consider separately the influence of external factors during the following periods of development:

(a). Existence in ovum.

(b). Nutrition in the vitelline sac (exclusively).

(c). Nutrition in the vitelline sac (in part).

(d). Period of free feeding.

In a general sense, we can therefore formulate the dictum that every external phenomenon, every characteristic--growth in this case--is the functional result of two variables, to wit: Internals and Externals.

In contrast to warm-blooded animals, some fundemental differences in the effects of these variable factors upon growth are of special importance to the fishbreeder.

(1). Fish have no "normal size" which may be spoken of as full size. Their growth is "unlimited", so to speak, and in this respect fish resemble trees and plants more than warm-blooded animals (in regard to growth, be it understood).

(2). Fish can be greatly retarded and even entirely stopped in their growth--through persistent undernourishment--without injury to their existence as well as to their faculty for growth.

(3). Through no amount of over-feeding can the growth of fish be advanced. The reason for this lies in the already mentioned relations between reproductive anabolism and environmental factors (even here the law of "Needs regulate rate" operates). The increase in weight through the deposit of unorganized reserve materials, such as fat and glycogen, is also negligible, and is not even desirable when production of meaty fish is aimed at.

Physiologists' (Zentz and Knauthe) have stated, nevertheless, that growing fish may be masted. This observation is based upon the fact that growing fish, usually, do not find sufficient sustenance necessary for the fullest function of reproductive anabolism.

(4). A still further step above and beyond mere standstill in growth is possible in fish: "Negative" growth, viz. excessive loss in weight. The explanation for this lies in the fact--already mentioned--that the necessary calories for proper metabolic functions will be provided, in case of undernourishment, at the expense of bodily substance. This, of course, must lead to loss in weight.

The resistance to starvation, in fish, is great. They can especially withstand it in winter, when their wants and needs are few, on account of low water temperatures.

In marked carp of 400 grams weight, I recorded a loss of weight of from 10 to 14 per cent, after a hibernation period of 16 days, in a pond, averaging a temperature of from 4 to 6 degrees centigrade. Their loss in length ranged from 3.8 to 6.7 per cent.

Brunner and Endress recorded in tench of 185 and 193 grams weight, a loss of from 7.7 to 7.8 per cent, at a water temperature of 7.5 degrees centigrade, starting the experiment on November 7th and lasting 120 days.

Demoll states that hungry carp may lose up to 35 per cent of their weight and tench up to 50 per cent. During the first few days of malnutrition, nitrogen-free reserve materials will be called upon, in an ever increasing rate, to provide the necessary calories.

Lindstedt records the loss in protein in a group of starving tench--for calorie needs--as 51.4 per cent during the first day of a hunger period. It dropped to 40.7 per cent on the forty-third day, when it again rapidly increased to 62.5 per cent on the sixty-third day.

It follows that the far more important proteins will be used up for caloric needs, once the reserve materials have been exhausted.

Brunner and Endress observed that fat, above all, will be used up during hunger periods, and that other parts of body structure--rich in protein--will eventually also suffer, muscles and intestines, for instances.

I have made an experiment in order to ascertain the influence of previous undernourishment upon growth, after resuming proper feeding. The experiment was made with normal 4 years old carp of about the size of 2 years old, and with fish of the same parentage and same size but greatly undernourished. Table I gives the respective figures.

Table 1.

	Length and weight of individual fish (in centimeters & in grams)						Individual increase, average from:	
	at time of stocking			at time of fishing			quoted figures	whole stock
Under-nourished	30 29.5 28	cm 392 g) " 339 g) " 292 g)	aver. 342 g	43 41.5 40	cm 1355 g) " 1235 g) " 1240 g)	aver. 1280 g	938 g	1023 g
Normal	30 29 29	" 443 g) " 424 g) " 404 g)	aver. 425 g	43 42 40	" 1560 g) " 1660 g) " 1580 g)	aver. 1600 g	1175 g	1212 g

Losses were alike in both categories. Although the "lean" carp were no longer undernourished, when fished out, the proportions in weight to size had remained constant in comparison with the "normal" carp. The "lean" fish had remained "slimmer". On the other hand, their capacity to recuperate from previous loss of weight was hardly impaired, notwithstanding their state of great emaciation.

Size as well as state of nutrition depend therefore upon numerous "external" and "internal" conditions.

As essential "external" conditions, we have to regard water temperature and food supply.

The most important "internal" factors are the inherited faculties for rapid growth, good food-conversion and for resistance. Growth and highest possible weight attainable within the different categories of fish (with advancing age) depend upon these factors.

Fishbreeders have striven for centuries to breed these "hereditary faculties" into fish, by means of selective breeding.

Under 2 and 4, we have mentioned that a retarded 4 years old carp of good stock can have the appearance of a 2 years old. But it is nevertheless of importance to be able to prove that a carp, apparently 2 years old, really is of this age. This would then prove that such a fish is really quick growing, i.e. is of good stock.

It is of utmost importance to the fishbreeder to be able to determine the age of pond fish, in order to safeguard himself against the acquisition of inferior stock. This is possible by counting the "year-rings" upon the scales.

Upon an examination of the scales, we soon discover well defined "zones" in the arrangements of the rings. We may speak of them as "summer" and "winter" zones.

In the "winter zone", the concentric rings lie closer together, while the rings in the "summer zone" are more widely spaced. This is explained by the higher anabolic rate and through better nutrition in summer and the lowered rate of growth in winter.

Examination of the scales is facilitated by first rinsing them in a solution, prescribed by Petrov and Petroschawsky, as follows:

2 parts of 10 per cent chloralhydrate
1 part of concentrated picric acid (watery solution).

By this process, a clearer field of observation is obtained.

One will notice that the rings in the "winter zone" are interrupted and also branch off. (See Fig. 1)

Fig. 1. Scale of a two-summer old carp; length of fish 16 centimeter. Two summer zones and one winter zone, well defined and visible even in lower parts, covered by skin. In its first year the carp reached a length of 8 centimeter; its growth in second year was artificially impeded.

Only perfect scales, preferably from the midriff section, where they grow first, should be used for an examination. Also, a certain number of scales--not only one--should be used, since one may have picked a scale, recently formed to replace a lost and older one. For one's own personal use, the technique of such an examination is easily acquired.

In case of a difference of opinion, one should always abide with the findings of a fish biologist, since special training and experience are necessary for more minute observations.

In isolated cases, especially in cases of irregular and impeded growth, a correct determination of age may become impossible or lead to low values. But even the most perfect scales cannot be relied upon for an absolute correct determination of age. Incidentally, the main gill cover of the gill cover apparatus may be similarly used.

Since I have discussed the possibilities of excessive loss in weight (under 4), I will give here—for the fishbreeder's use—a mathematical formula by which the "normal" ratio between weight and length may be calculated.

This algebraic 3rd power equation is based upon the mathematical theorem that "similar bodies are proportional to the cubes of their similar distances".

If we use P for weight, L for total length (from point of head to longest point of tail), K for coefficient, we have the following equation: P eq. $\frac{K \times L^3}{100}$.

I found as coefficient the following suitable figures:

For "normal" Galician carp ..... K eq. 1.8

For Tench .... K eq. 1.3

For Rainbow trout .... K eq. 1.1

For greater clearness I have drawn the developed function P for the values K = 1.1, 1.3, and 1.8, and for 5 L 25 (Fig. 2). The curves permit immediate determination whether, for example, a 10 cm. carp has approximately "normal weight".

This formula allows calculation of the weight of a "normal" fish from its length and vice-versa.

Small differences always occur, of course, due to loss in weight, filled-up intestinal tract, excessive development of gonads or over-feeding.

I found in rainbow trout—by normal feeding—always a somewhat lower weight (as about K eq. 1), and by over-fed specimens a somewhat higher weight (as about K eq. 1.2).

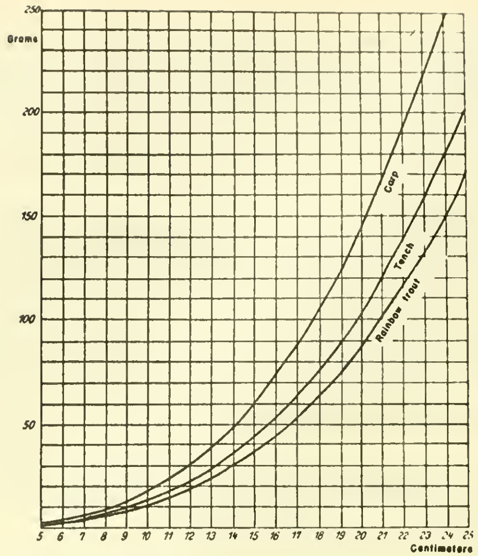

Fig. 2. Graphic chart of weight of Galician carp, Tench and Rainbow-trout of lengths of from 5 to 25 centimeters, by normal nutrition.

D. Nutrition of Pond Fish

1. Types of Food

In pond fish we distinguish between two forms of subsistence, to wit:

(1). Through food, supplied by the pond itself (natural food).
(2). Through feeding (food supplied by the fishbreeder).

In the first case, the fish hunt for food upon the "pastures" of the pond.

The two forms can be compared to the keeping of cattle in pasture and to stall feeding of them. Both forms can be made use of, in which case it will lead to an especially important middle form of subsistence, in carp.

2. Natural Nutrition of Pond Fish

Investigations upon the extent of natural nutrition of fish--by their hunting for food--have been made in regard to all pond fish. An actual count of their intestinal contents is the more recently prevailing method along these lines.

A real evaluation of the amount of subsistence, so obtained, is possible only by evaluating the nutritive value of the food consumed. For instance, a small Bosmina has only about the 1/1000 part of nutritive value of one middle-size larva of Chironomidae.

Today, the findings of P. Schiemenz, concerning nutritive values are generally accepted.

He divides all natural food stuffs into the three groups of: Main food stuffs, Occasional food stuffs, and Emergency food stuffs, (Schaeperclaus 1928)

By "main food" is understood the natural food which the fish, under favorable conditions will choose in preference and by which it thrives best.

"Occasional food" means well liked natural food, consumed whenever the opportunity presents itself. This kind of food can be of relatively high nutritive value.

"Emergency food" is what the name implies. It is taken in when all other food fails and the fish will always thrive badly upon it.

According to the food chosen--in preference--the fish are to be divided into: Vegetarians, Insectivores, and Predatory fishes. Among the insectivores, we differentiate again--according to the mode of existence of their prey--between: Plankton feeders, Bottom-life feeders, and Shore-life feeders. (In ponds, the last named ones may better be spoken of as "Vegetation feeders").

Carp, Lehmann and Gennerich, in 1922 carried on investigation anent the food habits of youngest carp fry. They used 64 carp of from 0.5 to 3.9 centimeters in length and 17 carp of from 2.3 to 4.8 centimeters. The test fish came from various fisheries of Northern Germany. Lehmann found that most of the carp, below 2.5 centimeters and which had not as yet completely consumed the contents of their vitelline sac showed the following intestinal contents: Sizable amounts of such plankton creatures as Losmina and Anurea cochlearis and A. aculesta, but in addition also similar amounts of such vegetation creatures and bottom creatures as Chydorus, Alona, Simocephalus, Cyclops, Canthocamptus and even Cypris. Formerly held opinions, viz. that young fry (of carp) are strictly plankton feeders have thus been exploded. The question if pure plankton is necessary for the nutrition of young carp brood has been negatively answered by the findings of Lehmann, who found that such brood of 0.5 cm. length can already exist upon small Cyclops, Cypris and Chironomus larvae. (vegetarian or shore animals)

The complete change in evaluation principles for pond plankton has unfortunately been misconstrued until recently by pond culturists and also by scientists, although P. Schiemenz has for a long time repeatedly pointed this out. Gennerich comes to the same conclusion as Lehmann, that it must be assumed that the nutrition of pond fishes in the individual pond industries can be different in accordance with a variable supply. This variability should not be overestimated, because drainable ponds generally show similar conditions. Lastly and worthy of mention, is that Gennerich frequently found the water flea Sida and in carps over 4 cm. also Trichoptera larvae. In brief, the carp fry are eaters of small animals rather than plant eaters. Their main nutrition consists of insect larvae and shore cladoceria, and they belong to the constant eaters of shore-animals (vegetation animals). Plankton is to be regarded only as opportune or emergency nutrition.

Basically, the nutrition of all larger carps is of similar nature and gravitates increasingly to insect larvae and somewhat from vegetation animals to mud animals, i.e. to bottom fauna. The nutrition of one-summer carp averaging 10.9 cm. taken on Oct. 9th from a pond industry in this province, according to Gennerich, consisted for each fish mainly of about 2,000-4,000 shore cyclopidae, about 100 cladocerae of various kinds (Sida, Kurycercus, Camptocercus, Alona, Chyderus) and 10-20 insect larvae (mainly Chironomus and Ephemera larvae). As insect larvae may be considered to have an average caloric content 50 times greater than small crustacean animals, then, accordingly, lower shore-crustaceans and insect larvae have each participated about 50 per cent in the nutrition. Nutrition of carps by plankton can in no way be considered; the carp is not a plankton feeder at any age.

Quite the same picture was shown by 7-9.9 cm. long carps in the first year of life taken in August from two ponds of a pond industry in Saxony. Two- and three-summer carps, examined by Wundsch (1919), had eaten in July and also in October (before the autumnal fishing out) principally Chironomus larvae and Ephemera larvae, and secondarily bottom Cladocerae (Chydorus, Alona, Camptocercus). Besides this, Trichoptera and Copepode larvae were occasionally taken up. Mollusks and all the remaining small animals remained in the background as nutrition animals.

This has changed, of course, all of the opinions with regard to the evaluation of plankton as broodlings food. It is considered evident today that plankton is nothing more than an occasional and emergency foodstuff.

Remarkable is the often high intestinal content of detritus and vegetable matter, especially in summer (observed by Wundsch), and which is characteristic for pond carp, according to the observations of other authors. This, of course, does not make the carp an outspoken detritus and plant feeder.

Smolian examined the bowel contents of 2 and 3 years old carp during the months of June, August, and November. The counting out of these contents gave the following figures (in decreasing order) from 4240 to 420 items:

Chironomus, Tanypus, Eurycercus, Daphne, Alona,
Trichoptera, Ephemeridae, Sialis and Sida.

The following chart gives the pro rata (procentuale) composition of the intestinal contents of 300 gram carp during various times of the year. The pond, used for these tests was so heavily over-stocked, that the carp could just maintain their original weight (weight at time of stocking of the pond). The chart shows that the most preferred food, i.e. insect larvae were eaten up at the beginning of summer. Until September, the qualitative composition of the intestinal contents is more or less stable. In October, when the most preferred foodstuffs begin to lack, the carp consumed less palatable nutrients (such as Sayomyia and Cypris) as a kind of emergency diet. This may also apply to other pond fish. Altogether, we may assume that only a very small amount of all available aquaties is consumed by the fish, perhaps 90 per cent and even more remain unconsumed.

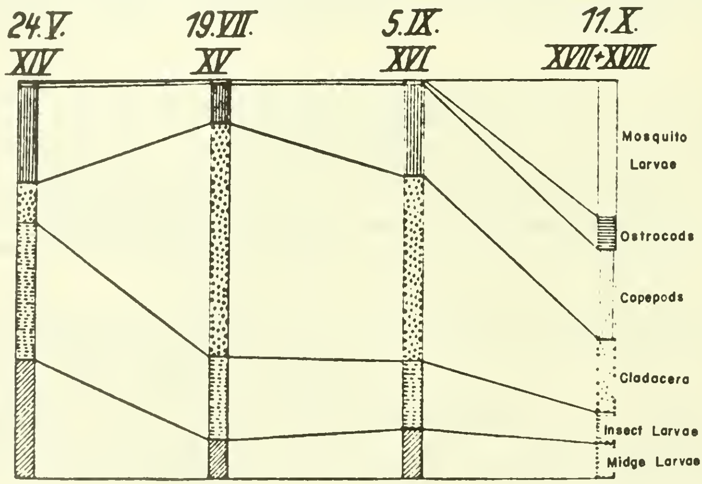

Fig. 3. Composition of the stomach contents of a two-year-old carp, out of sixteen overstocked pools, taken at four different times in the summer.

Tench. Tench are typical shore-life feeders. It follows that their food is extraordinarly similar to that of carps. Examination of tench from known carp ponds revealed little difference in this respect.

Only Dobers affirms that tench compete, in regard to food far less with carp than do perch and stone-perch.

In lakes, tench are less bottom-life feeders than carp, but have a marked preference for small mollusks. Their good existence is especially guaranteed wherever Bithynia tentaculata and Valata piscinalis are plentiful.

Ponds that are at all times well peopled with mollusks are therefore especially well adapted for the rearing of tench.

It is an erroneous belief that tench require entirely different natural food than carp or even feed upon the excrements of carp. This should be kept in mind wherever the mixed breeding of carp and of tench is attempted.

Trout. While trout are endowed with the dentition of predatory fish, they are nevertheless, and almost exclusively "Insectivores", during the first three or four years of their lives. Their predatory character, though is apparent, since they feed mostly upon larger insects. They will even swallow foreign matter, such as the usually wood and stone covered "quiver" of trichoptera. Even glittering, metallic objects may be found in their stomachs.

It is presumed that the long period of insectivorous food habits was developed in trout. As a rule, trout do not find sufficient numbers of companion fish--in brooks--upon which they may feed, such as minnow, for instance.

Also, trout fight shy of their own kind. The brown trout is an outspoken hermit and simply loves to hide out.

It is characteristic for trout that they will remain insectivores the longer, the more plentiful by such food can be had.

In small breeding tanks and in overcrowded ponds, the rapacity of trout asserts itself already in their own, small fry, as soon as they are able to feed. They will prey upon weaklings of their own kind and the smaller fish form a much appreciated diet for the larger ones. The brown trout surpasses the rainbow trout in this respect.

The gluttony of trout reveals itself already in the smallest fry. Even in their period of still partial vitelline sac feeding, they will already swallow Gladocerae, Copepodae, Chironomidae and Chaetopedae, (Schräder).

The main food of 50 days old trout, in larger ponds, consists of Chironomidae, especially the larva of such species as Ceratopogen, Tanypus, Tanytarsus, Orthocladius, but also of Chironomus. (Schaeperclaus 1928)

In less plentifully provided ponds, other larva, shore Cladocerae and Cyclopidae will be added to their diet by these young fish.

In the following table, arranged by P. Schiemenz (following Schaeperclaus), the different items of natural food, favored by trout are listed in the order of their importance.

In Brooks	In Ponds
Amphipodae	Larva of chironomida
Larva of trichoptera	Larva of trichoptera
Larva of chironomida	Larva of chrysopa
Larva of ephemera	Corixae
Haliotis	"Air foodstuffs"
"Air foodstuffs"	Sidae, Daphnae
	Alonse
	Cypridae

Amphipodae may be spoken of as THE trout diet, so much so in fact, that the abundance of trout in brooks quite often depends upon a plentiful supply of Amphipodae.

Rainbow trout and "Bachssiblings" (Salmon salvelinus) require the same kind of foodstuffs. Only in mountain streams do rainbow trout, more than brook trout, feed more on diptera larvae and mollusks, although investigations made by Stankowitch at different times of the year (1924) have hardly shown any marked differences.

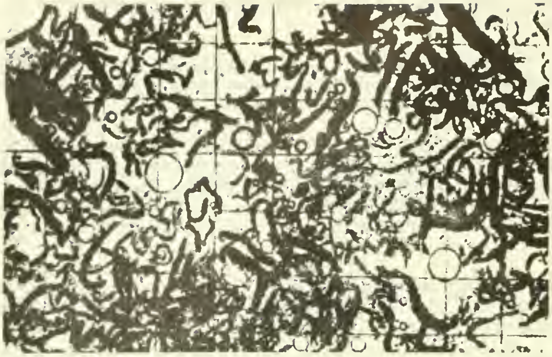

Fig. 4. Unsorted stomach contents of a 7.1 cm. length brook trout from a natural pond. Consisting almost entirely of small and large Chironomus larvae of various kinds. The intestinal canal of the trout contained a total of 556 Chironomus larvae, and 11 Cladocera (water fleas) and Copepodae (hoppers).

"Air feeding", i.e. feeding upon flying insects will play a role only during certain periods, when such a diet is available. Schaeperclaus (1930) found that caterpillars may be an important item of the diet in tree-surrounded ponds, but the disadvantages of shade certainly outweigh the advantages of additional "aerial" food supply.

Pike, Perch-pike Catfish. The pike may be considered the most rapacious of all fish. One-summer old pike, only about 20 centimeter (7 inches) long devour one-summer old carp without such ado nor difficulties. According to Scholz, pike will swallow chunks of from 20 to 30 per cent of their own bodily weight. Only medium and larger two-summers old carp are safe from the attacks of these voracious feeders. Naturally, they will also go after smaller dace, crucian-carp, smaller pike, perch and even after frogs and rats, if they can be caught at all.

The young pike is an insectivor and as such has a preference for dragonfly larvae and larger Crustacae, but their rapacity asserts itself in the first few days. In contrast to pike, the perch-pike, even when grown up, will feed only upon small fish. He lacks in agility to tackle larger fish and is also handicapped by its small mouth.

Its predatory nature usually asserts itself only in its third year. In its first year, the perch-pike feeds upon plankton and in the second year feeds upon the shore-life and bottom-life of the pond.

In certain parts of the country (Germany) the catfish is a bothersome nuisance and like the stickle-back is hard to get rid of. Its prey is mostly small fry but he is also suspected of preying upon spawn and fry.

Crucian, Dace, Stickle-back, and Minnow. All these are small-fry feeders (including their "gold" varieties), and they prey upon insect larva, crabs, mollusks and "aerial" food, just like the main pond fish. The bleak may be excepted as feeding chiefly upon plankton, while "Ploetze" (Leuciscus rutilus) and "Rotfeders" (Scardinius erythrophthalmus) feed also upon plants.

But all of them are more or less bothersome pests, depleting the larder of the profitable species, so to speak. They are also quite often disease and parasite carriers and for all of these reasons should not be tolerated.

3. Artificial Food Supply

Feeding of pond fish, in addition to the food provided for them by nature, is seldom done today, with exception made for the rearing of trout in hatching tanks.

As indirect, additional "artificial" feeding may be regarded as artificial encroachments upon the processes of disintegration (fertilizing, soil improvements, clearing away of reeds, etc.).

In table 3, one will find the most important and in practice most suitable fish foodstuffs. The general differences of such foodstuffs, as regards carp-like fish and trout will also be noticed. The selection of such foodstuffs depends, of course, upon the highly variable factors of times and prices. These may vary from year to year. In the case of carp and of carp-like fish, which do not properly consume their food, the price of foodstuffs is of greater importance than the composition of the same, provided the whole diet does not consist of from 50 to 70 per cent of natural food. In regard to trout-like fish, the temptation of low prices must not outweigh the consideration that trout require foodstuffs which will assure their sustenance and well-being to the extent that they will not have to rely upon natural food, i.e., they will not have to hunt for food.

4. Nutrition and Digestion

Nutrition experiments have repeatedly shown that a specific selection of food animals for each individual fish species does not take place. Pond fishes at least are extensively omnivorous in regard to small animals. In the crowded contraction of the living spaces of the bottom of the plant world (shore), and of the open water, it is understandable if the shore-feeders take up abundantly occurring bottom or open water animals as a welcome opportunity nutrition. Furthermore, in regard to taste, the nutrition-animal world does not show great differences (except with mites and strongly chitinized animals) which would cause a selection of special forms.

On the other hand, the feeding of fish is greatly influenced by certain mechanical factors, i.e., their abilities to take hold of, and to swallow the available supplies. Their physiological equipments in regard to senses also plays a role here. Both of these factors vary among the different species.

In regard to insect food, fish are more or less omnivorous. Trout and all predatory fish, such as pike, perch-pike, and perch grab their prey, lightning-like, with their well dentated mouth and swallow it whole. Trichoptera, for instance, are gulped down with their "quivers" (shell case), which can be felt against the stomach walls by mere outside examination of the midriff section of the fish. On the other hand, carp will dig larger larvae out of their "cases". It is this mode of feeding, combined with the pointed (acrocarpous formation) of their mouth which makes it difficult for predatory fish to feed upon deeply imbedded organisms in the ooze of the bottom, and forces them to seek freely placed or moving forms.

In contrast to the predatory fishes, the Cyprinides (carp-like fishes) by means of their proboscis-like, extensible, toothless mouth, take up bottom animals from which the adherent mud is more or less completely spat from the mouth by backward rinsing motions. The frequent high detritus content of the intestine shows the incompleteness of the cleansing process. The carps, tenches and related fishes therefore show an excellent evaluation of mud-dwelling animals.

Size and body shape also play a certain role in the successful hunting for food. Certain fish are thereby enabled to make their way into vegetation thickets, explore shallow shores, etc. The pharyngeal teeth in fish (according to Wundsch 1931) serve merely to crush the food, and probably also to "peel" lupine seeds and expectorate the shells uneaten.

In regard to the <u>physiological abilities of perception</u>, we have to distinguish between "eye fish" and "nose fish", i.e. between fish that rely chiefly upon their sense of vision in their hunt for food, and those which are directed to their food by the olfactory sense and partly also by taste.

The following table, worked out by Wunder (1931), throws some light upon this question.

Table 2.

Species of Fish	Eye			Lateral Line			Smell			Taste		
	Att.	Cond.	Cont.	Att.	Cond.	Cont.	Att.	Cond.	Cont.	Barb.	Lips.	Mouth
Carp	(*)	(*)								*	*	*
Tench	(*)	(*)								*	*	*
"Blei" (Abramis brama)	(*)	(*)									*	*
"Döbel" (Squalius cephalus)	*	*							*		*	*
Trout	*	*		(*)			*	*			*	*
Minnows	*	*					*	*			*	*
Pike	*	*		*	*							*
Perch	*	*		(*)			*	*			*	*
Stickle-back	*	*										*

Att.: Attraction; Cond.: Conduction; Cont.: Control

Every trout breeder knows how greatly trout depend upon vision in their search for food. On the other hand, it is interesting to note that in case of eye trouble, followed by total blindness, the olfactory sense will replace the sense of vision to a great extent, and will enable the trout to search for food upon the bottom of the pond.

Investigations by F. Schiemenz (1924) and Harter (1920, 1930) have revealed the fact that fish distinguish very well colors, size, differences in light and also shapes with their eyes, and soon learn the characteristics of their preferred food along these lines.

The digestive organs--of which we cannot deal here--of carp and tenches differ fundamentally from those of trout. Hence, differences also exist in the respective processes of digestion.

The relatively long intestinal tract of carp, which has seven windings, is without a stomach, hence, minus acid producing and pepsin producing gastric glands. The reaction within the intestinal tract is about pH eq. 6.7 to 7.7 and the task of producing protein digestion is chiefly performed by enzymes, developed in the pancreas. This is important to remember since pepsin performs a better task than trypsine, especially in the case of proteins derived from chicken, blood, curd, sinews, glue and horn-like substances, etc.

On the other hand, some authors maintain that trypsine reacts especially strong in fish. This perhaps explains the practical experience that artificial food is badly digested by carp-like fish, if not 50 per cent, at least, of natural food is given at the same time. It has been pointed out at all times that the intestinal ferments of eaten aquatics are of great importance--aside from vitamin contents--to the digestion of carp-like fish.

In connection with this, the findings of Kruger are perhaps valuable. He found that an acid reaction (pH 5.4 to 6.2) is present in the intestinal tract of Daphnae, i.e. a prevalence of pepsinases, much preferred natural food of carp-like fish--have an alkaline reaction (pH 6.0 to 7.8). i.e., are digested by trypsine. Intestinal ferments of Chironomus larvae add to and increase the total amount of ferments present in the intestinal tracts of carp and this total trypsine concentration and presumably its stronger action on vegetation protein will lead to better digestion.

The pepsines of lower crustacean species will automatically lose their efficaciousness in the alkaline reaction of the intestinal tract of carp.

The observations of Pollack are to the effect that carp alternate--probably normally--in the feeding of lupines and of aquatics. Walter was able to prove that intensively fed yearlings, which completely neglected natural foodstuffs, would grow badly in comparison with fish on a strictly natural food diet, and under otherwise like conditions.

On the other hand, carp which began to be fed artificially in August, having been on a natural diet up to then, and simultaneously maintaining natural and artificial diet, grew decidedly better than carp that were kept on a natural diet altogether. The first-named ones kept up their aquatic's diet quite naturally, thus supplementing their food requirements.

Trout have a peptogenic and acidogenic stomach (ph in stomachs under 5); and its functions resemble those of warm-blooded animals of the higher order, i.e. it has the advantage of good peptic digestion. The gut is relatively short.

An important hint for the rearing and feeding of trout is the observation that pepsin in trout and pike retains its digestive power even at a temperature of 0 degree centigrade; at 15 degrees centigrade it is at its maximum of digestive strength and remains unchanged up to a temperature of 40 degrees.

Little is known in regard to the digestibility, i.e. the digestion coefficient of the divers components of natural foodstuffs (nutritive elements of food minus residual nutritive elements in excrements, as percentage of consumed food).

Knauthe has made food tests with carp of 600 grams weight, at temperatures of from 19 to 20 degrees centigrade, and found the following figures, anent digestibilities:

crude protein .... 69% to 92%
crude fat .... 84% to 96%
carbohydrates .... 30% to 92%

These figures correspond with the values for higher animals and humans. For practical purposes we may assume that the digestibility averages from 70 to 80 per cent, i.e. is the same as for higher animals.

It seems that the digestibility of crude proteins from aquatics is especially low, but this may be explained by the fact that the almost indigestible chitin is always considered together with the proteins.

Digestion tests made with hepatone-pancreas extract from carp--laboratory tests--showed a superiority over the pancreatine of cattle and the dependency of digestibility upon proper mastication of foodstuffs. The complexity of the latter factor, such as size variation of small food animals and significance of their own ferments, lack of mastication of food, variable percentage of fillers, possibility of inclosure in fat, etc., makes it difficult or impossible to judge the actual extent of evaluation in individual cases.

5. The Components of Foodstuffs, Kind and Amount, Required by Pond Fish

Considering the importance of the divers components of foodstuffs, it must be borne in mind that the natural foodstuffs are best suited for proper metabolic functions.

The value of prepared food is to be judged in the light of this fundamental principle and should be adhered to in regard to the composition of all prepared foods.

Organic Foodstuffs

Of all the consumed food, the organic foodstuffs come first in the order of importance.

The organic food substances are the most important constituents of the nutrition. These are first divided into the nitrogenous, albuminous, or pure protein substances; the fats and oils, and the nitrogen-free extract material (principally carbohydrates). Besides there are nitrogenous non-protein substances, among which are mostly unimportant amounts of completely digestible amides, all of which are added to the pure protein to make up the "crude protein".

The almost indigestible chitin can hardly be classed among food constituents, and may be classed together with plant fiber.

Within the metabolic cycle of fish, the proteins fulfill entirely different functions from the fats and carbohydrates. The digestible proteins alone supply the necessary body proteins for weight increase (growth). Neither the nitrogen-free fats and carbohydrates nor the amides and chitins can produce protein. It follows that the protein content in the available or supplied (prepared) foodstuffs is of utmost importance. To maintain proper reproductive anabolic functions, protein-rich foodstuffs are required, almost exclusively.

If we consider for a moment that reproductive anabolic needs stand to basal metabolic demands in the proportion of 1:2, we see at a glance that in the case of well-fed trout, the proportion between digestible proteins and digestible nitrogen-free food constituents--the so-called protein ratio-should be 1:2 at the most.

To simplify and to generalize matters, the following figures are not based upon this "protein ratio" but always upon the "Sustenance ratio", namely, the ratio between all of the digestible, nitrogenous foodstuffs (digestible crude proteins) and the nitrogen-free food constituents, such as carbohydrates.

This "sustenance ratio" in the present case, and which differs little from the "protein ratio" should not amount to more than Nh;Nfr eq. 1:2. (Nh: nitrogenous; Nfr: nitrogen free). Such is really the ratio in the case of natural foodstuffs (aquatic aliments), where the proportional rate is not higher than 1:1.8. (See table 3.) It is to be presumed that half of the diet of carp consists of aquatics, with an average Nh:Nfr proportion of 1:1. Hence, the remaining half of artificial food theoretically need only to have a Nh:Nfr rate of 1:5.

If the natural nutrition, such as Chironomus, has a sustenance ratio of 1:0.5, then it covers one third of the protein requisite of the total nutrition and the artificial food may have an optional food ratio. A particularly high protein requirement is assumed mostly in young fishes in the process of strong growth. There are only a few isolated exact researches as to whether the ratio of reproductive anabolism to basal metabolism is different for larger fishes. According to details given elsewhere in this book, this is not probable. In practice, however, younger age classes are frequently given relatively more protein, that is, food with narrower sustenance ratio than with older classes.

The following tables, 3 and 4, set forth the important total protein contents or digestible crude and pure protein of foodstuffs and the "sustenance ratios" as well.

The "sustenance ratios" were arrived at by converting the economic value of fats into the respective production rate of carbohydrates (through multiplication with 2.2, as done by Kellner).

In the case of aquatic food organism (insects, crabs, mollusks, etc.) and in a few other isolated cases, the exact evaluation of digestible nutrient substances could not be determined. Since the digestibility of the nutrient substances of food organisms is the same in all cases, we can assume that any eventual errors in these figures are negligible.

It must also be stated that we have to distinguish between three groups of "sustenance ratios" to wit:

(1) The low ratio .... eq. 1:2 to 1:4
(2) The medium ratio .... eq. 1:5 to 1:6
(3) The high ratio .... eq. 1:8 to 1:12

Trout require a very low ratio, while carp tolerate a medium and even high "sustenance ratio" in their food.

Lack of proteins is just as detrimental to the well-being of fish as an excess in proteins; it will lead to toxic conditions and especially to hyperacidity. Just as important as the sufficient quantitative amount in proteins is the quality of available proteins. Leguminosae and cereals—chief supplementary nutrients of carp—are especially poor in concentrated proteins. They are lacking in the aminoacids tryptophane, cystine and lysine, that is, precisely in these food substances needed for protein structure in the body of animals and for these reasons are indispensable for them. This is another reason for supplementing the additional diet of carp with plentiful natural nutrients. There is perhaps no purpose in considering an incomplete protein in the nutrient ratio, if the shortage can be equalized by proper admixture, because it must be theoretically without value for replacement and growth metabolism. It is quite possible that mixing of animal forage flours with vegetable products holds great promise in the culture of carp.

Carbohydrates and fats perform, in general, similar functions within the fish body by supplying the necessary energies for proper metabolism. They also serve for an increased deposit of fats.

These two-fold functions are performed in conformity to the "isodynamic alimentary law", whereby said functions may be likewise performed by either carbohydrates, or fats, or even by proteins.

The supply of energy (for metabolic functions) depends altogether upon the energy contents of foodstuffs and their possible utilization. The "energy content" is merely another word for "calories" or combustion value and will be found for all foodstuffs (including the proteins) in the accompanying charts.

In table 4, the caloric value is given in kilogram-calories. In table 3, figures, calculated by Geng have been used. These are somewhat lower than the figures found by practical experiments.

His figures are nevertheless still somewhat too high, since they are not based—like the figures in table 4—upon the calories of the digestible components exclusively and since, furthermore, the calories of insufficiently oxygenated waste products, (such as urea, methane, etc.) were apparently not deducted.

Table 3.

Biological constituents, Sustenance ratio and caloric values of aquatic foodstuffs of fish.

(According to findings by Geng)

Name of Aquatic Organisms	Live weight per unit (in milligrams)	Calories per unit (gram-calories)	Biological constituents of organisms							Sustenance ratio (Nh:Nfr eq.)	Calories per gram
			Water %	Raw-protein %	Protein %	Chitin %	Fat %	Carbohydrate %	Ash %		
Chironomus gregarius	5.23	3.42	87.18	8.21	6.21	1.77	1.40	2.42	1.03	1:0.7	654
" plumosus	21.72	11.95	88.28	6.63	-	-	0.51	3.08	1.50	1:0.6	549
Macrocorixa geoffroyi	89.90	131.4	71.97	14.11	6.37	7.74	4.50	8.09	1.33	1:1.3	1461
Phryganea grandis	584.6	1024.00	70.42	13.57	12.78	0.79	7.08	8.17	0.75	1:1.8	1752
Lisnophilus rhombicus	216.1	175.17	78.71	11.31	10.28	1.03	1.58	6.71	1.70	1:0.9	810
Lestes spec	95.6	113.37	78.76	14.89	-	-	2.82	2.35	1.17	1:0.6	1207
Agrion spec	30.06	24.79	83.80	11.07	-	-	1.35	2.14	1.63	1:0.5	853
Ephemera vulgata	47.65	46.5	82.06	11.37	6.56	4.75	2.92	2.80	0.92	1:1.8	975
Cloëon dipterum	9.5	12.68	77.32	13.05	-	-	5.96	1.87	1.80	1:1.2	1369
Perla cephalotes	305.6	261.4	83.44	12.33	-	-	1.17	1.07	2.00	1:0.3	855
Cammarus pulex	24.0	20.39	78.44	11.32	8.93	2.39	1.28	2.69	6.28	1:0.5	845
Carinogammarus	29.5	29.33	77.63	11.25	-	-	1.73	4.77	4.62	1:0.8	994
Asellus aquaticus	27.17	19.76	80.23	10.15	-	-	0.88	1.69	7.02	1:0.4	744
Daphne pulex	0.34	0.13	90.67	5.42	1.47	1.47	0.61	4.07	1.70	1:1	371
Sphaerium spec	69.7	21.91	75.75	3.06	-	-	0.26	2.89	18.04	1:1.1	314
Dreisensia polymorpha	310.9	87.56	56.02	3.41	-	-	0.24	1.62	38.71	1:0.6	281
Bithynia tentaculata	139.9	62.29	67.19	5.04	-	-	0.29	3.28	24.21	1:0.8	445
Physa fontinalis	88.2	73.78	82.19	7.92	-	-	0.73	7.92	1.23	1:1.2	837
Limnea ovata	87.2	26.71	76.57	3.84	-	-	0.69	0.57	18.33	1:0.5	306
Lenciscus	4620	4801.5	78.0	15.75	15.06	0.57	1.26	0.91	4.21	1:0.2	1039

Table 4.

Composition, Digestibility, Sustenance ratio and usable calories of fish foodstuffs.

(According to tables by Kellner; some figures by other authors; sustenance ratio and calories calculated, according to findings by the present author.)

Foodstuffs	Raw Material						Digestible Matter					Sustenance ratio (Nh:Nfr)	Usable calories per 100 grams
	Water %	Raw protein %	Raw fat %	Nitrogen-free extracts (carbohydrates) %	Raw fiber %	Ash %	Raw protein %	Protein %	Raw fat %	Nitrogen-free extracts (carbohydrates) %	Raw fiber %		Kcal
Vegetable foodstuffs													
Tubers													
Potatoes (medium)	75.0	2.1	0.1	21.0	0.7	1.1	1.1	0.9	–	18.9	–	1:17.2	76
Grain													
Barley (medium)	14.3	9.4	2.1	67.8	3.9	2.5	6.6	6.1	1.9	62.4	1.3	1:1.03	286
" (fodder)	14.3	12.0	2.4	63.7	5.0	2.6	8.8	8.0	2.1	56.7	1.1	1:7.1	276
Oats (medium)	13.3	10.3	4.8	58.2	10.3	3.1	8.0	7.2	4.0	44.8	2.6	1:7.0	249
Corn (medium)	13.0	9.9	4.4	69.2	2.2	1.3	7.1	6.6	3.9	65.7	1.3	1:10.0	318
" (sweet)	13.0	11.5	7.8	63.0	2.9	1.8	8.5	7.9	7.0	59.7	1.0	1:9.0	327
Rye (medium)	13.4	11.5	1.7	69.5	1.9	2.0	9.6	8.7	1.1	63.9	1.0	1:7.0	298
Wheat (medium)	13.4	12.1	1.9	69.0	1.9	1.7	10.2	9.0	1.2	63.5	0.9	1:6.6	300
Legumes													
Fodder beans	14.3	25.4	1.5	48.5	7.1	3.2	22.1	19.3	1.2	44.1	4.1	1:2.3	294
Lupines (yellow)	14.0	38.3	4.4	25.4	14.1	3.8	34.4	30.6	3.8	21.9	12.7	1:1.2	322
" (blue)	14.0	29.5	6.2	36.2	11.2	2.9	26.3	23.3	5.2	31.2	10.1	1:2.0	322
Soja beans	10.0	53.2	17.5	30.2	4.4	4.7	29.5	26.2	15.8	20.8	1.7	1:1.94	356
Oily seeds													
Palm kernels	8.4	8.4	48.8	26.8	5.8	1.8	8.0	7.8	46.5	22.5	3.5	1:12.8	534
Sunflower seeds	7.5	14.2	32.3	14.3	28.1	3.4	12.8	11.1	30.7	10.3	9.4	1:6.8	396
Olive stones (ground)	12.7	2.2	0.9	28.1	53.7	2.4	0.3	0.2	0.6	3.6	4.1	1:30.1	35
Other kernels													
Horse chestnuts unpeeled, fresh	49.2	4.3	1.5	40.9	2.5	1.6	2.6	1.5	1.2	30.3	0.8	1:13.0	139
Horse chestnuts unpeeled, dried	18.8	6.9	2.4	65.3	4.0	2.6	4.1	2.4	2.0	48.4	1.2	1:13.2	223
Mill by-products													
Barley fodder meal	13.2	12.6	2.9	65.4	3.0	2.9	9.7	9.2	2.3	60.2	0.7	1:6.8	293
Rice fodder meal	12.6	12.0	12.0	45.2	8.0	10.2	6.8	6.0	10.2	36.2	2.0	1:8.9	262
Rye fodder meal	12.6	14.5	2.8	63.5	3.6	3.0	11.0	9.9	2.0	61.6	2.4	1:6.1	309
Rye bran	12.5	16.7	3.1	58.0	5.2	4.5	12.5	10.8	2.4	42.9	1.7	1:4.0	246
Wheat fodder meal	12.6	14.3	3.2	62.9	4.3	2.7	12.3	11.0	2.9	52.2	4.3	1:5.1	294
Wheat bran, coarse	13.2	14.3	4.2	52.2	10.2	5.9	11.3	9.1	3.0	37.1	2.6	1:3.8	227
Starch by-products													
Potato peels, dried	14.0	3.4	0.1	68.2	8.8	5.5	–	–	–	56.6	2.1	–	220
"Maisena"	9.0	26.5	2.9	51.1	7.1	3.4	23.0	21.4	1.7	41.9	3.8	1:2.1	292

(Continued)

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Foodstuffs	Raw Materials: % Water	Raw Materials: % Raw protein	Raw Materials: % Raw fat	Raw Materials: % Nitrogen-free extracts (carbohydrates)	Raw Materials: % Raw fiber	Raw Materials: % Ash	Digestible Matter: % Raw protein	Digestible Matter: % Protein	Digestible Matter: % Raw fat	Digestible Matter: % Nitrogen-free extracts (carbohydrates)	Digestible Matter: % Raw fiber	Sustenance ratio (Nh:Nfr)	Usable calories per 100 grams Kcal
Brewery and Distillery by-products													
Beer mash, dried	9.0	25.5	7.0	42.8	12.8	2.9	19.3	14.1	7.0	25.7	5.1	1:2.4	265
Potato mash, dried	10.0	24.3	3.7	40.8	9.5	11.7	12.2	9.4	1.8	20.4	2.0	1:2.2	165
Corn mash, dried, light	8.6	28.5	10.4	40.1	10.2	2.2	18.2	14.9	9.7	28.1	6.8	1:3.1	298
Rye mash, fresh	92.2	1.7	0.4	4.6	0.7	0.4	1.1	0.9	0.3	3.7	0.4	1:4.3	23
" " , dried	10.0	18.5	8.2	47.8	16.2	1.3	9.7	7.8	5.1	23.4	8.1	1:4.4	207
Oil cakes													
Palmkernels, ground, fatless	10.9	18.7	1.6	39.1	25.4	4.3	13.8	13.3	1.5	36.4	14.0	1:5.9	266
Rape seed cakes	10.0	33.1	10.2	27.9	11.1	7.7	27.4	23.0	8.1	22.3	0.9	1:1.5	284
Sunflower seed cakes	9.2	36.4	11.0	22.9	14.0	8.5	33.5	30.5	9.9	16.6	3.6	1:1.2	316
Animal foodstuffs													
Blood [1]	81.0	18.3	0.2	–	–	0.5	17.5	–	0.2	–	–	1:0	83
Blood yeast [2]	9.0	68.6	0.7	13.6	–	5.75	Phosphorous chalk				–	1:0.2	375
Blood meal	9.0	83.9	2.5	–	–	4.2	72.2	71.7	2.5	–	–	1:0.1	355
Fish fodder meal fat, poor	12.8	52.5	2.1	–	–	32.6	47.3	45.6	1.6	–	–	1:0.1	243
Fish fodder meal fat, rich	10.8	48.4	11.6	–	–	29.2	43.6	40.1	11.0	–	–	1:0.6	296
Meat fodder meal	10.8	72.3	13.2	–	–	3.8	67.2	63.6	12.5	–	–	1:0.4	418
Shrimps, dried [1]	11.2	34.6	1.6	–	–	39.7	–	–	–	–	–	1:0.1	172
Heart [1]	71.5	17.5	10.0	–	–	1.0	15.6	–	9.2	–	–	1:1.3	151
Carcass meal	7.0	50.3	17.0	1.0	2.7	22.0	39.7	24.6	15.8	–	–	1:0.9	319
Veal, lean [1]	77.0	20.0	1.8	–	–	1.2	19.6	–	1.7	–	–	1:0.2	106
Liver [1]	72.4	20.0	4.0	–	–	2.0	17.8	–	3.7	–	–	1:0.5	114
Lungs [1]	80.4	15.0	2.6	–	–	2.0	13.5	–	2.3	–	–	1:0.4	82
Melolontha, fresh	68.9	20.9	3.8	chitin	4.8	1.6	14.4	12.4	3.1	–	–	1:0.5	93
" , dried	14.4	57.6	10.5	"	13.1	4.5	39.7	34.0	8.7	–	–	1:0.5	259
Mytilus, whole, fresh [1]	55.5	3.4	0.2	–	–	39.6	–	–	–	–	–	1:0.1	18
" , shelled fresh [1]	82.2	11.3	1.2	–	–	1.3	–	–	–	–	–	1:0.2	63
Spleen [3]	–	17.8	3.9	–	–	–	–	–	–	–	–	1:0.5	116
Horse meat [1]	74.2	21.2	3.4	–	–	1.2	20.8	–	3.1	–	–	1:0.3	123
Cottage cheese [4]	–	20.9	1.0	4.3	–	–	–	–	–	–	–	1:0.1	105
Beef, lean	75.5	20.5	2.8	–	–	1.2	19.9	–	2.6	–	–	1:0.3	114
" , medium fat	71.5	20.0	7.5	–	–	1.0	19.4	–	7.1	–	–	1:0.8	151
Codfish	81.5	16.9	0.4	–	–	1.2	16.4	–	0.3	–	–	1:0.4	79
Pork, lean [1]	72.5	20.2	6.4	–	–	0.9	19.5	–	6.1	–	–	1:0.7	143
Dried spleen [5]	4.1	72.7	18.1	–	–	5.1	–	–	–	–	–	1:0.5	491

[1] fig. by Koenig; [2] fig. by Johansen; [3] fig. by Rubner-Thomas; [4] fig. by Berg-Vogel; and [5] fig. by Probst.

After deductions made, according to these figures, we find the following economic values of the different constituents of foodstuffs for fish (according to Keller):

1 gram carbohydrate (nitrogen-free, digestible extracts and fiber........ 3.76 kcal.
1 gram fat (digestible raw fat).. 8.57 " .
1 gram protein (digestible raw-protein)................................ 4.63 " .

I have calculated these figures in the accompanying tables, although I realize that they will not be correct in certain isolated cases for pond fishes.

The necessary digestibility of consumed proteins has been sufficiently referred to. Be it said, though, that the calculated average digestibility of a food product can be considerably lowered, upon occasion, through boiling or steaming it, or by exposing it to excessive heat while undergoing dehydration (lupines, fish-meal, blood-meal and meat-meat, etc.).

By abundant feeding, fats may be converted--outright and almost unchanged--into "body fat". The correctness of this was lately proven by Wieber in regard to eels.

The "pointhead", feeding upon fatty, aquatic organisms has a fat content of 27 per cent, as against 12 per cent in the fish-eating "truncate" (Breitkopf, "large head" eel). And in conformity with the oiliness of the fat of aquatic organisms, the body fat of the "point head" (Spitzkopf eel) is richer in clein than the fat of the "truncate" (Breitkopf eel).

This explains, perhaps, why the flavor of maize is conveyed, so to speak, upon maize-fed carp. In regions where the taste of maize is disliked, such fish become less marketable.

But while the isodynamic law--of food conversion--is applicable generally; the metabolic reactions of the individual foodstuffs may be specific in the metabolism of fishes. Also, the amount of fat deposits depends upon certain individual factors, the age of fishes, for instance.

Czensny made pond fertilization tests at Sachsenhausen. He found that the percentage of fat (expressed in calories) rose in carp of from 500 to 600 grams weight from about 20 to 30 per cent; in carp of from 1,300 to 1,400 grams weight. Naumana found the following figures for fat contents:

Lusatia carp (yearlings) 1.09%
Galician " (3 to 4 years old) 13.81%

The fat rate rises in proportion to the amount of satisfaction of the nutritional requirement, as is shown by the following table for 3 and 4 years old Galician carps in various nutritional circumstances.

Stock increased by 50% .... fat rate 8.49%
" reduced by 50% .... " " 13.36%
Normal stock rate but intensive feeding 13.81%

The calories produced are therefore not always reliable as a true picture of the qualities of certain foodstuffs. Fish are even less liable to tolerate large amounts of fat than warm-blooded animals.

After consideration of pond fish requirements as to the qualitative composition of important organic food constituents and their mutual ratios, we now turn to quantitative consideration, in order to calculate some accurate figures, concerning the required total amounts in proteins, carbohydrates and fat.

These figures are far more difficult to calculate and compare in fish, than is the case with warm-blooded animals, since the metabolism of fish depends upon a number of variable factors (such as size and temperature) and some of which are difficult to determine and compare, such as the rate of locomotion, for instance.

I will attempt here, nevertheless, as an example, to calculate the daily total requirement in actual calories of a rainbow-trout of 100 grams weight, in order to show that it can be done, after all (the foodstuff components have not been considered).

As seen from previous figures, the <u>hourly</u> caloric needs of a rainbow-trout amount to 60 gram-calories per 1 square decimeter body surface and at a water temperature of 15 degrees centigrade, i.e., to 1.44 kilogram-calories per day. Thus:

Body surface .... 1qdm (square decimeter)
Water temperature .... 15°C. (degrees centigrade)
Calorie needs per hour .... 60 gcal (gram-calories)
Calorie needs per day .... 1.44 kcal (kilogram-calories)

It is possible to calculate the body surface of a fish according to the formula of:

$$0 \text{ eq. } 10 \times p^{2/3}$$

Here 0 stands for surface, expressed in qdm and p stands for weight in grams. In the case of a rainbow-trout of 100 grams weight, we would have the equation of:

$$0 \text{ eq. } 10 \times 100^{2/3} \text{ eq. } 21.54 \text{ qcm eq. } 2.154 \text{ qdm.}$$

Therefore, the daily caloric needs of this fish are (in state of hunger and at a water temperature of 15 degrees centigrade):

$$E \text{ eq. } 2.154 \times 1.44 \text{ kcal/day eq. } 3.1 \text{ kcal/day.}$$

According to Lindstedt, the metabolic rate—through feeding—increases by about 25 per cent, raising the needs in calories, per day, to:

$$3.1 - 0.78 \text{ eq. } 3.88 \text{ kcal}$$

Assuming a proportion of 3:1 between caloric needs and metabolic rate, we find that a rainbow-trout of 100 grams weight requires a daily calorie supply of:

$$3.88 - 0.97 \text{ eq. } 4.85 \text{ kcal.}$$

An analysis made by Koenig (table 4) shows that 1 gram of seafish meat or meat from warm-blooded animals produces 1 kcal.

It follows that a rainbow-trout of 100 grams weight and at a water temperature of 15 degrees centigrade requires, in round figures, 5 grams of seafish meat or meat from warm-blooded animals, i.e., 5 per cent of its own weight, daily. In other words, a "Food percentage" of 5 per cent and which has been found correct by practical experience, and for the purpose of commercial fish breeding (in waters of from 10 to 15 degrees centigrade).

Crude Fiber and Other "Fillers".

Crude fiber, such as cellulose, pentosans (semi-cellulose), lignin, cutin (the fatty substance of the cuticula) is present in almost all artificial, vegetable foodstuffs. These constituents are nothing but "fillers", and while lowering the concentrated strength of the organic components of supplied foodstuffs, they act at the same time as a roughage, thereby aiding the proper functions of the intestinal tract. An over-rich diet is not at all desirable.

The addition of sawdust, of potatoe pulp, etc. to artificial, nourishing foodstuffs has given good results in the feeding of trout. Bothersome ailments, such as inflamation of the bowels, cirrhosis of the liver have been thereby greatly reduced. On the other hand, an excessive addition of "fillers" and "roughage" greatly lowers the nutritive value of foods and reacts unfavorably upon the well-being of the fishes.

Water and Inorganic Substances (Mineral Matter).

Similar to "fillers" and "roughage", the water also plays a role in the proper concentration of supplied food. Insufficiently moistened forage flour often leads to severe inflammation of the bowels, although the layman may reason that fish have water at their disposal at all times. The mere fact that the natural food of fish contains from 67 to 91 per cent of water indicates that fish require a great amount of moisture in their food.

An excess of inorganic elements, kitchen salt, for instance will irritate the intestinal tract, and so will bones, not sufficiently finely ground.

The different constituents of foodstuffs should never contain more than 3 per cent of salt, and for fingerlings not more than 1 per cent since trouts are sensitive to salt.

On the other hand, the inorganic materials are of great nutritive importance for the upbuilding and maintenance of the skeleton, and will also counteract hyperacidity, caused by formation of excessive amounts of injurious acids from oxidation of proteins.

In this respect, recent investigations have shown that full benefits of vitamin A are dependent upon the absence of hyperacidity.

The necessary inorganic elements—as to amounts and kinds—are best assured where natural foodstuffs are available, as seen from the ash contents in table 3.

Vitamins

Although little is known, at present, concerning the chemical nature of vitamins, they are also necessary for the well being of fishes. Lack of necessary vitamins will lead to disorders in the nutrition and development of fish, and since there is no limit as to the growth of fish, they seem to require vitamins during all of their life time. But, as always in the case of new discoveries, the importance of the vitamins has been greatly over-rated and over-emphasized.

We distinguish between the following vitamins:

I. Growth-producing vitamin A. It is soluble in fat and present in butter, codliver oil and in many plants. With the exception of corn and soja beans, it is present in only insufficient amounts in cereals and legumes.

The fishbreeder should know that heat, in combination with exposure to air will destroy the vitamin.

According to Haempel (1927), vitamin A is absolutely necessary for the growth of young fish. It is best to omit intense feeding of lupine, barley, etc., to carp fry and one-summer carps.

II. Growth-producing vitamin B. It is soluble in water and is plentifully present in rice, oats, corn, barley, all legumes, seedlings, spleen, liver, heart, kidneys, and also in fruits and vegetables.

Lack in vitamin B will cause disorders in stomach and intestines, and will interfere with growth and will generally lower resistance.

Especially for trout fingerlings, vitamin B is of greatest importance for proper growth. Calefaction, combined with exposure to air will destroy these vitamins, and so will prolonged storage of dried foodstuffs. Germination will increase the vitamins again in lupines. Through feeding with germination lupines, Haempel could reduce the food quotient of 4 to one of 2.5 per cent.

III. Antiscorbutic vitamin C. Soluble in water. Found in small amounts only, in non-germinated grains and legumes, but plentifully present in fresh vegetables, seedlings, organic fruit-acids, also in liver, kidneys, brains, muscle tissue and milk.

It is unstable with heat, alkali reaction, drying and storage. So far as is known, vitamin C is of importance for older fishes.

IV. Anti-rachitic vitamin D and anti-sterility vitamin E. Both are soluble in fat. The first, under the influence of ultraviolet rays is also produced in the cutaneous fat of animals. Its lack will cause rachitic bone diseases. Light, for reasons given above, seems therefore to play an important part in breeding ponds. Vitamin D is said to counteract the otherwise nonhereditary degeneration of gills and fins.

Of vitamin E, little is known as yet, but it can only be of importance in older fish, like the "respiratory vitamin" (Atmungastoff Vitamin), formerly included in vitamin B.

Vitamins D and E are present in green plants, seedlings, eggs, etc. Vitamin E was also detected in spleen, liver, kidneys and heart. Both are almost completely absent in grains and legumes.

We must regard natural foodstuffs as very rich in vitamins, although so far researches, made by Americans, have ascertained only vitamin A contents in sea plankton.

Natural foodstuffs are superior to any and all other foodstuffs, and the resistance of carps and trouts, feeding solely on natural food is greater than the resistance of such fishes which are fed artificially in addition to their natural diet.

The need for vitamins is one of the main reasons why carp food should consist of natural food to the extent of at least 50 per cent. But, once again we wish to warn the fishbreeder against overrating vitamins, and for the reasons that even trout--even under intensified feeding conditions--will still find some natural foodstuffs. These contain all the vitamins necessary for their well-being. It is certainly erroneous to try to explain everything by a lack in vitamins.

Haempel, for instance, has claimed that the poor results from potato feeding (their food quotient is 20) is due to their lack in vitamins.

Now, Schemmert and Berg have found that potatoes contain vitamin B in sufficient amounts, are rich in vitamin C and even show traces of vitamin A. On the other hand, most grains (food quotient 5) do not show larger contents in vitamins B and A than potatoes and are entirely lacking in vitamin C.

The previously enumerated factors play certainly a greater role in pond culture than the vitamins.

Form and General Conditions of Foodstuffs

On account of the peculiar, anatomical structure of their head, fish can take food only in small chunks or crumbs. But, then again, the size of "chunks" is of importance. It was Schiemenz (1925), who introduced the law whereby fish of the same species will grow the better, the larger the single chunks, or crumbs of food. He made his researches especially upon carp.

He made his studies especially upon broodlings and found that freaks which fed upon real plankton--necessitating much activity--were far behind in growth, compared with equal aged brothers and sisters which fed upon chironomus. This has been verified in other fish species. For carp breeders this is of great importance from the practical viewpoint, since by purchasing of small, retarded stock carp, such "stupid" freaks are mostly bought, while when purchasing well grown or overgrown stock, the buyer usually acquires "intelligent" chironomus feeders.

It should also be remembered that fish food (after cooking) must not be given too warm, nor should it be deteriorated. Care is also to be taken that neither poisonous substances nor bone splinters nor indigestible ingredients (over-heated proteins) are mixed with the food.

Rancid fats contain free fat acids and will irritate the intestines of fishes, and decayed food is altogether injurious on account of:

(1) the large number of living bacteria it contains, and

(2) through the ptomaines and catabolic products, incidental to the metabolism of said bacteria.

Very important in regard to fish food--although still little known--is the taste (savour) and general wholesomeness of the food. The best of food, if merely designed from the viewpoint of nourishing qualities will give poor results if the fish is averse to it or cannot tolerate it very well.

E. Creative Forces and Conditions of Life in the Pond

1. The Catabolic Cycle of the Pond.

In contrast to "autotrophic" plants, fish, like all other animals are not constituted to convert inorganic nutriments into body-building, organic matter. Fish require a constant supply of organic substances in order to exist and to grow. They are dependent upon the catabolic cycle of plant life.

The natural foodstuffs of fish consist of aquatic organisms, called here aquatics, for short. Let us study, therefore, the catabolic cycle of the pond, namely the transformation of inorganic matter into organic substance, that is, into fish sustaining nutriments and their conversion back into original inorganic matter.

The accompanying sketch attempts to clarify the elementary principles of this cycle, but these only, since many details of it are still little known today. Under the influence of sunlight and summer heat, the plant, through its powers of assimilation produces organic substances out of inorganic, nutrient salts (nitrogen, chemical combination of phosphate, potassium, calcium, magnesium, sulphur, iron, sodium, silica, chlorine, water, carbonic acid, and organic substances. The source of energy here is sunlight and heat.

The plants, in turn, that is, the submerged water flora, such as algae and plankton—algae constitute--in the state of freshness as well as in the form of detritus of disintegrated organisms--the aliments of aquatics.

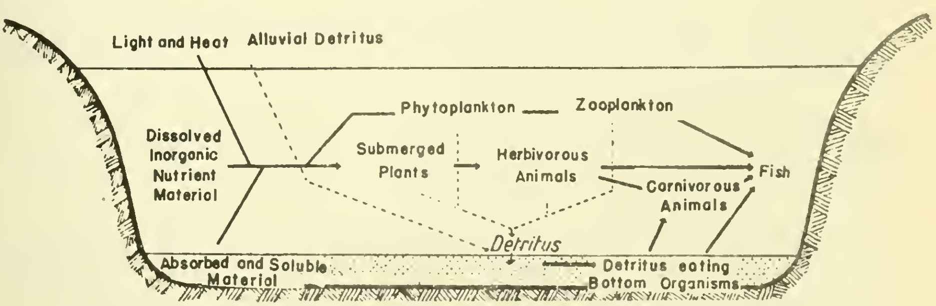

Fig. 5. Schematic view of the constructive part of the material cycle in the pond. The destructive activity of bacteria is not illustrated; it can start at every organic link and lead back to the original nutrient substance.

These in turn serve as food for other predatory aquatics—some of them are also eaten up by fish—and these again constitute the natural foodstuffs of fishes. We have therefore the complete cycle of:

Original, mineral (inorganic) nutrients
Original producers (the plants)
Intermediate consumers (aquatics)
Ultimate consumers (fish)

In addition to these we have further the reducing components of the cycle (not charted in our sketch for reasons of clarity) which conclude the process and bring back to their points of origin, all decayed organic substances. We may regard them also as consumers.

These reducers are chiefly bacteria, especially those leading to fermentation and putrefaction. It is through their respiratory labor—either aerobic or anaerobic, i.e., with or without oxygen consumption--that they gradually "mineralize" the reducible organic substance matter of plants and live organisms (carbohydrates, fat and protein) back into original, inorganic matter, therefore bringing to a close the whole catabolic cycle.

We have a perfect example of this cycle in the lake, which forms a unit and entity all in itself. We find there three well defined biological communities, to wit: Shore region, bottom (floor) region, and free-water region.

Shore region and upper (lighted) free-water region form creative, independent biological areas, where producers and consumers intermingle.

The bottom region, and also the lower (deeper) free-water region, are nonproductive areas, dependent upon the former for sustenance.

In contrast to the lake, and from the viewpoint of the above classifications, the pond is an out and out independent, biological community.

The reason for it lies in the fact that a pond is normally very shallow, so that light will penetrate to its very bottom, thus allowing for the development of plant life. In this respect the pond resembles the shallow shore regions of the lake, but not only upon its shores, like the former, but in its whole area. Life conditions in the pond therefore resembles and are as varied as those in the shore regions of the lake.

It would be quite insufficient though to speak of "shore plants" and "shore life" in the pond as is so often done.

In the pond also, we have to deal with three distinct biological communities, distinct from each other, but constantly reaching and cutting into each other's sphere.

Investigations by Pauly in Sachsenhausen have definitely established the fact that also in free-water regions of the pond, and between and within its flora, genuine plankton is to be found. That is, this form of small animal life which aimlessly drifts and swims around, devoid of will and oblivious to direction.

A second biological community consists of the higher submerged flora and of the "cover-algae", growing upon stones, upon poles and at the bottom and provides foodstuff for the numerous species of aquatic and of micro-organisms, and of which they are especially fond on account of the tender tissues.

All organic life found within the plant profusion or upon the "coverings" at the bottom of the pond is spoken of as vegetation animals. They will occasionally stray into the fresh-water regions but will always return to their base, which offers them sustenance.

The third and quite distinct biological community consists of bottom life, that is, the world of aquatic life dwelling upon the floor of the pond. Contrary to certain beliefs, this form of life is not only to be found in such spots which are free from vegetation but may be found, quite plentifully, near the roots of plants if other conditions of life are favorable. This is true especially of Chironomus plumosus, the most characteristic form of all bottom life organisms.

Some aquatics choose the hard bottom floor--destitute of organic life--for their abode and secure their existence by preying upon other forms of aquatic life. Ephemera vulgata, for instance, belongs in this class.

The most important and most numerous life forms of the pond floor are the mud organisms, which find their sustenance in the ooze of decayed organic detritus and which is rich in nutriments for these species.

This diversity of the enumerated biological communities makes the catabolic cycle somewhat complex, but figure 5 gives a sufficiently clear picture of the parallel course of each of the links in the chain of the cycle, and which finally leads up to the fish. Only a few less important details could not be included in the sketch.

The animal plankton, for instance, exists partly upon vegetable plankton but also sustains itself with dustlike detritus of many origins.

The cycle chain can be further complicated by an intermediary link, namely by the presence of predatory plankton forms (larvae of chironomida) for instance.

A continuous fluctuation of gain and loss in insects and insect larvae is caused by the falling of insects into the pond, by the laying of eggs of others into its waters, and also by the pupation of larvae, some of which fly off like so many of the water insects themselves.

Reference to the understanding of the catabolic cycle of the pond will occur frequently in later chapters. It forms the basis for rational exploitation, wherever the problem arises of exclusive or partial existence of fish upon natural foodstuffs.

All measures taken with a view to increase production mean nothing more than interference with the natural course of the catabolic cycle.

In order to do this in a rational manner, it has to strengthen the weakest link in the cycle chain "since this determines the strength of the whole chain" (Thisnemann, 1931).

All links in this chain are dependent upon one another and the degree of development of the living links depends again upon the existing average of external conditions of existence.

We have already thoroughly discussed the natural feeding of pond fish. It is therefore almost superfluous to emphasize again that the direct catabolic cycle chains of vegetation and bottom fauna are of greater importance than all others, especially these of the plankton.

The uncommon course (of the cycle) over detritus is of importance insofar as it makes detritus feeders independent from the course of development of plants. Although it is believed by many that an interference with the growth of plants is thereby avoided, I am of the opinion that this is of little importance. There are still plenty of plant feeders left to interfere with their growth, and on the other hand, the recuperative power and abilities of submarine flora--or of some of their parts--is really astounding.

The development of plankton is at times very irregular and without visible correlation to the productivity in fish meat.

It may be stated here, that the sum of vegetation and bottom organisms is the only reliable means for estimating the yield of fish meat. True, Pauly has found that all through the summer months there may occur a certain parallelism between abundance of plankton and greater yield in fish meat.

Just recently investigations made by me, and by others upon my request, at the hatcheries at Eberswalde, and also other experiences, are a confirmation of these views.

All measures to increase productivity must strive, on the one hand to improve the conditions for primary reproduction (of the kind of vegetation) and on the other hand, to provide a favorable condition of supplementary metabolism to the ultimate consumers, i.e., the fishes. It is not possible to directly increase the small life forms upon which the fishes feed.

Aside from these fundamental considerations for proper sustenance, it is necessary to have favorable conditions of existence for the different kinds of organisms, involved in the catabolic chain (sufficient oxygen, approximate neutral reaction of the water, absence of injurious substances) for the vital functioning of the catabolic cycle.

The means to achieve these ends are none other than fertilization, water conditioning, care of the pond, proper rate (limitation) of stock planting and feeding. (See chapters VI to VIII)

The links of the catabolic cycle of the pond rest ultimately upon the primary productivity of plants, the rate of which determines, in great measure, the rate of total productivity.

This primary productivity again is correlated to a great number of complex factors and our problem is to discover which of these factors exercises a controlling influence upon this productivity.

In regard to vegetable foodstuffs Liebig's law of minimums is still helpful here. This law, in its essence, reads as follows:

> "If one of the indispensable nutriments of plant life is present in only relatively small amounts (in minimal amounts), the total productivity will be lowered."

It has been proven that the pond is especially lacking in nitrogen and phosphoric acid combinations; therefore, any fertilization of the pond should tend to ameliorate this deficiency.

Thienemann (1926), by also taking into account other factors (light and heat) has formulated a general "law of effects of environmental factors" and which I partly quote here verbatim:

> "The mass development of an organism within a biological community is dependent upon necessary environmental factors which during its most exacting stadium of development (which has the least strength of adaptability) deviate the most from their optimum in amounts as well as in strength."

This means that an over-abundance of a certain factor may very well be detrimental to general productivity. Within a larger region, the different factors are mostly equally strongly or weakly developed.

In this respect, that is, from the "regional" angle, we differentiate first between:

Ponds and pond bottoms rich in foodstuffs (eutrophic) and ponds and pond bottoms foodstuff-poor (oligotrophic). Each one of these two groups has to be subdivided again into the following categories:

alpha-trophic
beta-trophic
ypsilon-trophic.

The division into foodstuff-rich and foodstuff-poor pertains originally only to the available amounts of nitrogen and phosphorus combinations.

But aside from ordinary "harmonious oligotrophy", we have to reckon, in pond culture, with a certain oligotrophy due to slightly acidulous water, that is, an overabundance of a certain factor and which plays a well defined role. Together with Naumann (1932), we speak in this case of "azidotrophy".

Aside from eutrophic and oligotrophic pond types, we have further the so-called "dystrophic" type, which is easily recognized by the yellowish-brownish color of its water, due to a rich, humus soil, a "brown-water pond".

Ein. Naumann (1928) has gone still further in the division of pond types, namely from a nutritive-biological angle.

He differentiates from geographical viewpoints and which determine the factor of warmth between ponds of temperate zones, ponds of arctic zones, and ponds of tropical zones. Within each group he differentiates again between autotrophic ponds and hetarotrophic ponds.

Into the last category--not directly producing organic substances but supplied with them from the outside--belong a great number of trade waste (sewage) ponds.

Other principles of differentiation--also in regard to nutritive physiology--are based upon the form of water supply, water percolation and upon the age of ponds.

I will deal with these questions later. Be it said, though, already, that newly planted ponds are much richer in foodstuffs than older ones. In the experimental station at Sachsenhausen, for instance, the newly planted ponds surpassed in productivity the ponds of secondary order by 43 per cent after fertilization even by 100 per cent.

Running water is also relatively richer than stagnant water, and will yield, according to their nature, from 2 to 10 times greater "crops".

2. Aquatic Animals in Ponds.

The small animal life of the pond, important for the alimentation of fish is determined by two chief factors:

(1). By the numerous and varying conditions of existence, and which are similar to these at the sea shore;

(2). by the periodical changes of replanting and drainage.

On account of the time and duration of various drainage procedures, according to the different kinds of ponds (nursing ponds, rearing ponds, holding ponds, and hibernation ponds), rather different aquatics are to be expected in the different kinds of ponds.

Also, the cool, rapidly flowing trout ponds differ from carp ponds, in this respect. We have a free-current loving (reophile) water fauna which prefers cool trout ponds, and a stagnation-loving (stagnophile) water fauna which finds the warmer carp ponds better to their liking.

In the following pages, we will tell briefly the most important forms of aquatic life, especially found in larger carp ponds which are drained during the winter months, and in which natural food plays the greatest role. Its natural history should be essentially known in advance.

Worms

Valuable foodstuffs are such bristle worms as Stylaris and Nais (of the Chaetopodae) which are often found upon Potamogeton vegetation and milfoil; also red mud-tube worms as Tubifex and Limnodrilus, which dwell in the mud.

Rotiferae

They are classified as plankton forms and as bottom forms. The former are more important and are used by the small and smallest fishes. In the eutrophic ponds of Sachsenhausen, Pauly distinguished groups which occurred predominantly in plankton only during one or several periods (Conochilus, Brachionus, Anurea); also the regular but sparing (Asplanchua, Synchaeta); and singly and irregularly occurring forms (Triarthra, Polyarthra, Rattulus and many others). The rotifers (Brachionus, Anurea and others) are likewise found regularly in the trout ponds.

Crustaceae

The higher (about 1 cm. length) crustaceae, ring crabs (Arthrestaca), flea crabs (Gammarus pulex, Carinogammarus) and water asellus (Asellus aquaticus) are found almost always in ponds, and the former particularly in trout ponds and in strong-current locations, the latter on plants and in muddy or slightly unclean places. Of the small, mostly 1 to 5 mm. sized vegetation and bottom forms, the lentil crab (Eurycercus lamellatus), the water flea (Sida cristallina) and various Cyclops species are particularly frequent.

Also found, but not exactly in large quantities are Ostracoda, Alopa species, Simocephalus and Daphne magna. They prefer small, freshly-planted or organically fertilized ponds. Some authors erroneously classify them as plankton forms, although they will dwell, now and then, upon solid objects.

Pauly, who investigated eutrophic ponds, found in carp ponds permanently prevalent pure plankton forms, such as the following: Bosmina longirostria, species of Diaptomus and of Cyclops (also their larvae, the Naupliae). Occasionally the following also are present: Diaphanosoma brachyurum, Daphne longispina, Ceriodaphnia and Polyphemus pediculus. Ceriodaphala especially is a typical representative of pond plankton, while other forms, prevalant in lakes (for instance Bythotrephes) are always absent in ponds. Therefore, we can really speak of a typical "pond" plankton.

Oligotrophic ponds are characterized by an abundance (between the middle of May to the middle of September) of the dustlike, upon detritus feeding cladocerae. On the other hand, Rotiferae are almost completely absent and Copepodae very rare. Animal plankton forms abound in summer.

Eutrophic ponds develop--during the summer semester--aside from vast masses of vegetable plankton, great numbers of Rotiferae, and which, according to Naumann devour great quantities of dwarfed forms of vegetable plankton, without hindrance by larger plankton plants.

While diptomus forms play a greater role, here, than in cligotrophic ponds, the amount of animal summer plankton is small in foodstuff-rich ponds.

Cladocaras become more rare when ponds go eutrophic, since their productivity is hampered by vegetable plankton. Exception is to be made, though, for strongly organically fertilized ponds, where Daphne and Sida forms get the upper hand in the beginning and retain it for some time.

Mollusks

Small and large mud snails (Limnae stagnalis, L. auricularia, L. ovata and L. glabra), also small plate snails (Planorbis vortex, P. albus and more rarely P. contortus) are found in almost every pond a short time after cultivation.

Scarce are Bithynia tentaculata, Valvata piscinalis, Physa fontinalis and other snails.

Nordquist and Jearnefeldt mention Limnae peregra in Swedish and Finnish ponds. This snail regularly invades trout ponds in Germany and multiplies extraordinarily within a short time.

Special attention has to be paid to this snail, on account of its poisonous nature. Even a small handful of them, thrown into a pail of water will cause cramps to fingerlings within five minutes, and will kill them within eight minutes (Wundsch, 1930).

Of clams, only Pisidiu, and upon occasion Spaerium will mostly be found in ponds.

Dragon-fly larvae

In every pond one will find all three categories, the short, broad larvae of Libellulidae, the slim, moderately broad Aeschnidae (up to 7 centimeter long at times), and the very slim agrionidae.

A short time after planting, one can follow their progress from week to week. The young larvae, especially of agrionidae, are to be found in all ponds during the summer months. Small forms of them compete for food with the fishes, larger ones will even prey upon fish hatch. Vast throngs of the biggest ones are revealed only at drainage time, when they are caught in the strainers.

Ephemera larvae

Together with chironomidae, they are most important foodstuffs in a pond. This is especially true in regard to the swimming forms of them, the Cloeon species, mostly hidden in plants. Also the Caenis species are to be mentioned. Less apt in swimming, they remain more at the detritus-rich bottom floor.

Stonefly larvae

Will be found—especially Neumura variegata--during the first period after spring cultivation in all trout and carp ponds, supplied by creeks and strong currents.

Neuropterae larvae

The predatory larvae of Sialis (Alder Fly) species are found in all mud deposits of the pond.

Trichopterae larvae

Have also been found, quite often, in ponds; are only rare in newly cultivated ponds. Only the small forms like Leptocerus and Trisenodes attained mass developments in the carp pond in Sachsenhausen, which was repeatedly found also in the practical industries. The large larvae of Phryganea grandis are especially noticeable at drainage times, but their number is usually not large. Also "naked" (lacking the shell) predatory larvae are to be found, chiefly—naturally again—in trout ponds.

Diptera larvae

Fly and also mosquito and gnat larvae are of negligible importance. The limpid, planktonic larvae of Sayonyia rests mostly near the bottom surface, while the larvae and pupae of Melusina are to be found, often in vast numbers against the dike boards and other solid objects of trout ponds. Chironomidae, of all forms, are the most important and most numerous of all the aquatics, upon which fishes will feed. In both, carp and trout ponds, one will find representatives of the following species: Ceratopogon, Tanypus, Orthocladius, Cryptochironomus, Chironomus and Tanytarsus.

Chiefly to be classified among the vegetation fauna, and therefore possibly feeding upon spawn are—according to Nordquist (1923)--small forms of Orthocladius, of Tanytarsus and divers larger, red forms, i.e. Ceratopogon forms. All other forms are chiefly detritus feeders, dwelling in the mud.

Of multitudinous occurrence in carp ponds are mainly: Chironomus olumosus, C. thummi, Endochironomus, Polypodilum, Nicrotendipes, Paratendipes, Orthocladius, Glyptotendipes, Cryptochironomus, Tanytarsus, Ceratopogon; in small flowong trout ponds: Tanytarsus (Cregarious group), Tanypus (Sectio Tanypus), Microtendipes and Orthocladius.

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Water Bugs and Larvae (Notomectae)

They are found in ponds, almost always in numerous species and in vast numbers. Especially common and always present in divers species are Coprixae, of predatory habits and occasionally eaten by fishes.

The also comman and predatory back-swimming Notomecta appears shortly after cultivation, mostly as larvae, but as fully developed specimens in fall. Also other forms, such as Nepa cinerea, Ranatra linearis, Naucoris cimicoides, and Gerrida are spawn robbers and food competitors of fish. Notomecta, on account of its sting may even become a nuisance to the breeder himself, at the time of drainage.

Beetles and Beetle larvae

On account of their ability to fly, a great variety of beetles and beetle larvae are always to be found in ponds after cultivation. The true swimming beetles are food competitors especially noted are Dytiscus, Cybister, Colymbetes and Acilius, and they fry up to a few centimeters in length. Their larvae are especially voracious.

Spiders and Mites

The predatory water spider is to be found, in isolated specimens, in every pond; and mites are also to be found everywhere. Since fish will not eat them, they are merely food competitors. Spiders, on account of their size, go also after fish hatch.

The World of Lower Organisms in its Relation to Surroundings.

The following classification of lower organisms—from different viewpoints—shall illustrate where and when the different forms are available in ponds for consumption.

From the dietary-physiological viewpoint we can divide them into the following groups:

(a) Large plant feeders (Amphipodae, mud snails, most of the encased Trichoptera, caterpillars).

(b) Small plant feeders:

  (1) Eaters of plankton algae (animal plankton)
  (2) Eaters of algae sprouts (Stylaria, Sida, Eurycercus, Chironomida, Cloeon and similar Ephemera, Bythipia tentaculata).

(c) Eaters of detritus (animal plankton, Amphipodae, mud dwelling worms and Chironomidae, except Tanypus).

(d) Predatory aquatics:

  (1) Eaters of plankton (Chironomida species)
  (2) Eaters of vegetation fauna and of bottom fauna (nonencased Trichoptera, Phryganea, Ephemera vulgata, Sialis, Notonecta glauca, water beetles and their larvae, dragon fly larvae, Tanypus, water spider, mites).

Only some of the predatory aquatics are eaten by fish, as for instance larvae of Ephemera, of Sialis, of small dragon flies, of Trichoptera, of Sayomia and of Tanypus.

Others are merely food competitors since fish will not eat them (mites, water spiders and smaller Notonectae (water bugs), and still others, larger species, are rightly feared as preying upon spawn and hatch.

Biological classifications based upon necessary conditions for existence are of value for the following reasons: By surveying the stock of aquatics, eaten by fish, we learn the inherent characteristics of the pond. This again teaches us the diversity of aquatic life which is reasonably to be expected.

As regards adaptation to varying calcium contents and variable reactions, we have to differentiate between:

(1) resistance to lack of calcium and to a low pH content are Corixa, Cyclops, also Cloeon and some Chironomida larvae;

(2) sensitive to lack in calcium and to low pH content are Amphipodae and mollusks;

In regard to adaptation to pollution caused by rotting organic matter, leading to loss in oxygen, we have

(1) sensitive to faint pollution and trifling lack in oxygen the following: Amphipodae, dragon fly larvae, Ephemera larvae (also "stone-fly" larvae);

(2) tolerating moderate organic pollution and moderate lack in oxygen are the following: Stylaria, Valvata, Bithynis, Sphaerium, Daphne pulex, Asellus aquaticus, Sialis larvae, Notonecta, water beetles, Tanytarsus and other Chironomidae (also "Mueckenegel")

(3) tolerating very strong organic pollution and great lack in oxygen we find mud dwelling red Chironomida larvae and also "Schlammroshrenwuermer" (mud-tube worms).

The kind of the chiefly preferred habitat of aquatics frequently determines their discovery on the part of pond fish. Also, the knowledge of their preferred location permits to figure out, beforehand, the chances of fish planting under certain conditions, respectively will permit to improve same.

A classification as to biological communities has been made, already, when discussing the catabolic cycle of the pond, when we found

(1) free-water organisms (animal plankton),
(2) vegetation aquatics,
(3) bottom dwellers.

A division, according to the mode of intrusion of aquatics into the pond, during the yearly cultivation brings us to the discussion of the productivity of aquatics during the different seasons.

After more or less long intervals after cultivation aquatics appear in quantitative vast numbers.

(1) Through influx with the fresh water and from out of remaining puddles in the drained off pond (worms, mollusks, Podurae, spiders, mites, large insect larvae and all other forms, including fishes in small numbers).

(2) Through climbing out of the pond bottom, where they have hibernated (especially at the edges of the frozen layers), as in the case of Chironomus plumosis and mollusks.

(3) Through development of life forms which are resistant to frost and aridity of which are carried into the pond by the wind (Cladocerae, some Poduras, leeches and Rotatoriae).

(4) Through eggs, deposited into the cultivated pond by flying insects (Chironomidae, Ephemerae, dragon flies, Chrysopae).

(5) Through flying insects which are aquatics even when fully developed and which come winging over from neighboring waters (Notonectae, water bugs).

A repopulation after drainage is rapidly achieved and in many ways. As a matter of fact, aquatics are plentiful again, shortly after replanting.

It is for this reason that, personally, I do not believe that a two years' period of operation, as proposed by Nordquist, will materially increase the fertility in German ponds. The advantage, therefore obtained of greater preservation of aquatic life during the winter months has its disadvantages, to wit: It interferes with proper stock regulation and also will result in incomplete mud deterioration.

Also important for mass productivity of aquatics, aside from their mode of intrusion after the yearly drainage, is their rapid propagation, i.e., the rate of their generations per annum. Wundsch (1919) made the following classifications from this viewpoint:

(1) Forms of polyannual generations (large Ephemerae and Trichopterae, some species of dragon flies—Aeschnae—and a few large water beetles.

(2) Forms of regular, yearly reproduction (small Ephemerae and Trichopterae, most of the dragon flies, larger Chironomidae, gnats, genuine water butterflies, all Notonectae and mollusks).

(3) Forms of many yearly swarm periods (every month or every other month) like small Chironomidae, genuine flies, mosquitoes, Amphipodae.

(4) Forms of numerous yearly swarm periods (shore and bottom dwelling Cladocerae).

As regards Chironomus plumosis, the recent investigations by Potonie, concerning their yearly cycle—later contested—seem to attest one yearly swarm period, i.e one generation per annum. This period occurs especially during the end of the summer but stretches—with less intensity—all through the summer months, thus assuring a relatively regular colonization.

The generative periodicity of insect larvae is also dependent upon food and weather conditions. The better these are, the more swarm periods.

The possibility of many generations per annum exist in the case of Cladocera where parthogenesis during the summer months occurs. Their winter eggs form often only in the fall or—in the case of unfavorable conditions of existence—issue from fertilized eggs.

The discussed generative modus explains in part the following individual maximae, as formulated by Wundsch.

(1) Species of a spring maximum (water fleas)
(2) Species of an early summer maximum (larvae) of Chironomdae and of most Dipterae, mollusks
(3) Species of a summer maximum (larvae of Ephemerae and Trichopterae).
(4) Species of late summer maximum (larvae of dragon flies).

We have a characteristic example of the varying rate of productivity of fish food during the summer months in the larvae of Chironomidae, the principal natural "provender".

For a basis I refer to an investigation by Contag (1931), conducted for me at the hatcheries at Eberswalde. Its results are almost completely identical with investigations made by Wundsch (1919) in Sachsenhausen, who went about them by means of "stake scrapers".

Contag's investigations were carried out with "bottom scrapers", which is the most modern implements for quantitative examinations.

The investigation took into special consideration the influence upon the two-year-old carp, that were present in the pond, by measuring the productivity of aquatic organisms when the numbers stocked were varied.

The total amount as to number and weight of carp, of existing Chironomidae larvae, at different times during the summer, upon a given area is the result of fluctuating gain and loss, chiefly due to the following causes:

1. Gain

   (a) Numerical increase through influx.
   (b) Weight increase through growth of larvae.

II. Loss (numerically and by weight)

   (a) Through pupation of larvae, metamorphosis into flying insects and death.
   (b) Through consumption by fish and other aquatics.

Figure 6 shall give an illustration to the points under discussion.

Fig. 6. Number _____ and total weight in mg. of Chironomidae larvae per 200 square centimeter bottom surface, in four differently planted (as to number of fish) experimental ponds during one summer's season.

Pond 3: Normal stocking with two-year-old carp.
Pond 4: Four times above normal.
Pond 5: Eight times above normal.
Pond 6: Sixteen times above normal.

We see at a glance that in all four ponds, freshly flooded in April, the number of aquatics is still very small, three days after the flooding. Three weeks later, this number has hardly been tripled, although the ponds were still not stocked. This increase in number and weight—quite apparent since a decrease is hardly possible—is naturally prompted through influx and the favorable conditions of existence.

On April 22, the ponds were planted (stocked) with two-year-old carp of an average weight of 265 grams, and an excessive increase in number and weight is still at hand.

With the rise in temperature of the water and the growth of fish, the food demands of the fish increased more and more, as did the inroads made by predatory aquatics. The results are that the numerical maximum of Chironomidae is already reached between the middle of May and the middle of July.

The more fish we have upon a certain unit of surface, the sooner this maximum will be reached and at a so much lower point (pond 6).

Equally decisive factors causing the vary early attainment of a maximum are the pupation and hatching which proceeds with a certain suddenness with the entry of warm May days. Of course, the weight quantity of the Chironomidae larvae, which alone is sufficient for the nutrition of the fishes, rises numerically beyond the peak and advances until July, as the remaining larvae, due to warm weather, mature rapidly, before the progeny of freshly hatched midges again becomes noticeable in the pond.

At the beginning of August, though, a very marked slide toward a minimum of Chironomidae larvae--in number as well as in weight—becomes apparent. P. Schiemenz (1931) confirms this upon the strength of his own experiments.

The fishbreeder, for practical reasons, must prepare to counter balance this loss; he will now resort to artificial feeding and also will prepare the development of large Cladocerae through rational fertilization of his breeding ponds.

The number of Chironomidae larvae now remains more or less constant until September, i.e. upon a minimal scale. Increase and decrease are obviously equalized.

The grown-up fish now consume all, up to an always present unusable remainder. But, this remainder of not consumed aquatics is relatively small in comparison with the early summer months, due to a far greater voracity on the part of the fish, during the fall.

If the ponds are not all too greatly overstocked, a slight rise in the number of larvae and a somewhat greater rise in their weight occurs again by the end of September and the beginning of October.

The decrease, due to pupation and consumption now becomes less on account of the falling temperature. But a corresponding slump in the increase must also be taken into account.

It has just been mentioned that the non-consumed remainder of aquatics is inversely proportional to the amount of fish stock, kept in the pond at different times.

We notice a more rapid decrease in food-providing aquatics in pond 6 (Fig. 6), planted sixteen times above normal, than in the other and less densely planted ponds.

The part of aquatics, consumed in pond 6 was greater, while the nonconsumed remainder is smaller. This means that a larger stock of fish will exhaust the available stock of aquatics to a greater extent, in other words the consumption quotient, the evaluation factor or the food detection factor really rises in proportion to the amount of fish stock present.

Watching a feeding pigeon, we notice that it picks up a grain, here and there. It does not continuously consume the grains adjacent to each other. The same applies to fish which go after their food in a similar way, picking up and gulping down a morsel of food here and there. Consequently, the greater the number of fish feeding in such manner, the smaller will be the number of nondetected morsels.

But, at the same time, we learn from the chart (Fig. 6) that a complete cleaning up of available larvae does not result even from overstocking (16, 2 year carps per 100 sq. m.), not even at the time when further increase of this kind of "provender" is out of the question.

Although this was presumed by many authors, experiences have proven otherwise, just as P. Schiemenz has maintained all along.

On the other hand, it is possible that organisms that are more difficult to detect on the part of fishes, multiply more rapidly and fill the niches in the habitat. Thus, new colonies of larvae conform to the tendency of all living organisms and multiply in relation to existing conditions of life and of sustenance.

Therefore, we may assume that a thickly populated pond in the course of a year will produce--numerically--more aquatics than a pond of like biological production category but of lesser density of stock.

When examining the influence of amount of stock upon aquatic life, another point is finally to be considered. Attention was called to it already by Walter, but it has not been mentioned here so far.

The reduction in the nonconsumed remainder of aquatics--due to a greater density of stock--brings forth a secondary check in the development and perhaps also in the propagation of certain aquatics. Theoretically, one can even assume a reaction, stretching into the following year, although I have been unable to confirm this by experiment.

On the other hand, general conditions favor propagation upon the grandest scale, and a check in the case of larvae, for instance, is almost inconceivable. Hence, it follows that the nutritional conditions from the limiting factor of mass development and that in newly formed ponds the full productivity or crop of individuals will be produced in a few days in summer.

And then again, the development of individual aquatics will undoubtedly be checked with an increasing population of the pond, and for the simple reason that a vast number of aquatics will be eaten up while in full growth.

It is characteristic that we note in pond 6 (Fig. 6) a temporary absence of the large larvae of Chironomidae, which fish can hardly ever overlook. Even the individual weight of such a larvae--in July--is remarkably low in pond 6, in comparison with the other ponds. But altogether, one should not attach too much importance to such losses in foodstuffs. What has been stated here, especially in regard to larvae of Chironomidae pertains also, of course, to all other but less important aquatics.

Upon the basis of the discussed investigations, I set forth again a differentiation of aquatic productivity as a whole during the period of summer cultivation with regard to varying degrees of stock. Chart VII will illustrate the points under discussion.

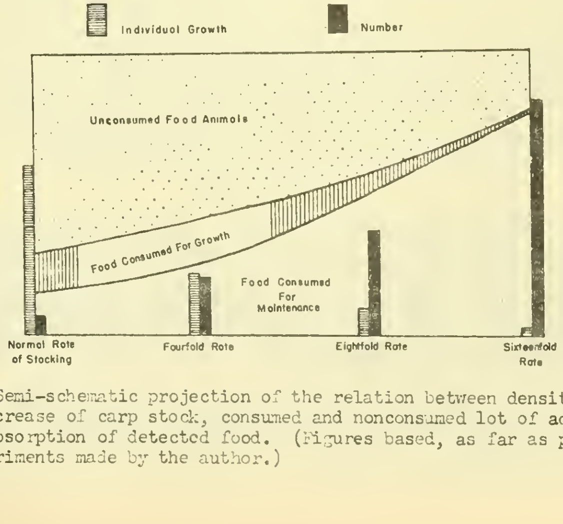

Fig. 7. Semi-schematic projection of the relation between density of fish stock, increase of carp stock, consumed and nonconsumed lot of aquatics, and the absorption of detected food. (Figures based, as far as possible, upon experiments made by the author.)

The ordinate shows the actual total aquatic productivity in the pond. The influence of the stock rate upon this productivity has not been considered; we deal therefore with like conditions all around.

At a normal rate of stock (individual increase at least 600 grams) only a relatively small portion of available aquatic organisms is consumed by fishes. Of this consumed amount 2/3 are used for mere sustenance and 1/3 for weight increase.

The individual increase rate is high but simply for the reason that the easy and slight exploitation of available aquatics only requires a minimum of effort.

Loss and gain of energy during feeding are in most favorable relations to each other in the individual fish, and at a lower rate of stock, would be more favorable still. The remnant of uneaten food animals, necessary for high individual growth, is called the "luxury requirement" by Walter.

As the rate of stocks mounts, a continuously increasing portion of available aquatics will be consumed. The reason for this lies in the fact that with increasing density of population the feeding area of the individual fish becomes more and more restricted, thus facilitating its detection of available aliments.

But the rate of exploitation of the "aquatic pastures" does not rise in proportion to the density of fish population. As this density increases—and with it "food detection", for the above stated reasons—the opulence of available "aquatic game" decreases. Finally, the hunt for food does not pay any longer, since the caloric value of the thinned out and scanty food supply does not compensate for the loss in energy, expended in the hunt. At a moderate rise in stock (four times above normal), conditions remain very favorable for the total growth increase. They are even better than at a normal rate of stocking, since the sustenance requirements of the individually smaller fish do not increase as rapidly as the ratio of consumed aquatics to unconsumed remains.

At eight times the normal rate of stock, conditions become very unfavorable, and at sixteen times above normal, almost all of the consumed amount of aquatics goes for mere sustenance of the fish. There is practically nothing left to further their increases, and the individual increase slumps down to zero. At all events, it is worthy of note that in ponds of the 3rd class yield stocked with carp of an average weight of 300 grams (1,650 fish per hectar) there is sufficient natural food to maintain the proper weight of fish. This experience deserves consideration in wintering and artificial repression of fishes.

A very important practical question is whether at any time-point of the year the available supply of food animals (which could be determined by investigations of fishery biologists), would allow a conclusion on the productivity of a pond in question. Nordquist and others have disputed the possibility of that kind of "appraisal", but they have probably gone too far. By considering the above-described quantitative variations of the food animals, the customary methods of industrial practice, and the somewhat constant individual growth of the various age classes, the amount of food animals found by fish undoubtedly permits sufficient conclusions on the true production of bottom animals and thus on the yield, because under these conditions, the uneaten residue of the total food animal production is much larger than the eaten portion.

Lundbeck made observations on carp ponds, introducing what he termed the "normal" F/B coefficient, i.e. the normal ration of the yearly flesh production of fish (F) to the average amount of aquatic bottom life (B). This coefficient is in Berneuchen (a German fishery) about 3, but varies between 1 to 6.5. According to my own findings, in 6 small trout ponds, the coefficients amounted to 5.8 and 9.9 on the average during two years. According to Lundbeck, the F/B Coefficient drops with rising individual growth, so the correctness of pond operation is better determined by the individual growth. For ponds, the F/B Coefficient is of no practical value.

The absolute average quantities of aquatics per square meter are not very well known, at present and vary no doubt according to the qualitative composition. From researches made at Eberswalde and (by Lundbeck) in Berneuchen, it was found that ponds of the II and III production rate (100 kilograms per hectar) had an average of from 2.5 to 5 grams of "exclusive food aquatics" per square meter, i.e. from 1,250 to 2,500 individuals at Eberswalde.

In the trout ponds at Eberswalde, with a II and III class production rate (30 to 70 kilograms per hectar) were found about 1,000 aquatics per square meter of a weight of 5 grams.

The fish biologist is familiar, of course, with the methods of such investigations. For the practical fishbreeder, we recommend the use of a certain net, as furnished by the National Hatcheries at Berlin-Friedrichshagen, by means of which he will be able to ascertain the relative fertility of his ponds and also their varying productivity at different times.

This knowledge is especially valuable in regard to hatching-ponds.

3. The Flora of the Pond.

From the viewpoint of biology and with regard to pond-cultural importance, the flora of ponds may be best divided into the three classes of:

(1) Surface plants

(2) Floating plants

(3) Submerged plants

Surface plants

The surface plants are rooted in the bottom of the pond and their leaves and floral shoots rise far above the water level. It is for this reason that they choose—preferably—the more shallow parts and shores of ponds. Almost without exception, the surface flora is noxious from the viewpoint of pond culture, therefore should be kept down and for the following, principal reasons:

(1) They contribute to "Delta formation" by raising the bottom of the pond (especially bull rush, reed mace, horsetail) or by starting floating lawns which eventually will also raise the bottom by sinking down to it.

(2) They shade the water to such an extent that ponds (or parts of it) covered by them make development of fish and productivity of aquatics practically impossible. Also the oxygen content of the water is often reduced by the growth of these plants.

(3) They make it difficult for fish to find their food, even in not too-thickly overgrown ponds. In this respect we quote the findings of Lundbeck, who arrived at the following figures for bottom aquatics—nonconsumed because not discovered—in all of the ponds in Berneuchen:

Upon clear bottom	6.28 gram per sq. meter
In case of submarine flora	6.41 " " " "
In case of surface flora	8.29 " " " "

(4) They deprive the pond of valuable plankton and work it into almost non-decomposable cellulose, while their own decayed remnants form quite an amount of cellulose and by themselves. This mud finally covers the bottom in gradually thickening layers, and since it can hardly be decomposed even by mud dwellers, it is of no food value whatever and soon leads to desolation of the bottom. (In a nondrainable pond of only a few hundred square meters and which was thickly covered with reeds, I found a layer of cellulose mud of 1.30 meter thickness and a water depth of only 60 centimeter! And this condition is not unusual.) Also, extensive penetration of the bottom with roots reduces the productive layers of decomposed matterand thus makes the pond still more unproductive.

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(5) They make it more difficult to clear a pond of fish and also make proper supervision more difficult. A dying off of fish, for instance, may not be discovered and predaceous fish find hiding places and nesting places in the labyrinth of reeds.

Only a few welcome advantages of a surface flora can be quoted as against these many disadvantages, to wit: In cases of very sparse growth with only a few stalks arising out of the water, they will somewhat increase the chances for the development of aquatic life. It is also true that a not too dense border of reeds, along the banks of wind-exposed ponds gives the best protection against slides.

With regard to their noxious character, the various species of a surface flora are to be differentiated.

Most harmful of all is the "Böttcherschilf" (Typha latifolia and T. angustifolia) and the "Ditch Reed" (Phragenites communis).

Somewhat less "hard", i.e. of less cellulose contents are the "Süssgrässer" (sweet grasses), i.e. the Glyceria species, sedge and reed bent-grass (Carex species), also horsetail (Equisetum), bulrushes (Scirpus lacustris), flowering rush (Butomus umbellatus), calmus (Acorus calamus), arrowhead (Saggitaria saggitifolia), water plantain (Alisma plantago). For this reason they are not so harmful as the Typha and Phragnites species.

Floating plants

By this term I understand those plants which float upon the surface of the water and are rooted in the water, not in the bottom of the pond. They will be found in profusion only in wind-protected ponds (small tree-lined ponds in parks, etc.), rich in foodstuffs.

From the viewpoint of biological productivity, their presence is harmful since they shade a pond almost completely without offering any compensating advantages. The Lemna and Azolla species belong in this class, also the less frequent Hydrocharis. Winter buds of these plants will sink to the bottom—as in the case of so many submerged plants—and thereby will outlast even a winter drainage of the pond.

Submerged plants

Under this classification come all these larger plants (weeds, in the language of the fishbreeder) which grow chiefly under the water level, even if their flowers and floaters reach up to the surface of the water. And although bacteria-plankton, "coating" and "sessile" plants should come under this heading, they are practically not counted among them, since they form a group apart, on account of their specific adaptations.

This flora plays a rather helpful role, i.e. in at least 50 per cent of the cases, and for the following reasons:

(1) They are the natural food of many aquatics.

(2) They are the most important factor for the development of aquatics.

(3) They are the ideal haunts for the vegetation fauna.

(4) The softer species of these plants contribute to the formation of productive organic slime.

(5) The decayed plants are a first class fertilizer in the following year.

(6) The submerged flora largely supplies the necessary oxygen, which so often is of great importance in trout pond, winter pond, etc. The oxygen production of the surface flora is far below the amount produced by submerged plants.

Seydel, who has made investigations along this line arrived at these figures:

	Temp. in centigrade	Oxygen in ccm per liter
In thick growths of reeds	14.7	2.979
In loose Glyceria growth	16.8	5.974
In clear water	17.2	5.716
Between frog lettuce	17.3	7.739
Above water thyme	17.2	8.503

An excessive growth of submerged plants will become noxious, of course, especially with the development of large floating leaves, since this will shade the deeper layers of water, thus making the discovery of food more difficult for the fish.

Also, an excessive growth of submerged flora leads easily to an extremely high oxygen rate, to strong biogenic decalcification and to a pH rate increase, especially during clear days, factors which in turn may produce sickness among fish, especially gas bubble disease among the brood stock (fin rot, etc.).

It has also to be kept in mind that plants, during darkness, consume but do not produce oxygen. A thick growth of plants will therefore reduce the oxygen rate of a pond during the hours of the night. The minimum is always reached at daybreak.

Many submerged plants are lacking in roots and even root-bearing plants use them chiefly only for support (exceptions are the water lilies). As far as is known today, water plants receive all of their nourishment—for example, alkaline and phosphoric acid combinations—through the whole surface of their epidermis. This also explains that the development of a submerged flora depends almost entirely upon the nutrient contents of the water. (P. Schemenz, 1927). Their very presence in ponds is thus characteristic.

The most common and at the same time most serviceable submerged plants—characteristic for productive waters—are the different Potamogeton and Myriophyllum species, also Elodea canadensis, Ranunculus aquatilis and Polygonum amphibium.

Elodea, according to Ruttner, ranks first as to assimilating performance, hence of growth, and is at the same time most productive in oxygen.

Next in line come Potamogeton praelongus, Chara foetida, Spirogyra, Ranunculus and Myriophyllum.

Their needs with regard to water, soil, light and warmth are little known; on the other hand, we also find quite often different Characeae species in ponds and their needs are somewhat better known, thanks to recent investigations by Stroede.

He found that all Characeas species adapt themselves readily to chemical factors (thermic influences, draining, etc.), and he classified them—in regard to salt contents of water—into sweet water, brackish water and seawater species. Most common in ponds is Chara fragilis (Nitella syncarpa?), and which adapts itself to low as well as to very high calcium contents, provided that the pH rate does not fall below 6.5.

The Fontinalis species are more rare in ponds but peat moss (Sphagnum species) will cover the floor of ponds in enormous quantities, regardless of low or very high calcium rates.

Nasturtium, Veronica beccabunga—partly surface plants—and also the Callitricheae species may be regarded as "conductor plants" for good and productive trout ponds.

Filamentous algae and different other algae species found at the bottom of ponds lead us over to groups 4 and 5 of submerged plants.

In smaller ponds, the whole floor is often thickly carpeted with filamentous algae, especially during the month of June. And while numerous aquatics give preference to this algae carpet for their haunts, the felt-like toughness of it—on the other hand—does not allow even the smallest fish to enter into it. The hatch often becomes enmeshed in it,. and these algae are therefore rather a nuisance than of use.

Sessile plants

We have mentioned already—when dealing with aquatics—that sessile plants or algae, i.e. algae which attach themselves to submerged plants of a higher species, together with the algae "coating" of inanimate objects form the most important nutriments of aquatics that feed upon sessile plants. The remnants of these plants—as a valuable component of detritus—fulfill still another important task in the productive chain, and are therefore of decidedly positive value in fish culture. They are essentially THE productive factor, chiefly responsible for production increase and will enormously multiply after fertilization of the pond.

It was V. Alten, who demonstrated that occurrence, form and size of certain diatomaceae are dependent upon the phosphoric acid contents of the water.

The investigations of Willers have confirmed that the productivity of sessile algae of a pond is strongly influenced by the species and also by the nature of submerged plants, since the possibilities for their existance vary, according to the different plants.

Among the most important of sessile filamentous algae are the Cladophera species (as long as they are still young), and as most typical representatives of this kind of vegetation, we have the Gomphonema (in gelatinous threads) and Cocconeis species of the distomaceae group; the latter are to be found everywhere.

Plankton plants

Plankton plants or "phytoplankton" performs a twofold as well as productive-biological task.

(1) Phytoplankton feeds the plankton fauna (in its fresh state as well as after decay).

(2) It creates most extensively the fertile, fine-colloidal slime at the floor of a pond.

Phytoplankton is detrimented to the metabolic cycle only in exceptional cases, for instance, when through their enormous development the water becomes turbid (formation of "waterbloom", "Wasserblüte"). Really injurious to fishes is only the decaying waterbloom (through its oxygen consumption).

The plankton flora is divided into two classes: Net-plankton, ie. plankton which can be caught with the plankton net, and Dwarf-plankton (or nanno-plankton) which will slip through a net of even finest meshes. The latter was unknown for a long time. It is chiefly composed of small, autotrophic algae of a size up to 2/u (microns). It forms one of the most important nutriments of plankton feeders and also of the otherwise non-planktonic Daphnidae.

Pauly found that phytoplankton is almost absent in the spring but increases in activity in the height of summer, while in the fall, it even dominates the animal plankton. Fertilizer, especially the nitrogenous kind reacts strongly upon the propagation of phytoplankton (especially upon Volvox) but without greatly influencing its specific composition.

The most important and always present representatives of phytoplankton (in ponds) are the silicaceous algae Melosira and Fragellaria. Among those appearing at times in enormous masses are the Polycistis and the Volvox species, while blue-green algae—in the height of summer—are the typical "water bloom" producers. The number of species present in negligible amounts is very great.

Bacteria

In the previous pages we have dealt only with autotrophic plants, important from the productive-biological viewpoint and producing autotrophic organic substances. But aside from the flora of the pond, we have also to consider pond-bacteria and their destructive and conversion functions. The knowledge of these functions is absolutely necessary since the mode of treatment as well as of fertilization of the respective ponds is determined thereby.

The functions of the bacteria within the metabolic cycle are chiefly heterotrophic, causing destruction of organic substances, hence may be considered as "reducing agents", and for the simple reason that as consumers they also need organic substances for their existence.

The essential life conditions as well as the propagating possibilities for bacteria are so favorable in a pond, that they are found practically everywhere and in enormous quantities. The purest natural water can still contain 100 germs per 1 ccm, filthy water as many as 10,000, and very filthy water even up to a million and more. In fact, we can accept it as a rule that the multitude of bacteria is almost entirely dependent—aside from warmth—upon the amount of assimilable organic substance.

The pond-bacteria may very well be grouped together with the above named flora, since among them also we have free-floating species, sessile species—attached to objects or to higher organisms—and species which live upon the floor of the pond. Some feed upon dissolved organic matter, others upon solid organic matter.

The immensely important and useful functions of the bacteria consist in dissolving (mineralizing) dead remnants of organic substances, upon which process all vegetation depends. The lack of bacterial activity will lead to peat and morass conditions.

In the process of decomposition of organic matter, the most important nutritional item for plant life—carbon dioxide—is liberated. This in turn dissolves and binds calcium (and other substances) so that carbon dioxide—in combined form—is preserved for the pond and will thus aid in the assimilation of other important nutriments.

The nitrogen, contained in waste protein is decomposed into urea and ammonia through the activities of putrefactive bacteria and these substances again are converted into nitrite and nitrate through the activities of nitrifying bacteria. (Plants consume all nitrates with preference.) These biological processes are possible only in waters, rich in oxygen and non-polluted by organic matter, therefore, such process will take place to only a small extent in the uppermost mud layers of the pond floor and are of advantage by stimulating productivity.

The sulphur of proteins—when dissolved in the slime, is acted on by anaerobic putrefactive bacteria, under exclusion of air—undergoes the transformation into hydrogen sulphide (noticeable by its foul egg odor) and under the influence of air oxidizes into sulphuric acid.

All detritus and morass—especially mud, containing cellulose—is most quickly and most completely dissolved by bacteria under the free admission of oxygen, i.e. through aërobic putrefactive and fermentative bacteria.

In thicker layers of mud, where oxygen cannot penetrate deeply enough, this dissolving process remains incomplete and leads to the development of marsh gas and other gases, but without reducing the masses of mud to any perceptible extent.

A more intensive and more complete disintegration of mud-products and of by-products is one of the purposes of the periodical drainage of ponds, since air becomes thus freely admitted and the work of aërobic bacteria intensively decomposes the intermediate and end products of anaerobic decomposition processes.

Here also, the temperature is an important factor. Kästli found in 1 ccm of pond mud, at a temperature of 3° centigrade, 55,000 germs (in round figures), at a temperature of 10° centigrade already 85,000, and at a temperature of 15°centigrade over 120,000 bacterial germs.

Notwithstanding our present-day incomplete knowledge of pond conditions, it is known, nevertheless, that in ponds are also found bacteria which are able to build up protein by extracting water soluble nitrogen. Lantzsch and Demoll have been able to show the presence of azotobacteria and of aminobacteria—the most important nitrogen "fixaturs"—in large numbers at the floor of ponds. They were rarer upon plants and totally absent in the water. Their development is favorably influenced through oxygen, slight alkaline reaction, fine colloidal bottom, slime with high organic contents, and also by phosphatic fertilizers.

But aside from their usefulness, pond bacteria may also exercise a noxious influence, and by this we think not only of the fish-pathogenic species.

The sudden introduction of dead organic substance, for instance, (organic fertilizer, mowed reeds, etc.) can provoke such a rapid, oxygen-consuming decomposition—especially in summer—as to consume all the water-soluble oxygen in a pond.

At the same time, the oxygen consumption on the part of the bacteria (which are always present in small amounts) outweighs their oxygen production and even the admittance of new oxygen from the outside. The consequence of this loss in oxygen is naturally the dying off of fishes, aside from many other disturbances of the metabolic cycle.

Loss of oxygen must therefore be prevented at all costs.

Through the presence of organic substances, combined with lack of oxygen the denitrating bacteria—especially *Pseudomonas fluorescens*—will further exercise a noxious influence by depriving the important nitrates of their oxygen and thus destroying them. Conditions for these bacteria are especially favorable under temperatures of over 20° centigrade.

We are thus confronted with a continuous struggle between nitrogen-fixing or nitrifying bacteria and denitrifying bacteria, and it is up to the fishbreeder to aid in this struggle so as to favorably influence the productivity of the pond.

Unfortunately, at present it is known in only rudimentary fashion that he can accomplish this by carefully controlling the necessary oxygen content, (especially in summer), and through proper care of the pond floor.

4. The Water

Fundamental requirements

Two fundamentally different requirements confront the fishbreeder with regard to the physical and chemical conditions of water, which is, after all, his most important stock in trade.

(1) The water must offer the fish (as well as all other productive-biologically important organisms) the most favorable conditions of existence.

(2) The water must contain the necessary nutriments, needed for production and especially primary production, in best possible optimal amounts, or they must be regularly renewed from the outside or must be replenished through decomposition processee within the pond.

These two fundamental requirements overlap each other in many instances, so that it is almost impossible to deal with them separately. It is for this reason that we will discuss here the requirements for the different factors.

The pond-cultural most important properties of water: depth, shore conditions, movement of the water, in their relations to the factors of light and warmth.

The relatively high productivity of the pond is due—in greater part—to its shallowness, which allows the penetration of light down to its very bottom and at the same time facilitates the rapid warming up process of the whole mass of water. Based upon these theoretical considerations, the depth of the water—in practice—has quite often been calculated too low, with resulting bad shore infringements and which led to costly upkeep. Excessive shallowness of ponds is even impractical from the strictly productive-biological viewpoint.

The investigations of Ruttner on lakes have shown that the assimilative functions of submerged water plants, i.e. their productivity does not lie directly under the surface of the water but in a depth of from 0.3 to 1.00 and even 2.00 meters. These investigations have also shown that the assimilative functions are regulated more strongly by the thermic factor, in a depth of from 1 to 2 meters, than by the factor of light, i.e. during daylight hours.

A third reason for not choosing below 1 meter depth in a pond is the fact that temperature changes are more pronounced in shallow waters, which of course reacts unfavorably upon productivity conditions.

Also, the greater the contact surface between soil and water, the more nutritional matter will be extracted from the soil, which means, of course, that the possibilities of existence—for flora and fauna—are vastly increased. It also facilitates a better warming up of the water. This explains the relatively higher productivity of smaller ponds and of all ponds where the proportions between shore line and water surface, the so-called shore quotient are especially great.

I need not mention here again the productivity-increasing influence of light and warmth and the productivity-lowering influence of shady shore trees, surface and submarine flora in carp ponds. But I will mention here—that aside from phytoplankton—turbidity of the water can also be caused through the rummaging feeding habits of carp through which the bottom of ponds is often greatly stirred up.

Motion of the water, especially in combination with renewal of water is also favorable to productivity, provided this motion is not too strong nor of unfavorable influence upon the temperature. In small trout ponds, a "through current" of water is absolutely necessary for hygienic reasons. Trout love a continuous "through current" of a certain force, but it is not absolutely required where the stock is kept at a rational rate.

On the other hand, such a "through current" may prove altogether injurious in case of certain diseases (Gyrodactilus). In large carp ponds, a too strong motion of the water may be dangerous to the dams on account of wave action.

The "through current" in trout ponds touches upon the space factor, which is very important in trout culture. Miller has shown that the size of hatching baskets plays a great role in the hatching process. Demoll has demonstrated that in the fattening process, ponds of 12 by 2.2 meters show less results in growth and worse utilization of food than is the case in ponds of 28 by 5 meters (at 1 meter water depth).

Now, the space factor is not something uniform (absolute); it must be divided again into separate factors. Free-swimming fish are influenced by:

(1) The total size of a pond, the so-called "run-out factor" (Auslauffakton) as Willer calls it. If this factor becomes too small, it will restrict the liberty of movement. In this respect we wish to call attention to the fact

that the "run-out factor" is without influence upon the pike (in the aquarium in Berlin), since the pike remains mostly motionless. It really grows faster in the aquarium then in free waters. (The relatively higher water temperatur is also to be considered, here, of course.)

(2) By the space quotient, i.e. the ration of space to a certain number of fish (respectively of eggs). If this space quotient is too small, lack of oxygen, accumulation of excrements, unfavorable food competition, mutual irritation etc., aside from restricted liberty of movements will soon become noticeable, especially if these disadvantages are not compensated by an increased "throug current".

The pond-cultural most important chemical qualities of the water.

Existence and nutrition of the productive-biologically most important organisms of the pond depend upon the following basic-chemical substances, 11 of which are of real importance while 7 others are less important, to wit: Oxygen, hydrogen, carbon, nitrogen, sulphur, phosphorus, potassium, calcium, magnesium, iron, also sodium, chlorine, fluorine, silicon, manganese, iodine, arsenic.

Most of these substances are found in the water in sufficient quantities through contact of the water with the soil and the air (dissolved forms). Undissolved deposits of them come into the water from the outside, through a washing-out process of organic detritus Rain and snow are by nature very poor in those substances and consequently can become dangerous, even at a sudden onset of thaw.

The quantities of dissolved matter vary in the different regions, according to the properties of the soil, bringing about regional variations in the fitness and productivity of the waters.

The following substances fall mostly below the optimal limits: Calcium (peat and moor waters), nitrogen (in usable form), phosphorus (in most cases only fractions of 1 mg or of a few milligrams of phosphoric acid (P_2O_5) per liter will be found; under oligotrophic conditions—according to Naumann—up to 0.5 mg per liter only of P_2O_5 is present), and finally potassium.

Care ought to be taken to supply these substances, if necessary through fertilizer.

The fact, that the above named substances are present in combined (compounded) form is also of importance, and so is the form of their combinations. The presence in free form of these substances would lead to poisonings. They must be present in usable combined and productive forms, and the reaction of the water depends upon the nature of their available combination.

Some of these substances (phosphate, magnesium) are not only nutriments but also irritants which release special processes. And then again, the mutual ration of some substances such as (calcium and potassium-ions, for instance) is of importance, since combinations in which one of these substances predominates (in the above named one, calcium, for instance) have slight toxic effects. While they are nontoxic if present in proper ratio

The chemical analysis of water.

Water analysis by trained experts—a fish biologist or by the laboratory of a scientifically conducted hatchery—has to precede the construction of all new ponds, hatcheries, etc.

If water samples are sent to laboratories, it is recommended to take samples from different points of the pond and without stirring-up the bottom. Each sample ought to consist of at least 3/4 of a liter, and only clean, completely filled and well corked bottles should be sent in. They should be forwarded immediately after taking the sample. Proper description of the samples, the time at which they were taken and a description of local conditions, accompanied by a sketch should be included.

In some cases, where certain dangers occur regularly, the practical fishbreeder should be able to exercise a certain and simple control over the chemical conditions of the water. It is for this reason that we set forth here some of the principal chemical properties of the water, giving at the same time some information for their proper detection.

Oxygen content.

Oxygen is not only important for the existence of fish—their respiration—but also for the existence of all living organisms in the pond, with the exception of some species of bacteria.

Only water-dissolved oxygen is utilizable for respiration (i.e., the form in which it escapes by the boiling of water), but not the combined oxygen.

Now, in a pond, we deal with oxygen consumers—especially certain bacteria—as well as with oxygen producers, such as the green water plants.

The oxygen content of the water always tends to maintain a normal value toward the saturation point, and which varies according to variations in temperatures.

We have here the following figures for this "normal rate":

at 0 centigrade	14.57 mg per liter.
at 5 "	12.74 mg " "
at 10 "	11.25 mg " "
at 15 "	10.07 mg " "
at 20 "	9.10 mg " "
at 25 "	8.27 mg " "
at 30 "	7.52 mg " "

We see from these figures that a rise in temperatures causes a drop in the saturation points. When the saturation point falls below normal or rises above it, it leads to an interchange with the surrounding air, and at a more rapid rate, the greater the deviation, i.e. from normal, and the greater the surface of interchange in proportion to the volume of water.

This—in conjunctions with previous discussions—explains offhand why lack of oxygen is especially found:

(1) In the water of springs and in piped water (usually shut off from direct contact with the air for long periods of time) and where no plant life supplies new oxygen to balance the continuous consumption of it.

(2) In winter ponds without a current, shut off from air and light—through snow and ice—for quite some time.

(3) During the early morning hours of hot summer days. At such times, the saturation point is low and the "exhaustion" (i.e. the loss in oxygen during 24 hours and at a temperature of about 20 centigrades by complete exclusion of air and light), and the consumption of oxygen on the part of fishes and aquatics in high; in addition, the plants have not produced any oxygen during the hours of the night (due to lack of light) but have consumed oxygen.

(4) When putrefactive substances are present in the pond (waste waters from sugar refineries, from starch and cellulose factories, from breweries, etc. Sewage waters from cities, mowed reeds, hay, decaying algae and submerged plants in late summer), and especially in summer time and also shortly after the freezing over of the pond.

(5) In transportation of fishes in heavily loaded tanks of relatively small water surface, especially if this surface is not increased through occasional moving about of the containers, and when the water is too warm.

As mentioned already, a sufficient oxygen content is also desirable from the viewpoint of productivity. One of the most important problems—in time of danger—is to know what oxygen rate is critical for pond fish and what rate, if maintained for any length of time will eventually become deadly to them. Only this knowledge allows to properly determine the rational rate of oxygen. To generalize on the subject is impossible in practice—and we call especial attention to it—since the oxygen rate depends upon so many and constantly changing factors.

An oxygen rate of from 3 to 3.5 mg per liter is in general already disagreeable to carp, they flee from it. At a rate of only 0.5 mg per liter, carp and also tench suffer from excessive shortness of breath, which they try to alleviate through struggling for air, an effort, which they cannot long survive. An oxygen rate of from 5 to 5.5 mg per liter is critical—in summer—for salmon species. They begin to suffer from shortness of breath at a rate of 4 mg per liter. A rate of 3 mg per liter does not suffice for any length of time and when the rate drops to from 1.5 to 2 mg per liter, they will die within a short time. A still lower rate is only tolerated by them for a very, very short time.

For a simple oxygen estimation one needs:

(1) A bottle of uncolored glass of about 100 ccm capacity, with a properly fitting glass stopper. The fish biologist uses accurately graduated bottles, so-called "oxygen bottles".

(2) A solution of manganous-chloride $MnCl_2$—(60 g in 100 ccm. aqua destillata), in a dropping bottle - 8 drops = 0.5 cc.

(3) Caustic soda solution—NaOH—(50 g. of caustic soda to 100 ccm. of aq. dest.) in a bottle with rubber stopper (Careful! Strongly caustic!) and a graduated rubber-capped pipette marked to withdraw 0.5 cc. of fluid.

Manganous chloride solution and sodium hydroxide solution may be obtained in glass tubules, each containing 1/2 cc. of solution (measured and ready for use). The bottle is filled so completely with the water to be tested, that upon inserting the stopper, no air bubble remains behind. Then by means of the pipette 1/2 cc. of sodium hydroxide solution, the 1/2 ccm. (8 drops) of manganous chloride solution are added. Both additions must be made carefully (if tubules are used, they must be dropped in with the openings on top), so that the fluids sink to the bottom. The stopper is then replaced so that no bubble remains under it. By thorough shaking a precipitate forms which is white at first, but immediately changes to brown with the oxygen contained in the water, and of course, the more oxygen present, the darker is the brown. If no oxygen is present, the precipitate remains white. Ivory colored precipitate indicates at most 2 to 3 mg. of oxygen. A coffee brown precipitate indicates sufficient oxygen. It is best to make a comparison test with a second sample of known good water. The tests keep only a short time.

pH rate.

The natural reaction of any liquid, also pond water, may be either alkaline, acid or neutral. Formerly, such tests were made with color indicators such as litmus, which reacts with a blue color to alkalines, with a violet color to neutral and with a vivid red color to acid. Today, it is not only possible to determine the natural reactions, but to also determine the degree of acidity, or of alkalinity at the same time.

An alkaline reaction is present when the amount of hydroxyl-ions (OH-) exceeds the amount of hydrogen-ions (H+). In the reversed case, the reaction is of course acid while a neutral reaction is indicated by equal amounts of OH- and of H+ -ions. We have therefore:

$$(H+).\ (OH-)\ \text{eq.}\ K_w\ \text{eq.}\ 10^{-14}$$

which means the product of hydrogen-ions and of hydroxyl-ions in gramions per liter is equal to the electrolytic "dissociation constant" K_w, i.e. the amount of ions present in absolutely pure water, and which is practically unchangeable.

It is therefore sufficient to always know the exact amounts of hydrogen-ions to ascertain the reaction. In cases of neutral reaction, where the amount of (H+)-ions is equal to the amount of (OH-)-ions, the amount of hydrogen-ions will be equal 10^{-7}.

In order to avoid calculations with these bothersome small figures of the actual hydrogen-ion concentration, it has become the general custom to use the negative logarythm of these figures, i.e. for neutral waters the figure 7. This is spoken of as the hydrogen exponent or —for short and in general practice—is expressed by the symbol pH. Hence, we have

pH eq. 7 neutral reaction
pH $>$ 7 alkaline reaction
pH $<$ 7 acid reaction

A good pond water has usually a pH rate of from 7 to 8, i.e. a feebly alkaline reaction. This is chiefly due to the presence of dissolved calcium bicarbonate (the responsible factor for acid combination capacity) which is the salt of a strong base and of a feeble acid. If present in sufficient amounts, it will form—in combination with carbonic acid—an especial "regulator" (a Buffer, as it were) which will counteract too strong variations of the pH rate. A good pond water with sufficient acid combination capacity will not show any strong lowering or rising of the pH rate (under 6.5 or over 8.5).

In 1926, Schaeperclaus could show, for the first time that the water of numerous "lime-oligotrophic" (lacking calcium) ponds fisheries in heath and moor regions is of low acid combination capacity and has therefore a pH rate below 7.

Over and over again, these fisheries suffer from a dying off (acid mortality) of fish, caused by too high an acidity of the water, although there is no inflow of acidulous waters. The natural acids of the soil are sufficient to bring down the pH rate to 5.5 and in some cases to 3.5 during prolonged rains or when the snow is melting.

Schaeperclaus further more has shown that a pH rate of about 5 or less—if lasting for any length of time—will cause diseases of the skin of fishes and of the gills, and the fish will die eventually.

The more exact "acid danger point" for carp is a pH rate of 4.8, and which is deadly within a short time. Its rate, of course, depends upon various factors and is therefore somewhat variable. When iron is present, for instance, the "danger point" is somewhat higher. Other pond fish are similarly sensitive.

Sometimes a dying off of fish will suddenly occur in ponds where such calamities were never before observed. This has been especially observed after a re-forestation—with scotch pine or spruce—of the tributary water regions. It is reasonable to conclude that Pinaceae stands lead to an accumulation of organic acids in the soil.

The low acid combining capacity is then soon so completely exhausted that the pH rate drops sharply and the "danger point" is easily reached—especially in winter—and even surpassed.

It is hardly necessary to mention that ponds with a pH rate of little more than 5 acidotrophic ponds are little productive and therefore belong in the oligotrophic class.

But also a strong increase in the pH rate is possible and not only through inflow of trade waste but from natural causes, such as the consumption of carbonic acid through assimilating plants.

It is possible for water plants—in "lime oligotrophic ponds" when the carbonic acid rate is low on account of a lowered acid combination capacity—to so completely drain carbonic acid from the calcium bicarbonate contents that only calcium hydroxide (mild caustic) remains.

Upon the shores of the Müggel Lake, I could determine a pH rate of over 12, i.e. in the water above the growing submarine flora, and under the most favorable conditions of a water temperature of 31 centigrades and of strong sunlight.

The "alkaline danger point", which presumably lies around 9 was therefore certainly over-reached. Such conditions, of course, will normally occur only during the afternoon hours of certain days and under especially favorable conditions. The fish have then the chance to retreat into deeper waters until conditions become normal again during the night.

I wish to emphatically state that it is erroneous to presume that strongly calciferous waters have a high pH rate. i.e. are especially alkaline. Rather the opposite is true.

Highly calciferous waters merely maintain a more steady pH rate, around 7 to 8. The sufficiently high acid-combining power prevents pH variations.

At the hatcheries of the Forest Academy in Eberswalde, where the acid combination capacity varies between 3 and 4 (on account of a CaO- content of from 84 to 100 milligram per liter), I could mostly find a pH rate between 7.4 and 7.8, and never over 8.6 or below 6.95, although my tests were done regularly and even under extreme weather conditions (temperature up to 30 degrees centigrade). At a calcium CaO rate of from 150 to 200 milligram per liter, I always found a pH rate of between 7 and 8, as was theoretically to be expected.

For the fishbreeders use, we have condensed here our findings anent the importance of the pH rate into a short table. Statements with regard to "normal pH rate" in waters of different calcium contents will be found upon page 56.

Table 5.

pH value	water reaction	pond-cultural evaluation
9.0) 9.0)	strongly alkaline	Alkaline danger point. Can sometimes occur in summer and when the acid combination capacity (A.C.C.) is low, and in plant covered ponds. Addition of lime (CaCo 3) often to be recommended.
8.5) 8.0) 7.5) 7.0)	slightly alkaline neutral	Normal reaction and latitude of variation of good pond waters with medium and high A.C.C. addition of lime not necessary as long as limits not over-reached or disease germs not to be combated.
6.5) 6.0) 5.5)	slightly acid	Reaction of bad waters with low A.C.C. in heath and moor regions. Great danger of further lowering of pH rate. pH rate must be continuously watched. Addition of lime urgently recommended.
5.0) 4.5)	strongly acid	Acid danger point. A.C.C. always very low. Deadly for pond fish and their eggs if kept in such waters for any length of time. Should be dosed with lime immediately.
4.0) 4.0)	very strongly acid	Water unsuitable for fish breeding. A.C.C. negative. Improvement of water through lime almost always useless.

In all regions of low calcium water, the fishbreeder must know how to determine the pH rate and to constantly keep check of it. Of the many methods in use for such purposes, we recommend—as especially simple and giving sufficiently correct figures—the method by means of Merk's Universal Indicator.

One needs for this:

(1) Merk's Universal Indicator (to be had at P. Altmann). We recommend the phenophthalein indicator, according to Czensny which gives better colorings at pH rates of from 7.5 to 9.5.

(2) Glass tubes of 12 millimeter diameter or white porcelain cups (egg cups).

Add 4 drops of universal indicator to 5 cc of the test water. Like litmus, the indicator reacts with different colors, with this difference though, that its color scale is more finely divided than the litmus scale. With the aid of the scale as given here in table 6, (first published by Czensny in 1929) one can now determine the pH rate with an error of ± 0.3 to 0.5, i.e. sufficient for all practical purposes.

Table 6.

Color scale of Merk's Universal Indicator with added phenophthalein by pH rates of from 4.4 to 10.

Color	pH rate	Color	pH rate
red	4.4	blueish-green	7.6
yellowish-red	4.8	greenish-blue	8.0
orange	5.2	greenish tinted blue	8.4
orange-yellow	5.6	blue	8.8
yellow	6.0	blue-violet	9.2
greenish-yellow	6.4	light violet	9.6
yellowish-green	6.8	dark violet	10.0
pure green	7.2		

A still more exact pH test—up to differences of ± 0.1 in pH—is possible with Czensny's graduated colorimeter (also to be had at Altmann's). After proceeding as before, the colors are then compared with different glass tubes, graded as to colors and which color solutions are sealed into these tubes. The apparatus has been especially designed for fishbreeders use and is very handy and reliable.

To determine the pH rate with still greater exactness, i.e. differences of from ± 0.1 to 0.2, is in practice as well as for all pond-cultural purposes mostly nonsensical, since extremely slight variations will naturally occur and do not mean anything for practical purposes. Complicated apparatuses, so designed, are therefore impracticable for the fishbreeder.

The Hydrochloric Acid Combining Power
(calcium (CaO) and carbonic acid content).

The functions of carbonic acid and of oxygen in ponds are closely inter-related. Where green plants liberate oxygen, carbonic acid is consumed; where consumers and reducers use oxygen, carbonic acid is produced.

If, on the other hand, carbonic acid is considered with lime instead of with oxygen, the reason is that there is a much closer relation between carbonic acid and lime. (The relations between carbonic acid and magnesium are similar but these combinations are always present in only such negligible amounts that especial reference to them can be omitted.)

Calcium oxide functions as the regulator of carbonic acid economy and of the natural reaction of the water. This justifies a somewhat more explicit treatment of the subject.

Carbonic acid is present in the water in three different forms, as a free gas or in more or less combined forms, and everyone of these forms plays a vital role in the metabolic cycle of the pond.

We distinguish:

(1) Free, water soluble Carbonic acid (CO_2).

(2) Bicarbonate-carbon dioxide in combination with calcium bicarbonate ($Ca(HCO_3)_2$) which occurs in solution only.

(3) Monocarbonate carbon dioxide. It appears combined with calcium carbonate ($CaCO_3$) which is soluble in only small amounts (13 milligrams, corresponding to an A.C.C. of about 0.23) in carbon dioxide-free waters, but which is never present in waters containing free carbon dioxide, hence will normally be found—in concentrated form—only at the bottom of the pond and upon plants, as $CaCO_3$.

There exists a state of equilibrium in the ratio of carbon dioxide to calcium carbonate, and whenever unilateral changes occur, there is a tendency toward re-establishment of this equilibrium.

Tillmanns and Heublein (after Schaeperclaus, 1926) found that a certain calcium bicarbonate rate (practically proportional to the A.C.C.) corresponds to a certain rate of free carbon dioxide. In table 7, we have the figures as found by Tillmann and others.

Table 7.

State of equilibrium between bicarbonate-carbonic acid and carbon dioxide at different rates of hydrochloric acid combination capacity (A.C.C.) and the "normal" pH rate resulting therefrom.

A.C.C. cc. n HCl per liter	corresponding calcium content mg.CaO per liter	bicarbonate carbon dioxide mg CO_2 per liter	"corresponding" free carbon dioxide mg. CO per liter	pH rate
0.5	14	22	0.1)	8.3–8.0
1.0	28	44	0.6)	
1.5	42	66	1.3	8.22
2.0	56	88	2.3	8.10
2.5	70	110	3.9	7.97
3.0	84	132	6.2	7.83
3.5	98	154	10.0	7.69
4.0	112	176	16.0	7.56
4.5	126	198	24.5	7.43
5.0	140	220	36.0	7.31
5.5	154	242	49.0	7.22
6.0	168	264	63.6	7.14
6.5	182	286	81.0	7.07
7.0	196	308	101.0	7.00
7.5	210	330	122.5	6.95
8.0	224	352	147.0	6.90

An example will best illustrate the significance of these proportions and the mode of carbon dioxide regulation.

At an A.C.C. rate of 2.0—which corresponds with a CaO-content of about 56 milligrams per liter—the water, according to table 7 contains 88 milligrams per liter bicarbonate carbon dioxide and 2.3 milligrams per liter "corresponding" free carbon dioxide.

These normal proportions between the slightly alkaline reacting calcium bicarbonate and the slightly acid carbon dioxide lead to a "normal pH rate" of 8.1.

Now, if through the assimilation process of plants the water loses 1 milligram free carbon dioxide, the pH rate rises on account of this great loss in acid properties. At the same time, a certain amount of calcium bicarbonate breaks up into calcium carbonate and free carbonic dioxide until a new equilibrium, with a corresponding pH rate has been established.

The calcium carbonate is then deposited in concentrated form upon the plants or into the water—since only 13 milligrams $CaCO_3$ are soluble in carbon dioxide—free water—and sinks to the bottom of the pond.

The A.C.C. naturally drops proportionally; a biogenical decalcification has taken place. The introduction of caustic lime has the same effect, by absorbing carbon dioxide.

On the other hand, when carbon dioxide is produced so that the water contains more than 2.3 milligrams per liter of free carbon dioxide with a corresponding subnormal pH rate, the aggressive excess carbon dioxide dissolves the calcium carbonate—deposited upon the plants or at the bottom of the pond—into calcium bicarbonate. The A.C.C. rises until the equilibrium has been reached and the pH rate has become normal again.

A lime enrichment process of the water has taken place. In other words, we deal here with a reversible process which can be expressed in the following equation:

$$Ca(HCO_3)_2 \longrightarrow CaCO_3 + CO_2 + H_2O$$

(dissolved calc. bicarbonate) ⟵ (net undissolved calc. carbonate) (carbon dioxide) (water)

Such metabolic processes—in one or the other direction—take place continuously in a pond, and since this is the case one cannot expect the pH rate—just as the oxygen rate—to remain normal at all times, the less so since through the presence of other mineral combinations the pH rate can undergo slight variations.

Free carbon dioxide and bicarbonate carbon dioxide form a great nutritional supply for plants. For this reason, carbon dioxide can never reach a minimum, as long as the A.C.C. is sufficient (over about 0.6) and the pH rate is not too high. This fact was completely unknown 15 years ago and is even today still quite often ignored.

Naturally, the carbon dioxide supply is the greater, the regulation of its rate and of the pH rate the better, the higher the amount of bicarbonate, i.e. the calcium bicarbonate content with its corresponding A.C.C.

But the rise in the rate of bicarbonate carbon dioxide is not the only deciding factor here since—as shown by table 7—the "corresponding" free carbon dioxide rate rises at the same time and relatively even higher.

At an A.C.C. rate of 0.5, we have a proportion of 220:1, but at an A.C.C. rate of 4, this proportion of bicarbonate carbon dioxide to free carbon dioxide is only 11:1.

If the absolute content of "corresponding" free carbon dioxide is at the same time very high, the introduction or elimination of 1 milligram free carbon dioxide will react upon the normal proportions only very slightly. The maintenance of the pH rate in waters with a high A.C.C. (calcium content) is ultimately due to this circumstance.

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Before proceeding any further, we shall tell first how to determine the A.C.C.

In table 7, we find the A.C.C. in like proportions to the bicarbonate-carbon dioxide content or the calcium bicarbonate-content. As a matter of fact, and for all practical purposes, the A.C.C. expresses the prevailing calcium content of a water. It is quite true that small amounts of carbonate magnesium salts (also of sodium and of potassium salts), of humic acid and of silicic acid and of phosphoric acid compounds of alkaline earths, and of alkaline metals have a part in the A.C.C., but one can neglect them in practice. Through titration with hydrochloric acid, one may easily determine their amounts. Only in cases of a very low A.C.C. will they play a more significant role.

It can be regarded as an unwarrented, purely theor etical exaggeration when for these reasons the A.C.C. is disregarded as an unreliable measure for the calcium rate.

The estimation of the A.C.C. is based upon the elimination of carbon dioxide from the calcium bicarbonate by adding strong mineral acids (hydrochloric acid by agreement) to the water and through this process bring about the formation of calcium chloride.

To a certain amount of water (100 cc), one adds hydrochloric acid until the water becomes acid and the pH rate drops below 4.4, (when freed carbon dioxide does not influence the pH rate any longer). This is seen by the color change of methyl-orange, previously added to it.

The expressions "alkality" and "alkalinity", formerly in use for A.C.C. are misleading and should be avoided, since one may mistake them for the natural reaction of the pH rate. Still, they are made use of, occasionally, even in the written opinions of experts.

Identical with A.C.C. are the terms titration alkality, alkaline reserve, basic surplu and also—by dividing with 3.8—the term carbonate hardness.

For A.C.C. tests one needs:

1. A graduated glass of 100 cc.
2. A drip bottle with 1/10 normal hydrochloric acid.
3. A drip bottle with methyl-orange.
4. Wide mouth titrating flask, 200 cc. capacity.

Fill the titrating flask with 100 cc of water and add 3 to 5 drops of methyl-orange. The water takes on a yellow color. Now add—drop by drop—hydrochloric acid until the water turns orange-red. The number of drops, carefully counted indicates the rate of A.C.C

A more accurate titration apparatus for special use by fishbreeders was designed by Czensny and may be had with directions from P. Altmann. It consists of a burette with a pinch cock graded at 1/10 cc. It shows the consumption of 1/10 normal hydrochloric acid per 100 cc of pond water in cc, i.e. the hydrochloric acid combined as cc of N/1 HCl per liter of water. (15 drops equal about 1 cc but this should always be checked in cases of a requested expert opinion.)

An A.C.C. of 1 corresponds to 2.5 degrees of "German" hardness or 28 milligrams CaO per liter.

Every progressive fishbreeder should be able to make his own A.C.C. tests. The continuous checking of the A.C.C.—especially in calcium-poor regions—is indispensible for a progressive fishery. The proper estimate of the A.C.C. is equivalent to a proper estimate of varying calcium content.

From the above findings, we can deduce that a very low A.C.C. exposes a pond to a sudden "turning sour" of its water. At the same time, a very low A.C.C., even a medium one of from 1 to 2 causes a very low supply of "corresponding" free carbon dioxide (see table 7 so that one observes frequent changes in the pH rate and a relative lack of carbon dioxide. This, of course, lowers the productivity of a pond; it becomes oligotrophic, i.e. food-poor as P. Schiemenz has shown long ago.

Also, from the limnological side, Ein. Naumann has rightly placed a lime content of up to 25 mg. CaO per liter in the "oligo" stage, of 25 to 100 mg. CaO in the "meso" stage, and of over 100 mg. CaO per liter in the "poly" stage of the lime range.

In regard to the effects of a high calcium content, my own observations have made me arrive at opinions which greatly differ from those of other authors.

First of all, I do not agree that a high calcium rate brings about an especially strong alkaline reaction, i.e. raises the pH rate. Rather the opposite is true, as seen from table 7, and also by observation. <u>The pH rate is merely more constant, but the carbon dioxide reserve is much greater</u>.

I have also found that the supply of aquatics—natural fish food--is not lessened at a CaO-rate of over 100 milligrams, i.e. at an A.C.C. rate of over 3.5.

In the brooks of Baumberge in Westphalia, with an A.C.C. of 7, (Beyer quoted it as 6.1), I observed an extraordinarly high rate of productivity.

Also the blue Alpine lakes--of a reputedly high calcium content, causing lack of plankton--are not always so calciferous. The Christles Lake, for instance (in the Allgäu), and which appeared to me as extraordinarly clear has—according to <u>Lotz</u>—a pH rate of 2.4 and a hardness of 5.8 "German" degrees, which corresponds to a rate of only 59 milligrams CaO per liter.

I have not encountered a pond in my practice--up to now--which I would regard as <u>too rich in calcium</u>. In my opinion, there are no sterile ponds <u>solely</u> on account of a too high calcium content; at any rate, I do not know of any example of the supposedly noxious effect of too high an A.C.C. rate.

Table 8 defines once again the significance of an A.C.C. of varying rates.

Table 8.

A.C.C. n HCl/per liter.	Pond-cultural significance.
0 or negative.	Water strongly sour, unusable for hatchery purposes; adding chalk to the water unprofitable in most cases.
0.1–0.5 cc eq. 2–8 drops. (eq. 2.86–14 mg. CaO per liter)	A.C.C. very low, pH rate mostly below 7. Great danger of water turning sour and of the pH rate reaching the acid danger point. Danger of dying off of fishes, pH rate variable, carbon dioxide supply poor, consequently water not very productive.
0.5 to 2 cc eq. 8 to 30 drops. (eq. 14 to 56 mg. CaO per liter)	pH rate variable, carbon dioxide supply medium high, consequently mediocre productivity. No danger for the health of fishes, since a natural turning sour of the water is not to be feared.
2 to 5 cc eq. 30 to 75 drops. (eq. 56 to 140 mg. CaO per liter)	pH rate varying only very slightly, great optimal carbon dioxide supply, water very productive, health of fishes not endangered.
5 cc eq. 75 drops (eq. 140 mg. CaO per liter)	Rarely to be found, pH rate very constant. An alleged decline in productivity not proven, so far. Health of fishes not endangered.

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Iron and Poison Substances.

Iron is found as an accompanying phenomenon in "sour" waters, especially in sour springs of a pH rate below 7. For this reason, the presence of iron denotes a poorly productive water, although some iron is needed for the growth of plants. As soon as the water becomes alkaline and contains sufficient oxygen, the iron is precipitated as a red iron hydroxide mud. One can therefore get rid of it through airing of the water and introduction of chalk.

From the amount of ferric mud at the bottom of the pond, one can draw conclusions as to the iron content of the water.

Iron is very easily deposited upon the alkaline gills of fishes and also upon the eggs of trout, causing irritation and blocking of the respiratory channels. In other words, it becomes occasionally quite noxious. It causes necrotic white spots upon the gills of trout fry. Hence, it is important that waters feeding trout ponds and hatcheries be kept free—or freed—from larger deposits of iron.

With regard to the presence of natural poisons in the water, we refer once again to the elimination of Limnaea peregra.

Ebeling has shown that Thuja oil is leached out of the needles of arborvitae trees, causing cramps in fish and often killing them. Arborvitae should therefore not be tolerated in the neighbourhood of ponds.

Saponines, which are present in many plants (in horse chestnut trees, for instance) kill fish in even so small amounts as 5 milligrams per liter (0.5 to 1 mg. of horse chestnut), according to Schuring, 1925 and Ebeling, 1931.

Waste waters can bring many toxic substances into ponds; the most frequent injuries are caused through chlorine and phenols. Such substances cannot be detailed here, but the operator should consult fish biologists and institutes. Spraying of arsenic dust (from aeroplanes) has so far seldom caused death to fish, since the commonly used arsenic compounds (with the exception of Hercynia KÜ, RÜ F and VII and calcium arsenite) are hard to dissolve in water, according to Bandt. They will become deadly to the most sensitive fish only in amounts of 20 mg. As_2O_3 per liter.

The amounts, sprayed by aeroplanes are relatively small and a pond would have to draw its water from a wide area, undergoing spraying, in order to bring about a toxic concentration.

In regard to gases developed in the mud of ponds, only carbon dioxide and hydrogen sulphide are toxic (according to Bandt), but not methane (marsh gas). Altogether, gases are rather negligible, and to be found only in poorly kept reservoirs.

5. The Bottom of the Pond.

The nature of the pond floor is of no lesser importance—from the productive-biological viewpoint—than the water of the pond, and stands in closest relation to it.

The normal bottom of older ponds is distinctly divided into two layers, to wit: The chiefly mineral ground floor, i.e. the original bottom, and the overlaying mass of organic mud, which is the result of metabolic processes within the pond.

The task of the whole bottom is threefold, from the viewpoint of metabolism:

(1) Emission of nutritional matter from the underground into the water.

(2) Fixation and chemical combination of nutritional matter—either produced through metabolic processes or through introduction from the outside—and which by and by rejoin the metabolic cycle.

(3) Offering shelter and food to bottom fauna, especially to mud dwellers.

The first task is well known through the experience of all fishbreeders, that ponds of heavy soil, rich in food stuffs (eutrophic bottoms) yield larger crops of fish than ponds of lighter, i.e., poorer soil (oligotrophic bottoms). Sour (acideous) bottoms do not supply any nutritional matter but deprive the water of calcium and other substances.

It is for these reasons, that Ein. Naumann favors a regional division of pond culture, since ponds in oligotrophic scil make different demands upon the fishbreeder--with regard to treatment and improvements--than ponds in eutrophic soil. I should like to say that the facts have gone ahead of his ideas.

In Germany, at least, the methods of chalking and of fertilizing (organically and inorganically), of stock raising, of hibernation of fishes, etc. vary in the different regions of the land. Trout culture in Hannover is handled differently from trout culture in the central mountain regions and in the regions of the lower alps. Of course, it must not be overlooked that these important regional factors are not brought about by geological-mineralogical conditions alone. The economical environment also plays a role in those matters.

With regard to the influence of geological differences upon the natural productivity, opinions still differ. According to some, the difference of the water under different soil conditions is of preponderance, while according to others the conditions of the soil itself is the most important factor.

The same differences of opinions exist with regard to the matter, quoted above under 2. Personally, I am of the opinion that the differences in viewpoints are partly caused through insufficient studies in these matters, and partly through all too theoretical reasoning.

The colloid content of the soil, especially of the mud layer is undoubtedly a controlling factor for productivity. Colloid containing soil fixes or chemically binds the nutritional matter, created within the metabolic cycle, or the alimentary substances introduced from the outside. Due to its action, they become gradually reintroduced into the cycle on calcium precipitation.

Some experiences, such as the high production rate of new ponds, lacking in mud layers, seem to contradict the generally held opinions with regard to the importance of colloid contents.

But on the other hand, it is a fact that old ponds with a good layer of foul mud are more productive than equally old ponds without such layers. These mud layers quite often not only owe their productivity to the high colloid contents of the soil, but a good mud, formed from out of decayed matter (algae and fine detritus "gyttja" contains quite an amount of precipitated chalk, aside from absorbed nutriments.

In three neighboring ponds of a hatchery, where the inflow of water had an A.C.C. of 3.3 and a pH rate of 7.7, were found the figures, quoted in table 9.

Table 9.

Showing the calcium oxide rate and contents in organic substance of the soil of three neighboring ponds with like water supply.

No.	Size of pond in hectar	Soil conditions	Loss on ignition of bottom; % of the dry weight	Calcium oxide of the soil; CaO percentage of the "dry weight".	Natural increase in carps. Kilograms per hectar. Average of several years.
1	9.0	sandy, little mud.	10.59%	2.1%	140
2	4.25	black detritus mud.	24.09%	20.47%	300
3	4.75	much celluolose mud.	69.2%	4.37%	100

These ponds, up to then had been neither fertilized nor chalked, nor had the fish been fed.

In hatcheries with occasionally sour water (as predominating in Lower Lusatia, for instance), the calcium content of the soil is very low, often much below 1 percent. It is difficult to say how far the layers of detritus mud are of importance for the absorptio and adsorption of nutritional matter. It is also difficult to say to what extent these layers of mud offer shelter to aquatics and to what extent they are merely end-products, i.e. an index for high productivity.

It must be denied—although it is an ever recurring assertion—that the adsorbing and absorbing activities of the bottom mud are definitely proved by the fact that phosphatic fertilizers show strong after effects through the following years. It is also quite possible that especially valuable organic mud forms during the first year but is utilized to its fullest extent only in the second and succeeding years (by mud dwellers or through very rapid decomposition and reintroduction into the metabolic cycle).

On the other hand, the investigations of Lantzsch (according to Demoll, 1925) have demonstrated the importance of the bottom mud as a bottom "laboratory" of the nitrogen-fixing bacteria.

But whatever the case, the presence of an easily decomposing, organic mud, rich in colloids will best guarantee the maintenance of a relatively high productivity.

In connection with this, we emphasize again the exceedingly strong influences of the different species of pond flora, of the noxious effects of the coarse, slightly decomposing cellulose mud, and of a bottom over-run with the roots of surface plants. The species mentioned will eliminate the activity of the fine colloidal mud in every direction.

In order to preserve the characteristics and productivity of the mud—so important for the fishbreeder—we alternate between periods of mud producing (trophogenic) cultivation and periods of mud-decomposing, i.e. mineralizine (tropholitic) drainage of ponds. This procedure forms—as so often emphasized, the essential basis of rational pond culture.

At this opportunity, naturally the water holding power of the bottom, its workability, and many other production biological factors are indirectly of importance. A sowing of the pond floor, the production of a plant formation during the dry period, which may be carried out at the time of cultivation, accelerates the drying of the mud covered bottom and thereby the mineralization and production power.

The plants, through their roots draw much water, especially from greater depths, then evaporate it again. The thicker their growth and the longer they are allowed to grow, the better will the bottom be dried out and the better will it be aired.

The top layers will remain moist nevertheless, on account of shading by the plants. This is quite necessary for the completely (and favorably) changed world of bacteria, especially for the aerobic fission fungi, so valuable for the decomposition of cellulose.

Chapter II
CONSTRUCTION OF PONDS

In Germany the term "pond" is popularly misconstrued, so that it can no longer be exactly defined. It does not mean only small, only drainable or only flat bodies of water. In pond industry the "fish pond" always signifies a drainable flat body of water; but also, the only conditionally drainable mill-ponds, hydraulic-hammer ponds, fire protection ponds, drinking-water ponds, and the non-drainable dammed ponds for power production, village ponds, irrigation ponds, park ponds, peat cuts, and other ponds should be included when possible in "pond industry".

Pond culture is profitable only under favorable fishing conditions, i.e., where drainage of ponds or fishing with nets is possible. Non-drainable ponds, with the exception of village ponds and of irrigation ponds (always supplied with organic substances) are little productive; hence, they are less profitable than drainable ones.

We divide ponds into the following classes:

(1) Non-drainable or at least not periodically water-covered ponds.

(2) Drainable, i.e., periodically water covered ponds, "fish ponds".

Only the latter will be considered for the following discussions on pond construction.

The fish ponds again are divided—according to the nature of their water supply--into:

(1) Spring water ponds (including underground-water ponds).

(2) Rain water ponds.

(3) Brook ponds:

a. Dike ponds
b. Feeder ponds

(4) River ponds.

Ponds under 3a are possible only in regions, free from the danger of floods.

When making a choice for the location of a pond, it should be kept in mind that a location upon sandy or muddy soil is profitable for the reason that such a soil is practically unusable for other purposes. Since the construction of a pond requires capital, such an undertaking will only be profitable if the pond ensures a better income than any other use of the soil.

The bottom must be not too porous, since an artificial packing with clay will be of benefit only in small trout ponds. At the point of dam construction, the underground must be solid and absolutely impermeable for water. Dam construction upon quick sand or upon filled-in ground is to be avoided.

Aside from small trout ponds—which occasionally can even be dug out and arranged regularly side by side, the location must be such that the investment for the rather costly dam is low in proportion to the ultimately obtained pond surface, so that interest and sinking fund may be recovered from the expected returns.

Most important is the water supply. Conditions of legal regulation by the Prussian Water Law of April 7th, 1913, must be clarified. Injuries to the over and under surface by the withdrawing of storage water or ground water must not occur. In such a case, in Prussia, an application for a grant must be placed with the governing committee of the district. A landowner may be granted the right to withdraw water from a water course even though his land does not border on it.

The next most important question is whether the amount of water is sufficient for the planned purposes. In all ponds, which are not to be intensively operated for trout culture, or practically ponds about 500 square meters or over, only a sufficient amount of water to replace losses by seepage and evaporation need be available. The water requirement varies greatly according to the season and location, and the average variation is about 1 liter per second per hectar of water surface.

In the case of trout ponds where fingerlings and adults are to be raised by intensive feeding, the necessary amount of water has to be correlated to the intensity of the feeding as well as to the quality of the water.

At lower water temperatures, and in very clear spring water, rich in oxygen, less "through current" is required than in warmer, less clean brook water.

In very actively conducted fisheries it is important to see that the whole mass of water is renewed at least five times daily (at least in ponds for adult trout), through a continuous inflow and outflow of water. Only then will the necessary "through current"—so greatly favored by trout—be created. For a pond of 100 square meters this means an inflow of 5 to 10 liters per second.

<u>The ideal is to use the water of a pond only once.</u>

Personally, I do not regard this as absolutely necessary. It would mean an inflow from 500 to 1000 liters per second, per hectar, and some of our most famous trout hatcheries (in northern Germany) would long since have gone out of business if such an inflow was an absolute necessity.

I know of one hatchery, for instance, covering a pond area of more than 3 hectar (about 9 acres) with an inflow of only 13 liter per second (in summer) and where the water passes from one pond into another in a continuous chain.

Another hatchery, noted for its good water, has an inflow of 100 liter per second for its 30 ponds, covering over 0.75 hectars. Fingerlings and 100 cwt of adults are produced in these ponds.

In the plains, 10, 20 and more ponds of 150 square meters each are run with an inflow of 20 to 30 liters of spring water and with best results.

It is practically impossible to generalize upon the subject. In all cases of new constructions, it is best to call an expert and to proceed slowly, in order to avoid costly repairs and to gradually adjust the whole project to prevailing water conditions.

The problem of water conditions once settled, one begins with designing the plan of the whole project intended. Here again, one cannot generalize with regard to the most favorable arrangement of the ponds, their size, etc. These questions have to be dealt with and have to be decided in each individual case.

According to the given conditions it must be decided whether carp ponds or trout ponds should be constructed. The depth and size of the ponds must be adjusted not only to the kind of fish to be grown, but also, to the manner of operation with brood, fingerlings, or other age classes, and according to the methods best suited to carp culture or trout culture individually considered.

As an example, we give in figure 15, the plan of a complete carp fishery and in figure 37, a view of the greater part of a trout hatchery in the plains of Central Germany.

In the case of small ponds, nivellation and construction can be undertaken without outside help and counsel. Larger plants call for the advice of an expert and of a construction engineer, specializing in such work.

Take for example, the case that a pond is to be constructed in a valley through which a small brook flows. The first requirement is that a sufficient flow is available. Only then can good fishing be accomplished; only then can diseases such as carp pox, contagious abdominal dropsy, and others be combatted. If this requirement is fulfilled, then the dam is projected at a constriction of the valley, provided the pond can be made sufficiently deep. The dam should be as short as possible. Where the brook will cross the future dam, will be the deepest part of the pond, here the outflow arrangement (sluice board) must be built in. From this point on, the vivellation is to be undertaken. Next a pole is hammered down perpendicularly, so that it extends as far above the soil as the depth of the pond is to be at the sluice (for carp ponds about 1 m. to 1.3 m.). Over this first and a second pole, (hammered in successively at different places in the circuit) a leveling staff is laid horizontally with the aid of a hydrostatic balance. By sighting in the direction of the future shore line, a helper is given the exact location in which to drive a marking stake. The procedure is continued by driving in the second pole at other successive locations until the entire future shore line is marked by stakes. If it is found that the pond is too small, or that the upper part of the pond will be too shallow, then a greater depth at the sluice must be chosen, or several ponds may be terraced above each other. The banks should be steep, sloped everywhere if possible, to provide a depth of 30-40 cm. at the shores. Only then will good pasturage and flight possibility be given to the fishes on the fertile shores.

In the construction of several ponds, each should be provided with separate inflow and outflow (see figure 15 and 37). This is very necessary in trout ponds and hatching ponds, because flowing water easily carries the most dangerous diseases, such as; gyrodactylus, furunculosis, dactylogyrus, gill rot and abdominal dropsy.

The dam is to be constructed so that the width of the crown is about equal to the height (a) of the dam. If the dam is to be used as a road for larger vehicles, it will obviously have to be wider. The height (a) should be such that the crown of the dam is about 30 cm. above the water surface; if the ground still sinks, the height of the dam must be further raised another 30 cm.; if the pond depth at the sluice amounts to 1 meter, then a height of 1.50 meters at least, should be chosen.

The normal profile of the pond dam is shown in figure 11. On the outer side, the dam has a slope incline of 1:1, on the inner side of 1:2. In small ponds and also when heavy ground is used, the inclination of the inner side can be increased up to 1:1. In large ponds, with strong wave action and light ground, the inclination must in some instances be lowered to 1:4. Before filling up the dam, it is best to mark off the profile with laths.

A loam core, such as was formerly used for every pond dam, is generally superfluous. Moreover, every soil material which does not contain too much decomposable organic substances; wood, foliage, etc., may be used for dam building. Even peaty earth, contrary to other statements, may be used for dam building. Rotting wood causes holes which make the dam leaky; also, stakes must not be driven into the dam. Clayey sand is the best material for dam building; too permeable a soil may be made usable by a mixture with humus soil. When using loam it is advisable to cover it with other material, otherwise, on drying it readily develops cracks and becomes brittle.

Before the filling of the dam, the territory on which it is to rest must be freed of grassy covering, of humus layers, and permeable soil, so that the dam rests firmly on the subsoil and cannot shift later. The removed grass sods are set aside and later are placed on the outer or inner sides of the dam. In the exposed subsoil along the median line of the dam "sole" a further 50 cm. wide trench is excavated. This excavated material is heaped on both rims of the trench. By this means the dam is more securely bound to the underground and it has a better rigidity and density (see figure 9).

The actual filling of the dam is to be avoided, if possible, during frost or when there is a heavy precipitation. Obstructive ground rises in the pond can be removed and used as ground material for the dam and by this means enlarge the pond surface. The transportation of the ground may be conducted over the nearly completed portion of the dam. The dam is thereby compressed and the dumping is made easier. The place in which the sluice is to be built remains exposed at first (see figure 12). In damp weather, that part of the finished dam which has not been covered by grass sods is sown with grass seeds (from the hay-loft). The planting of trees or willows on the dams is unsuitable. They shade the shores and make supervision difficult and lure dam-destroying rats, fish foes, and fish thieves. Rotting dead roots cause holes, and the roots of wind-swayed trees bring about the loosening of a dam.

The pond floor surface in a carp pond should be as undisturbed as possible, especially, since grassy coverings and humus layers remain. Their removal would make the pond unfertile. Before the pond is filled with water, only excessively high grass growth should be mowed off. A "fish skeleton shaped" system of ditches is laid out in the bottom, which allows a complete and thorough drying of the pond bottom. In the foregoing example, the original brook is used as the main ditch. On the inside of the dam foot there is a ditch to lead to the sluice, the excavated earth to be used for dam building. Lateral obliquely branching ditches must connect the deeper places of the remaining bottom surface with the main ditch, so that on draining no puddles remain, and the whole pond runs dry and all the fish are carried along by the outflowing water. In case of necessity, cavities in the pond bottom are to be filled in. Boggy and other bottom spots, which are raised up, form floating islands when the pond is covered with water, and are covered with other soil, as they cause an unfavorable productive biological action by shading and the formation of cellulose mud (see section VIII, B). Naturally the ditches must later be restored to order after each fishing out. The main fish ditch is particularly and carefully constructed in front of the sluice. It is advisable to widen the ditch slightly here and to fortify the banks of the ditch close to the sluice with fascines, so that the bottom is to some extent passable without stirring up mud during a fishing out procedure. Trout ponds are a certain exception, insofar, that for hygienic reasons the best possible bottom grading and sloping must be undertaken. Furthermore, the bottom must be as firm as possible. Fish ditches, on the other hand, are spared this.

It must again be particularly emphasized that the bottom board of the sluice must form the deepest part of the ditch and in fact of the pond (see figure 11). No deepening or so-called fish cavity of any kind is made in front of the sluice (see Eckstein, 1929), as such an arrangement greatly aged and formerly used in large ponds only hinders fish removal. In the cavity always filled with water, disease instigators and fish remain behind to endanger the regulated management in the following year. Also a deepening of the trench outside of the pond behind the sluice, the construction of a so-called sluicepit, is of no use and, therefore, should be omitted. By keeping single damming boards in front of the sluice, the water can be retarded or controlled at will until the fish have been removed, without later having a continually filled water pit remaining. In very large ponds the fish trench is strongly widened as closely as possible in front of the sluice.

In the above mentioned example, it is desirable to construct a so-called by-pass ditch, so that the brook water need not flow continually through the pond, and especially to prevent a flood from flowing over and endangering the dam. The ditch may branch off of the brook somewhat above the entrance of the brook into the pond; and the ditch may be so constructed as to run almost horizontally along the slope above the pond surface. A weir may be erected, if necessary, in the brook where the ditch branches off, or in minor circumstances, it will suffice to close the conduit to the pond with earth, if the water flow is to be partially or completely stopped. In the vicinity of the sluice, the by-pass ditch may be so constructed that it can provide holders to serve in fish removal.

If there is danger of the fish disappearing from the pond and into the brook, then the water inlet must be screened off. In the absence of a drop, several oblique grates (of parallel to stream rods) should be built, one behind the other, and in such a way that solid objects carried by the stream are automatically shoved up on the slanted planes of the sieves (see figure 9). Free swinging suspended grates, which allow swimming matter to disappear automatically, (Krause) can at times also be advantageous. The simplest way is to let the water fall into the pond through a clay pipe. In trout ponds, if the fall is very small, a horizontally placed screen on four rods is built in under the outflow of the clay pipe, thus preventing trout from jumping into the pipe. At the same time the water is finely divided and enriched with oxygen. Spawning ponds must be protected, if necessary, against penetration of fishes and fish foes, by means of gravel filters (Fig. 8) which are built in wide portions of the water inlet. Overflows for leading off water from one pond to another should be provided with horizontal sieves. They must be placed so that trout rising from the under pond can not injure their dorsal fins when they enter the overflow and get under the sieves. Naturally, glazed clay pipes may be built into the dam at the water level. They are closed at one end by attached sieves.

Fig. 8. A simple filter erected in the water inlet for the detention of fishes and fish brood and for superficial water cleansing.

Fig. 9. Overflow for connecting groups of trout ponds in series. The separation of the ponds takes place by horizontally or obliquely placed sieves of perforated or slitted metal sheets or by rod grids placed in the direction of the water flow. Each pond has its own sluice.

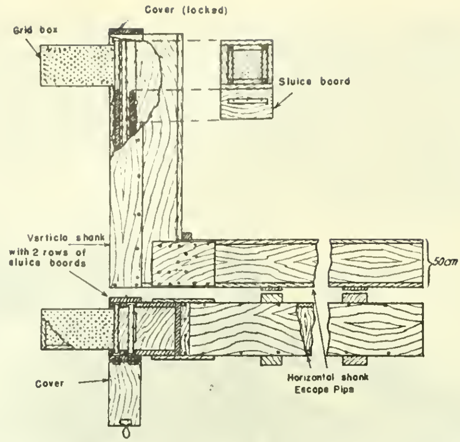

Fig. 10. Elevation and plan of a wooden pond sluice.
In very wide sluices, the single bottom board and the cover board of the horizontal shank, and the wall of the vertical shank, opposite the sluice boards, may be replaced by little cross boards fitted closely to each other.

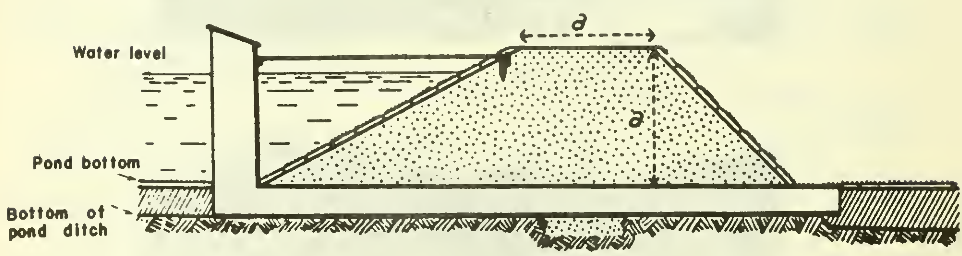

Fig. 11. ABOVE: Cross section through a pond dam with suitable and correctly built-in sluice. BELOW: Two hardly suitable types of sluice installation. CROSSLINED: Natural ground; DOTTED: Filled ground.

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Fig. 12. Finished wooden pond sluice being installed in a brook obstructing pond.

The completion of the pond construction lacks only the installation of the outlet arrangement, the sluice. The sluice (Fig. 10) is completely built before it is installed. It consists of a horizontal tube of rectangular cross section, which must be as long as the width of the dam bottom, and of a vertical shank of at least 30 cm. width, which is open in front (see Fig. 12). The little sluice boards are shoved down the vertical shank between two grooves (see Figs. 10 and 12). It is best to make the sluice from knot-free pine wood having a thickness of about 4 to 5 cm., as shown in Fig. 10.

In the place where the sluice is to be installed in the dam, the ground is to be leveled, prepared, and firmly compacted (see Figs. 11 and 12). By means of the horizontal shank, the sluice is set up slightly inclined so that the vertical shank stands free in the pond at the ground line of the dam (not in the dam). Two small cross laths are placed under the bottom board (Fig. 10), so that later no water runs under the sluice. In order to make sure that the under running of water is prevented, the ground about the sluice must be carefully and firmly tamped in.

To reach the vertical shank an easily removable runway plank is later laid from the dam to a bracket nailed to the vertical shank (Fig. 11). In my experience the described arrangement of the sluice is by far the most suitable. It makes a special fortification of the fish ditch in front of the sluice superfluous. An endangering of the free standing shank by ice pressure need be considered only with trout ponds and winter ponds, but mostly it does not happen because no strong ice formation occurs in the flowing water about the sluice, however, it can be easily removed. The fastening of the vertical shank to the dam (Fig. 11) is unpractical, because according to experience, wood is most rapidly destroyed by contact with earth or air. Installation of the vertical shank within the dam likewise brings disadvantages. Rotting easily starts in wooden sluices and supervision is made more difficult. Besides, the vertical shank in this case must be at least wide enough so a man can climb in. The free standing shank finally is not less protected than the other constructions from injuries by subsequent earth movements.

The sluice may also be so arranged that the horizontal tube can be made of glazed clay pipes (unglazed clay pipes are less effective especially with acidulous water) of at least 20 cm. diameter. The vertical wooden portion is then set down about 50 cm. into the ground. In a similar manner the vertical shank or even the entire sluice can be constructed of brick at the site. In every case it must be free of fissures which will allow bursting in frosty weather.

The water conduction power Q represents the quantity of water flowing per second from a pipe of q square meters cross section, and may be approximately calculated according to the formula.

$$Q = q.v \text{ liter seconds,}$$

in which v is the water velocity in meter/seconds. The water velocity is approximately

$$v = \sqrt{2g.h}$$

in which g is the acceleration of gravity which amounts to 10 meters per second, and h is the head (height of water pressure) in meters. On account of friction which increases with the length of pipe line and which is inversely proportional to the pipe diameter, the water quantity calculated in this way, has been found by experience to be about 1/3 too high (Schaeperclaus, 1927). The exact calculation is, however, so intricate that I shall refrain from giving it.

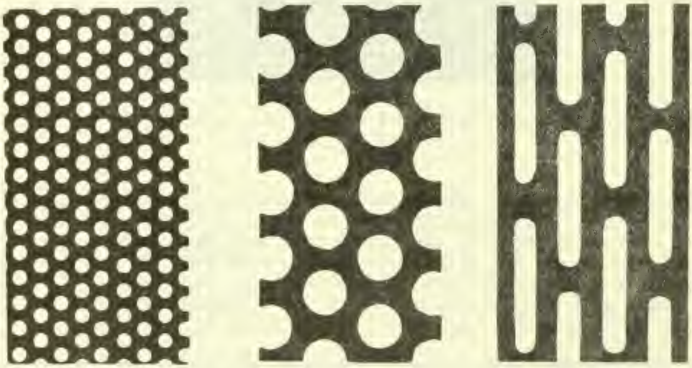

Fig. 13. Perforated zinc sheets in three standard round and slit perforations. Standard 1 for trout alevins, standards 2 and 3 for trout fingerlings. Natural size; Thickness - 1.5 mm.

The little sluice boards are made about 30 cm. high and not too wide on account of later swelling. Up to the closing edge of the uppermost and nethermost boards the little boards are closely fitted to each other by roof-shaped slopes and indentations in the top and bottom edges. On the central surface of each sluice board a ridge or cleat is nailed, which allows the board to be pulled out (Fig. 10). At the desired water level, an Eckstein grid box had best be inserted in place of the sluice board, to provide a large filtering surface and an automatic removal and dropping of foliage carried in the water current when the pond is filled with water. In Hungary similar sieve boxes of a triangular plan are used. For ponds with larger fishes, coarse rakes made of strongband iron or round iron rods, are to be recommended. Perforated zinc sheets (see Fig. 13) are to be recommended for strainers, as they may be obtained, with standardized perforations for every size of fish (for example at Seidl and Mayer, in Munich W12). Wire netting and wire screen of every kind have too short a time of durability. Perforated and slitted metal sheets are more easily cleaned on account of their smooth surfaces.

During the fishing-out procedure two frames the same size as the sluice boards, which are covered with metal sieve sheets or provided with grid rods, are required for each sluice.

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During the time of water covering, sluice boards are to be set in above the projecting Eckstein sieve box, up to the rim of the sluice. The sluice is to be locked against theft by means of a cover to be placed on top of the side wall (Fig. 10).

The costs of pond construction are mainly the combined costs of the sluice and of the dam construction. The ready cut wood for a sluice of pine wood with a vertical shank of 2.5 meters height and a horizontal shank of 5 meters length cost in 1931 about 40 national marks. Eight to ten working hours were required to put it together. The durability time is about 25 to 30 years. The amount of earth to be moved, which is equal to the amount of the dam, is easily calculated as the product of the cross section area and length of the dam. With an incline of 1:2 on the inside, the cross section of the normal dam for a pond of 1 meter depth (the height a = 1.30 meters and a crown width of about 30 cm.), is approximately

$$Q = \frac{a\ 1\ 4a}{2}(a\ 1\ 0.30) - \frac{1.30\ 1\ 5.20}{2} \times 1.60$$

$$= \frac{6.50 \times 1.60}{2} = 5.2 \text{ square meters.}$$

The mass of earth in cubic meters is obtained by multiplying by the length of the dam.

Chapter III

TYPES AND SIZE OF POND FISHERIES

Pond fishery (Pisciculture) is divided into two main branches:

(1) Carp fisheries, also frequently called Carp and Tench Fisheries, are conducted in shallow ponds (of about 1.30 meters depth) of warm water (in summer 20 degrees centigrade or higher) with little or no "through current". Since carp—and also tench--require large, "natural feeding grounds", their ponds are always relatively large and less stocked with fish than trout ponds, even when conducted upon an intensive scale. Carp and tench culture is mostly conducted upon large areas, periodically flooded and by exploiting their natural productivity.

(2) Trout fisheries, requiring even under intensive culture only small ponds but with a strong "through current". Brook-like ponds, rather long are best suited since trout are raised almost exclusively by artificial feeding. The pond is for them only a stable, an abode, so to speak. The "cultivation" of the pond as well as the exploitation of the natural productivity of the pond play practically only a secondary role.

The water of the masting ponds must be cool, 1 to 2 meters deep and even on hottest summer days below 20 centigrade. We find trout fisheries therefore mostly in the regions of secondary mountain chains and in plains, near springs. Aside from ponds, trout fisheries require hatchery troughs and natural waters (brooks) for the rearing of the spawn. Trout fisheries therefore extend beyond the territory of "pond culture".

From the foregoing it is obvious that carp and tench culture on the one hand, and trout culture on the other are two distinctly different branches of pisciculture. We even find quite a distinction between trout breeders and ordinary fish-pond keepers.

Trout culture is more frequently found in Hannover, Westphalia, the Rhineland, Hessia and in Southern Germany, while carp fisheries will be found foremost in Silesia, Bavaria, Saxony and in Brandenburg.

The distinction between the two classes of fishbreeders is even outwardly apparent. There is an Association of German Fishbreeders and an Association of German Trout Breeders.

Through an Ordinance of January 5, 1931, the Prussian Department of Agriculture, Estates and Forests has created--with regard to trout culture—the three classes of pond apprentices, of helpers and of pond masters. This in itself denotes a higher development of this brand of pisciculture in comparison with other branches.

Recently in trout culture the operation of larger ponds and the utilization of their natural productivity for brood raising and growing spawn trout has become very important.

Within the two main branches, many fishbreeders go in for diversified industries and some side lines. Carp and tench breeders often also raise Gold Alands at the same time, while brook trout culture is often combined with the culture of rainbow-trout.

We can furthermore distinguish between them

(1) Extensive management of a fishery, where, according to the definition of <u>Aerebosic</u> the individual fish enjoys relatively much space within the pond, and

(2) Intensive management, where the individual fish lives with relatively restricted space, and where its existence is guaranteed more through artificial feeding, fertilizing and more general care of the pond than through prevailing natural conditions.

Small secondary industries, since they must be simple, must be essentially extensive or half intensive. The general division of the industries into secondary and main industries does not mean much, since even very large industries are often the secondary industries of still larger agricultural industries.

On the other hand, the distinction is important between

(1) Fisheries proper, where fish are raised and cultivated from eggs to adults, and

(2) Partial fisheries which specialize in only certain classes (grades) of fish, according to age or size.

Carp-growing industries are preponderantly full industries. Small secondary industries, with few exceptions, must always be special industries which are concerned only with carp growing or trout growing and produce only food fishes (see section XIII). The very large pond industries which produce mainly food carps and food trout, must often buy larger additional amounts of stock to add to the stock material they have raised.

In table 10, we have a classification of the different fisheries (in Germany), their size and number, according to figures by Röhler, K. Schiemenz and Jaisle.

Table 10.

	Carp Fisheries			Trout Fisheries	
	Size of the individual fishery	Number of fisheries	Pond area in Germany in 1925	Annual production of adult trout by the individual fisheries	Number of fisheries in Germany
"Dwarf" and small fisheries	< 10 hectar	?	10,000 ha (16.5%)	< 10 dozen	600 (83.3%)
Average fisheries	10 to 500 hectars	800	37,500 ha (62.5%)	10 to 100 dozen	100 (13.9%)
Larger and "Giant" Fisheries	> 500 hectars	15	12,500 ha (21%)	> 100 dozen	20 (2.8%)
			60,000 ha		720

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Naturally this division into large classes is very arbitrary, but despite this it gives a good general view. It must not be forgotten that divisions serve the reader only as a temporary introduction but they may actually be erased by transitions.

Taken accurately the trout pond industry is included in the figures of table 10 for carp-pond industry, but the error is only very slight, since medium trout pond industries are only about 0.5-4 hectars in size and the largest German and European trout fishery of Schnede covers only 15 hectars (about 57 acres).

Of all inland waters (excluding Haffs) of Germany, the area of ponds amounts to only 6.6 percent. While this figure is small, it does not properly express the importance of pond culture forpisciculture as a whole.

In the first place, ponds produce about twice as many fish as rivers and about three times as much as lakes (per like area). Furthermore it must be kept in mind that pond fisheries are conducted intensively and practically without waste, making use of all available resources to the fullest extent. This, of course, is never the case in free waters, such as rivers and lakes.

The total production of adult trout in Germany, during the years 1930 and 1931 amounted to 15,000 dozen, while in 1931, 65,000 dozen of carps were produced.

By adding to these figures the amount of brood fish and of fish raised for special purposes, we find that the total production of carp and trout pond fisheries in Germany amounts to about 12 percent of the total fresh-water fish production in Germany (by figuring this total annual production at 125,000,000 kilograms).

It must further be kept in mind that the amount of fingerlings, furnished by carp, tench and trout hatcheries for open waters cannot be evaluated by mere weight, because regulated operation in many natural waters depends on procuring first class healthy stock from pond fisheries.

Finally, pond culture—from the theoretical standpoint—is the great educator in all matters of pisciculture and has thus rendered invaluable service to fishery as a whole.

In the division according to fishery size classes, it should be further stated that the heaviest fry production is with the larger medium fisheries. Small and large fisheries produce mostly food fishes. Large fisheries, as mentioned above, frequently purchase additional stock material, small fisheries must practically always purchase their stock. Only seldom do small fisheries grow younger age classes for neighboring large fisheries. The small pond fishery (see Section XIII) as a rule is not a hatchery, but is concerned only with fish maintenance, especially with carp maintenance. Small pond fisheries predominate in East Prussia, and in the central, southern and western parts of Germany.

Chapter IV
CARP FISHERIES

A. The carp. Market demands. Types of scale formation. Objects of rearing. Races of carps. Breeding of carps through rational selection from the viewpoints of race purity and of best productivity.

The main commercial commodity giving the name to the carp-pond industry, is the carp (Cyprinus carpio L). A knowledge of its form, external markings and body structure as shown in Fig. 14 is taken for granted. The confusion of the carp with other fishes can only occur in the case of the crucian carp which has a certain resemblance to the carp. In the possession of 4 barbels on the upper jaw, which even at the age of 25 days attain a length of 3.2 cm. (Stankovitsch, 1921) the carp may be distinguished from the crucian carp by closer observation. It is therefore completely unfounded, when small-pond operators take the viewpoint that it would be unsuitable to buy carp for stock because they cannot be distinguished from the poorly growing crucian (see Crucian carp).

Fig. 14. Two-summer Galician Mirror Carp (Line carp), from a distinguished North German stock-producing fishery. Length 25 cm. body ratio H:L = 1: 2.3.

In the light of present-day knowledge, Central Europe cannot be regarded any longer as the homeland of the carp. Even the presence of carp in Germany, in pre-historic days is disputed today. The carp is a native of the mouths of rivers, which shed their waters into the Caspian and the Black Seas. This fact still reveals itself today in the hatching habits and habits of hibernation of the carp. In natural waters, carps will spawn rarely (in the Müggel Lake, for instance, in 1930, after long years of nonspawning, and then only in the warm days of any early summer).

The first carp breeders in Germany--during the Middle Ages--were monks. Then as now, the ultimate goal was to raise carp for the table and also to raise sufficient brood for their own and foreign ponds. At present, carp are even planted in lakes, expecially adaptable for this purpose. Main considerations, of course, are the market demands.

Nowadays, these demands are:

(1) Carp of from about 750 grams to 2,000 grams in weight (mainly of a weight of from 1,000 to 1,500 grams, although in Java, according to Buschkiel, carps of only 75 grams are mostly in demand.

(2) A firm flesh, not too much fat, small head and relatively few bones in comparison with the flesh; none or very few scales, as the skin will then be more palatable and preparation becomes more simplified.

The scale carp (Schuppenkarpfen), which is the original, normal species is little in demand upon the German market. It was thought, until recently that this species suffers less from parasites (on account of the hardness of scales), but Plehn found little evidence for this belief and Sklower none at all.

The mirror-carp (<u>Cyprinus rex cyprinorum</u>) has much less scales (the greater portion is involuted), its scales are somewhat longer and rather loosely attached to the skin. A more or less complete "mirror line" of scales covers the sides. If this line is not interrupted in places, the carp is spoken of as a "Zeilkarpfen" (line carp?).

For a time, the mirror-carp was greatly in demand but is now mostly replaced by the leather carp.

This sub-variety is almost without any scales whatever. Only a few will be found at the bases of the fins. It must be borne in mind that these various kinds of carp do not constitute different races or species, but merely sport varieties. We have similar variations among Roach, Tench and Crucian (Wiese), and these variations do not react upon other characteristics, such as growth, for instance, as was demonstrated quite recently by Sklower, through experiments conducted in East Prussia.

The experiments by Rössler--conducted for six continuous years--have shown that at times the "scalers", and at other times, the mirror-carps showed better increases in growth.

Considering the above-stated market demands, the carp breeder also considers the following points:

First class fish shall:

(1) Grow fast, since this makes for food saving. They shall grow so fast that the table weight is reached before the fish mature, i.e. within three summers or four summers at the utmost. The possibility of their spawning would complicate their culture out of the ordinary.

(2) Use the natural food to the best possible extent and artificial food to good advantage, in other words, they shall have a good "intelligence factor".

(3) Be resistant against disease, against temporarily bad water conditions (slightly sour water), against drainage, transportation and hibernation. They shall be hard to see and to find by enemies and thieves.

(4) Under like environmental conditions within one and the same "race", show like and strongly inherent genotypical characteristics. Only then can one speak of a race (species) and only then is it possible to achieve similarity in the table product.

(5) Be raised in various and variously endowed races, adapted to regional conditions. It is practically impossible to breed a race with hereditary characteristics which eventually become so paratypical and adaptable as to develop a race which under all and the most differing conditions (rough and mild climate), even by slightly sour water will still produce a first class table fish. In order to be able to distinguish between the different races, i.e. stock of different characteristics, it is advisable to inbreed into each different race an easily distinguishable external characteristic.

(6) Be well propagating and produce resistant brood, easy to raise.

Like Kronacher, I understand by "race" a group of fish, best suited from the economical viewpoint for certain conditions, and which under like conditions will transmit their most important and outstanding characteristics to their progeny. Of course, to rear an absolutely pure race is in practice almost impossible, but with planned purpose one will come as near to it as can be reasonably expected.

Out of the total purposes of selection, it follows contrary to earlier attempts, that no value needs to be placed for example on the height of the back, which even led to the selection of spawn carps with shortened or curved (Kypholordoic) spinal columns.

The body ratio, i.e. (Ratio of greatest body height to body length, both measured without the fins) serves only to differentiate single races. It is also immaterial if the flesh is found in a high or in a broad back, or in any other part of the body, barring prevailing fads of the market.

Less stress, nowadays, is laid upon "form", since it has been demonstrated that a "high back" depends strictly upon environment and will develop more easily under fully satisfactory metabolistic conditions than under less favorable ones (for instance, by rearing in cool water, as was observed by me and Demoll (1928) by raising carp in trout ponds, keeping the stock low and feeding well).

With increasing age, the length--in proportion to the height--increases not inconsiderably (v. Rudzinsky). Exceptions to this rule are perhaps traceable to paratypical factors upon which all bodily conditions are depending. After all, the rearing of young carps differs in the different fisheries.

The bodily proportions cannot be taken one-sidedly into consideration with regard to "race identification", as enumerated under point 4 (page). They can be considered only under like environmental conditions, since they do not depend upon genotypical factors alone, but also upon paratypical ones.

The same applies to the color of the skin. For instance, under plentiful feeding with maize, belly and sides may take on a sulphur-yellowish hue, due to an accumulation of maize fat in the tissues.

The relative size of the head--largest in Aischgründ carp, smallest in Lusatian carp--and which decreases with a general increase in size--is also unusable for a differentiation of the races, according to Demoll. Upon his suggestion, the German Leather carp association tried to induce fisheries to breed some distinctive scale formations for each race. Although these efforts are promising and necessary to follow through, they have led to two great difficulties in practice. In the first place, the complete scale formation required in the Lusatian carp has in itself no appreciable production advantages since the Lusatian race has been almost completely crowded out of the fisheries, because it is contrary to market demands. It was similar with the next attained "line carps" of the Galician race in which Opitz very correctly finds fault with the great danger of scale losses. A purely external parking must in no case conflict with industry. Secondly, the attainment of a pure particular scale formation, inheritable without throwbacks, has such great and unsurmounted difficulties that the development of the marking has to a great extent become the main object.

The breeding of "pure stock" of leather carp seems to succeed more often than the breeding of "pure" mirror-carp, but there are many fisheries here, which by crossing leather carps, obtain offspring which include one third mirror-carp and even some "scalers". Nothing absolutely sure is known, concerning the hereditary transmission of the scale coat.

Rudzinski, who thus far alone has investigated the matter found as an absolutely certain fact, that even scalers need not be of "pure stock", and that in case of crossing, one will have 25 percent of fishes with entirely different scale coats.

The crossing of scalers with mirror-carp or leather carp always produced only 50 percent of scalers, while the others were either mirror-carp or leather carp.

It follows that neither a lack of scales nor a complete scale coat can be considered a recessive or even a dominant characteristic.

The factors to be stressed most in fishbreeding are good health, marketability and productivity. The mere breeding of a racial "label", so to speak, can never be an ultimate goal. The "pure stock" question has always to remain more or less in the background, just as in horticulture, for instance, the question of a "pure species" is never made to interfere with strictly market consideration.

Finally, the scale coat is not the single guaranty for genotypical characteristics, which—as some believe—are inherent in fishes of a certain type of scales. This formation only shows the origin. With regard to racial conception, I shall also refer to experiments on the trout (V B, 2).

I shall briefly give the characteristics of several important races set up as guide lines by the German Leather Carp Association, although the whole domain of race breeding still requires further elaboration and although many noteworthy foreign races like the Bohemian and Hungarian, as well as very constantly successful and productive domestic hybridizations (between Aischgründ and Galician races in the Lüneberg Heath) were not included in the existing German researches and production tests. The productivities of these races were tested under similar (though regionally conditioned, hence not generally applicable) conditions by the researches of Eberh. Naumann, Walter and Demoll (1928) in the fisheries of Zeissholz (District of Kamenz in Saxony) and Wielenbach (Upper Bavaria).

(1) Aischgründer carp. Body proportions 1:2. Leather carp, no scales at all or only a row of scales along each side of the backline, and a few stray scales at the fin roots. Short tail stem, short, pointed, low head, strong nape. Evenly curved lines of back and belly.

(2) Galician carp. Body proportions 1:2.5; mirror carp with uninterrupted mirror scale line or with a mirror scale coat in either the front or rear quarter, or in some cases even without scales, like a leather carp. Scales may also be found upon the lines of back and belly, either singly or in a closed line. Belly line and head line almost upon the same plane. The back line is evenly curved.

(3) Lusatian carp. Body proportions 1:3, scaler. Short, steeply rising head. Back line steeply rising behind the head and then flattening out.

(4) Franconian carp. Body proportions 1:2.3; leather carp, no scales or at the utmost with one row of scales along each side of the back, and some stray scales at the fin roots. Small, low head. Backline evenly rising from head to back fin (in a smooth curve) and then evenly descending toward the tail. More or less distinguished by a blueish side coloring ("Bavarian" carp).

With regard to the Hungarian carp, recently introduced—and with success—in some fisheries in Northern Germany for crossing purposes, I wish to mention that today--according to Unger—an improved "race" of *Cyprinus carpio* var. *Hungaricus* has attained quite some fame, the so-called *Cyprinus carpio* f. *nobilis Hungarica*.

This variety is the offshoot from pre-war crossings of the Jugo-Slavian carp with Cyprinus higoi and Japanese carp. The variety is raised as scalers, mirror-carp and leather carp and is remarkable--in Hungary—for rapid growth. One of its characteristics is the suddenly rising back--immediately behind the head—and a great width. Body proportions are about H:L eq 1:2.3, height:width eq 1:1.8. The last word has not been spoken about this race and its name.

I will not speak here at length of the Bohemian race, but will mention that some fisheries make use of them even today—every few years--for introduction of fresh blood into their stock. It is said that the pretty long fish increase the resistance of the Galician carp, and they are raised upon an extensive scale.

In view of steadily increasing diseases, especially of abdominal dropsy and of gill rot, such an increase in resistance is quite often more important than all other characteristics, such as good food assimilation, etc., not to speak of external characteristics.

A comparison of the different German races brought out the following facts in Germany:

The Lusatian carp is the liveliest, hence in greatest need of oxygen, while the Aischgründer is the laziest.

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With regard to growth, the Aischgründer—formerly through lack of experiments, considered the best of all--was found to be 10 percent behind the other races. After all is said, the Lusatian carp is still the fastest growing and best food assimilating fish. It is also said of it that it is especially adaptable to drainage and gives still best results under unfavorable climatic conditions. The remaining three races showed, in Wielenbach, practically the same growth results, for the 5 percent greater growth of the Lusatian was partly equalized by the weight of the scales which amounted to 1 percent. The Lusatian remains, despite this, the most rapid grower and the best food evaluating fish. It is further renowned for being particularly adaptable and having the best success in less favorable climatic conditions. In the ponds of the Upper Harz, which are subject to a cool raw climate with a mixed stock of Lusatian "scalers" and Galician mirror carps I could not detect a better growth average with the Lusatian carp. Of course, I cannot restrain the impression that the growing of Lusatians is in bad repute because "scalers" occurring frequently in the growing of Galicians and other races are designated as "Lusatian scale-carps".

With regard to the inclination to add protein or fat in the constructive metabolism, the Lusatian surpasses the other races if stipulations for high backs are not given, or is inferior to other races if these stipulations are favored. Galician carps of three to four summers in Zeissig showed about 4.27 percent higher fat content than the Lusatian carps.

The most widespread race today is the Galician carp. The Lusatian, on account of its complete scale coat disappears more and more from the market. The Franconian carp, quite popular in Southern and South-western Germany has been largely supplanted by the Galician, while the Aischgründer is almost exclusively restricted to this local region.

The Galician is to be found everywhere, today, in all parts of Germany and in the rest of Europe. This race is therefore the most important from the pond-industrial viewpoint.

Aside from the specific, but varying productive power of the different races, it can be said that all well cultivated carp under normal conditions grow into good adults within three years. They will then attain a weight of about three pounds, a weight, which ordinary--so-called peasant carp--will never attain within this space of time.

Before the war, the following weights were considered more or less normal for the different classes of carp, according to age:

Yearlings................	50 grams
Two years old............	500 "
Three years old..........	1500 "
Four years old...........	2500 "

Today, in these days of recurrent crisis, all weights have become more fluctuating. In general, the following weights and sizes are now considered normal:

Yearlings...............	35 grams	(9 to 12 centimeters)
Two years old...........	350 "	("150", so-called)
Three years old.........	1250 "	("40", " ")

The fishbreeder, too, has to adapt his wares to changing times and market conditions. In Java, Italy and Latvia, carp up to 500 grams are in demand. In Berlin, in 1930, carp of the so-called "80" class, i.e. of 600 grams of weight were mostly in demand, while in 1931 carp of the so-called "30" class (larger fish) were so greatly in demand that it was difficult to supply them. These changing weights are easily obtained by proper stock regulation.

The figures here quoted apply only to ponds of medium productivity. Under less favorable conditions a lower individual growth is striven for, so the density of population does not get too narrow, and the feeding surface quotients are not too high, and therefore the evaluation of natural food not too poor. In highly productive ponds, on the other hand, higher weights may be profitably attained.

Modern carp fisheries conduct their enterprises according to the "grading" system and which has supplanted the old-time "Femel" system most everywhere.

Under this old-time method, fish of all ages were kept in one and the same pond, were even left to spawn in them. Fish of marketable sizes were caught as needed, with the result that in the end only the least worth-while fish remained to spawn. Under such conditions, the whole stock, of course, would gradually decline, more and more.

Under the new "grading" system, the different grades (according to age) are kept separately. In this way the growth of the individual fish can be continuously studied and watched. The rotation is normally a three year one. A four year rotation increases the cost of maintenance for an additional year without adding anything to eventual profits. Conditions are more favorable only when the fish have been strongly retarded in the first two years. In the two year rotation there is too great a risk in obtaining yearlings which must be of about 250 g weight. In the fishing out there will soon be too small and too few yearlings. Besides this, in the two year rotation, the yield per unit surface is decreased by the reduced stock density necessary for the high individual growth.

In regard to the methods of race breeding much isstill to be desired. Incidentally, Baur has rightly said that fish breeders should learn from horticulturists and that the obtaining of positive qualities in pond fish breeding could not be expected. The fish must not be judged by appearance but by the results to be expected of their progeny. Similarly as in plant breeding, this requirement can be easily fulfilled since the progeny of the fish is so numerous. Only the best of the numerous offspring are selected and hybridized.

Proper selection is to be begun among the yearlings of one and the same pond, expressed elsewhere in this book. The fish of such a pond must have been kept separated from the others. Only in this way can it be avoided that the best fish will be gradually taken out, and that a badly growing 3-year-old fish will in the end be mistaken for a good growing 2-year-old.

Cernajev and Nowak have objected to such a procedure upon the ground that the bodily proportions of yearlings differ from those of older fishes, and would therefore not permit a reliable judgement. This is meaningless as they should be valued first as to results and secondly as to form.

At the first selection, ten times more yearlings are chosen than will be needed for spawning (or spawners). These fish must only be kept together with older fish so as to remain easily distinguishable. A permanent marking would be still better, of course, but such a method has not been found as yet.

In the fall of the second year 50 percent of the best of these carp are again selected, in the third year 25 percent of the best of these, and finally in the fourth year 10 percent of the best three-year-olds. The remainder goes to market.

The so selected fish are kept as prospective spawners (parent fishes) and are brought together in ponds with young fish (about 4 to 8 prospective spawners per hectar) and are left to spawn from the 5. to 7. year.

The question has been raised at times, if future spawners are to be fed - or not. Since noticeable injury to spawners, from feeding them has not been observed, so far, I am of the opinion that light feeding, toward the end of the first summer is indicated, or at least not to be objected to. Only in this way can it be found out if carps, aside from being good natural feeders, will also assimilate artificial food and show this by increased growth. Feeding in later years has only disadvantages. It is quite possible that the resistance of the offspring is lowered thereby.

Still more important is the choice of spawn ponds. These ponds must be rich in natural food and must also be not too small. Only then will the sex products ripen well (according to observations by Schau), which perhaps is the effect of the "space factor" complex, referred to previously.

One will make the same observation with pike spawners if they are kept in ponds that are too small.

The danger of inbreeding of stock with resulting deterioration and latent disease appearance by crossing is not all too greatly to be feared. Fish and their parents with visible hereditary defects (especially malformations of all kinds) are to be removed.

As long as no ill effects are noticeable (or no new characteristics are intended), the introduction of strange carp, of unknown hereditary characteristics among well cultivated stock is always risky and ought to be avoided.

If on the other hand, it becomes noticeable that frequent introduction of fresh blood increases the resistance against diseases, such a course is obviously to be recommended, eventually even if other qualities should suffer.

Lack of resistance against certain plagues is one of the gravest dangers of modern pond culture.

In order to aid the small fishbreeder in the selection of reliable fresh blood, the respective agricultural departments now issue diplomas to hatcheries which conduct their establishments upon the most rational basis, and have necessary breeding arrangements, and health requirements.

Such hatcheries keep their stock continuously under the control and supervision of scientifically trained experts and the small fishbreeder is thus assured of good material for the freshing-up of his own stock.

B. Carp Culture upon a large scale.

I. Size and division of the necessary pond area.

Since the rearing of carp requires a relatively large area, it is evident that carp fisheries can be profitably conducted only then, when the necessary terrain is available. The minimal requirement for such fisheries is an area from between 30 to 50 hectars (about 90 to 150 acres).

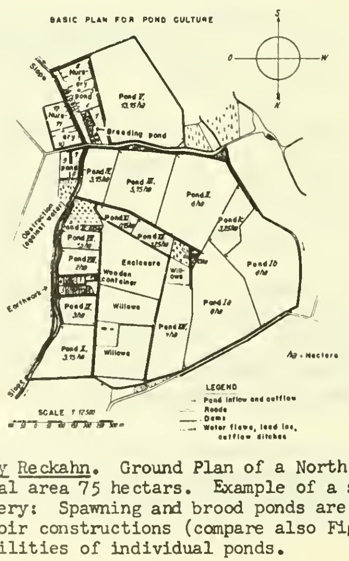

Fig. 15. Pondfishery Reckahn. Ground Plan of a North German Carp and Tench Pond Industry. Total area 75 hectars. Example of a standardly arranged larger stock-growing fishery: Spawning and brood ponds are situated at the water inflow, good reservoir constructions (compare also Fig. 59), separate coverage and drainage facilities of individual ponds.

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The "grading system", so necessary in carp raising, requires a large series of different ponds, such as spawning ponds, nursing and rearing ponds, ponds for adult fish and also hibernation ponds, aside from a pond for the spawners.

Presuming that a fishery raises its own stock, the necessary pond area must be in proper proportions to the requirements of the different grades, i.e. from the egg to adult fish, and in proportion to the differance between stock taken out to stock put in. In other words, the available space must be in proportion to the increase of stock of fishes of the same year during the three years rearing period and in the following proportions:

35:315:900 eq. 1:9:29

The proportions will fluctuate, of course, on account of the hazards and of the losses incurred during the first year, and later on through the varying productivity of the ponds and the greater voracity of the fish in the third year. For these reasons we recommend to base such calculations upon the figures in table 11.

Table 11.

Year	Kind of ponds in order of successive requirements.	Part (in percentage) of total pond area.
1	Breeding ponds	0.25%
	Nursery ponds for alevins and fingerlings	2.75
	Nursery ponds for fingerlings and yearlings	10.00
2	Rearing ponds for yearlings and two year olds	23.
	Hibernation ponds	3.
3	Ponds for adults (2 and 3 year olds	60.
	Ponds for spawners, etc.	1.
		100.

Local conditions will continuously make for alterations and adaptations of these enumerated percentages, the more so since few large fisheries abstain from the sale of stock. Some of them raise stock almost exclusively.

With regard to the location of the different ponds it is to be remembered that breeding ponds require fresh water, i.e. water which has not been used already in other ponds. This is most important in order to avoid diseases. Among larger fish (in other ponds) there may always be some disease and parasite carriers and the water from their ponds may carry germs into the brood ponds, even though they seemed healthy when placed in the pond.

Hibernation ponds and the ponds for spawners must be so located as to make constant supervision possible and to discourage fish thieves.

2. The First Year.

General. Upon the basis of regionally varying climate, local conditions, water conditions, also considering the kind and number of available ponds, the experience and enterprising spirit of the individual fishbreeder, we have today four principal methods for the breeding and raising of carps. In the following pages we are going to discuss and to evaluate them.

Breeding of carp and rearing of yearlings by means of hatching ponds, nursing ponds and rearing ponds (Dubisch method).

(a) Hatching. The Dubisch method (named after this fishbreeder, 1813-1888) uses special ponds--sometimes called Dubisch ponds--for spawners as well as for spawning.

These ponds must have a sunny exposure and must be well protected from winds. It is best to use ponds of a size of 6 by 15 meters. All around their dam runs a ditch of about 40 to 50 centimeters depth. Between the ditches rises the so-called spawning board, slightly (roof-like) slanting at an angle of about 1:15, with a water depth of from 20 to 30 centimeters.

The ditches serve as an abode for the spawners, they facilitate their catching (by two men with landing nets), as well as the fishing out of the brood, and also facilitate the drainage of the ponds.

Some carp fisheries use spawning ponds where the bottom drops gradually from the point of inflow to the point of outflow (in German, the point of outflow is referred to as the sluice "monk"). The bottom of the spawning pond is well covered with sweet grasses into which the eggs are deposited (see Fig. 17). Very long and especially soft grass is mowed off before the spawning begins in order to reduce oxygen consumption.

Some breeders prefer to raise harder grass--by keeping the bottom moist--and which is less exposed to rotting and has not to be cut. Where grass is lacking, the bottom may be covered with juniperus twigs or other suitable material.

The bottom of a spawning pond must be absolutely impermeable so as not to require a continuous inflow. The outflow (monk) must be carefully packed--best with clay--between stowboards. The inflow of water must come from above in order to forestall a rising of the brood. It is also indicated to protect the ponds against other brood or brood enemies by means of sieves or filters at the point of inflow (see Fig. 8).

As soon as the spawning process is over, the Dubisch ponds have to be disinfected with quicklime in order to destroy eventual parasites and their intermediate stages. They are then left to dry out until the spawning period of the following year. Two to ten such ponds are required according to the size of the establishment.

Occasionally only one such pond is used by even medium sized hatcheries, but a number of ponds should be the absolute rule for more safety's sake, the more so since the construction and upkeep of such ponds are not very costly.

The inflowing water is best taken from a shallow pond (not stored with fish, though) which allows the water to warm up (Fig. 15). In order to avoid the accumulation of predatory insect larvae, the ponds are filled up only shortly before the spawning starts. Wild fish, which almost always are parasite carriers, and snails which frequently are hosts to parasites in different stages of development are to be carefully kept out of the feeder ponds so as not to bring them into the spawning ponds with the inflowing water. To guard against diseases is better than to cure them! In the case of brood, prophylaxis is especially indicated since brood diseases may eventually contaminate the whole stock.

The ponds are to be filled only after the water temperature lies continually over 15 degrees centigrade and does not drop all too much during the nights (in Germany this means usually not before May 15), since eggs as well as brood are highly sensitive against low temperatures and great changes in the temperature. It is recommended not to begin with the filling of the pond during the early morning hours, but to wait until the bottom of the pond has had time to warm up somewhat through the action of the sun.

The spawners are brought into the Dubisch ponds as soon as the ponds are filled up. Up to now, the two sexes have been kept separated in special spawner ponds (the female can be recognized by a cone-like, reddened torus, the vagina of the fish, so to speak, and by a greater corpulence). These ponds must be kept well tempered—not too cool and not too warm—so that the eggs may properly mature. There should be more spawners than necessary to provide a reserve in case of failure.

Great care is to be taken in the transfer of the spawners from their ponds into the Dubisch ponds. At great distances, they are best transferred in water, at shorter distances they can be carried in wet clothes or upon burlap covered stretchers. (The belly of the female, when ready to hatch is very soft, and rough handling of the male can interfere with its ejaculation which should occur quite easily).

Immediately preceding the transfer of the fish into the Dubisch ponds, external parasites, adhering to their skin or scales are completely removed with a pair of dull tweezers. In order to remove microscopically small skin and gill parasites, it is advisable to rinse the spawners in a 2.5 percent salt solution for about fifteen minutes. This does not interfere with the ability to spawn.

Under a system of rational selection, only one pair of spawners is put into each pond. It is the generally prevailing custom, though, to put 1 to 3 sets of spawners into a small pond of 100 square meters (one set comprises 2 males and 1 female). I know of a fishery which regularly puts 40 spawners in their Dubisch pond of 1 Morgen size (about 2/3 of an acre). That is simply waste, traceable to the highly unsuitable size of the pond.

The spawning—also called stripping—usually begins shortly after the storing of the pond or on the following day, under animated swimming to and fro of the spawners. The spawners have been "duped", so to speak, into spawning through the transfer from the cooler ponds into the relatively warmer Dubisch ponds, and also through the bringing together of the two sexes.

According to Hoffer, the ovary of a female of from 2 to 2.5 kilograms weight carries from 400,000 to 500,000 eggs. (In an eleven-year-old carp of 8350 grams of weight and 72 centimeters of length, I counted 860,000 eggs.)

It is quite true that even under the most favorable circumstances only about half of this number will be hatched.

The eggs are glass-clear, of a diameter of about 1.5 millimeter and are pasted upon the grass or other plants (Fig. 17). Whenever possible, the parent fish should be taken out of the Dubisch ponds immediately after spawning and before the brood leaves the eggs. In larger ponds this is best done by a quick drainage of the ponds—followed by immediate refilling and restoring—during the cool evening or morning hours.

Although the ponds will be dry for from 4 to 5 hours, this will not hurt the eggs at all. In large ponds, not provided with ditches, the spawners can be fished out with wide-meshed nets.

This removal of the parent fish is a prophylactic measure. Like the "bathing", referred to above, it shall protect the brood from eventual contagion through diseases or disease germs of the parents.

It is precisely in spawn ponds that germs and parasites find the best opportunity to settle upon the new carp generation, if these safety measures are neglected.

Fig. 16. Carp Spawning Pond (Dubisch Pond) is a sunny protected location. Ditches running alongside the pond dam. The spawning bed is provided with well cultivated grass growth.

Fig. 17. Carp Eggs attached to plants from a Spawning Pond. In the eggs, the embryos and their eye spots are distinctly recognizable. (Taken from the UFA-Culture film "Secrets of the Egg Shell" with the author's collaboration).

One of the greatest dangers to the eggs of carp is a sudden drop in the temperature of the water. An experiment was made by placing 10 eggs in a glass and cool the water down to a temperature of 4 degrees centigrade. Only 2 fish emerged from these eggs, while in a control glass all 10 fish came out of 10 eggs.

About 2 to 3 days after spawning--and at a water temperature of 15 centigrades--the embryos become visible in all live eggs. The nonfertilized and dead eggs are by now milky white. The alevins emerge from the eggs within about 6 days, according to Stankowitch, i. e. at a water temperature of 15 degrees centigrade In warmer waters this process occurs naturally somewhat faster, while in cooler waters the process is somewhat slower. The alevins are about 5.5 millimeters long. In the beginning, the alevins hang to the grass stems but soon begin to swim about. In comparison with the vitelline sac of trout brood, the vitelline sac of carp alevins is rather small, i.e. contains less nutriments. The consequence is that this food is consumed within 8 days--the alevins are now about 8 to 10 mm. long--and the brood begins the active need for and taking up of food, even before the nutriments of the vitelline sac are completely consumed.

In the small Dubisch ponds this cannot be done for any length of time, therefore the alevins are brought into larger and more nutritional ponds--latest within a week--the so-called nursery ponds. The alevins are now about 9 mm. long.

(b) The rearing of brood in nursery ponds.

The nursery ponds for accommodating carp brood by the end of May or in June are still relatively small since this in itself assures the possibility of proper care and also facilitates the future fishing out. Both factors must absolutely be taken into consideration. Too small ponds--on the other hand--have their disadvantages. It is best to adjust the size of nursery ponds to the planned sojourn of the brood in them.

If only a short stay is contemplated--of about 4 weeks--the size of a nursery pond should be from about 0.25 by 1.00 hectar (1/2 to 2 1/2 acres). If an eight weeks stay is planned, larger ponds of even 3 hectars area (7 1/2 acres) are of great advantage. The average depth should be about 50 centimeters. Too shallow ponds are exposed to strong changes in temperature, while deeper water will naturally take longer to warm up.

Fig. 18. Living carp brood (Alevins) shortly after hatching. (Taken from the UFA-Culture Film "Secrets of the Egg Shell" with the collaboration of the author.)

Fig. 19. Drainage of a standard 2 hectar Nursery Pond.
A firm completely drainable bottom with grain stubble. Carp and Tench brood are driven forward in the fish ditch, by a stick, to the sluice (front right), and thence into a trap box outside of the pond to be fished out.

The most important task for any hatchery is to look after the health of the brood. Aside from prophylactic measures against contagion from parasites and other disease germs--which may enter brood ponds from inflowing water or may be spread through the invasion of larger fish--the strengthening of resistance of the brood plays the most important role.

This is possible by providing proper natural food and in such quantities that the brood can fully satisfy their appetites up to and until the very last day of their sojourn in these ponds. The idea being to foster a rapid growth during the first few weeks, since the most dangerous period of the brood for eventual afflictions (Dactylogyrus, Costia, Chilodon, Ichtiophthirius) is the time when the young fish are only 5 to 6 centimeters long.

It is from this viewpoint that the Dubisch method--i.e. transfer from spawning ponds into nursery ponds--is the best guaranty against the dangers, besetting the brood. In the nursery ponds they can fully satisfy their appetites (provided rational stocking of the ponds is adhered to) during the first few weeks.

Nursery ponds are really the best prophylaxis against brood diseases, but they require constant care and supervision by an experienced fish breeder in order to bring results. The following rules are to be especially observed:

(1) Nursery ponds are to be filled up only after the brood has emerged from the eggs, i.e. five days after the filling up of the spawning ponds. Walter (1926) had best results from this procedure. This waiting time allows for the development of sufficient quantities of Infusoriae and even of Bosminae, Chydorus, Eudorina, etc., (the main food of the brood up to 7 or 8 mm. length) and at the same time prevents an accumulation of predatory insect larvae. Tadpoles will later on appear, nevertheless and will greatly interfere with a fishing-out of the brood. How to deal with these pests will be found later on in this book.

(2) The nursery ponds, while still completely dry should be sown with weeds and grasses since this will greatly improve bottom conditions. After the filling of the pond, but before stocking them, paths are cut through the weeds and the mowed-off plants are set up in stacks. Later on, when the brood has reached a length of 3 centimeters, these stacks are again distributed in the pond. The oxygen content of the water—on account of the rotting process of the weeds—has to be constantly watched. The ponds are also to be treated with mineral and organic fertilizer but again in such a manner as to avoid lack in oxygen. Strong and frequent doses of liquid dung, of blood meal and of fish meal and general care are also necessary. As a result, water fleas (Daphnia pulex) will develop plentifully and will protect the brood from want of food even during the months of June and July when the larvae of Chironomida begin to slip their eggs.

(3) After drainage, the ponds must be properly disinfected with quicklime.

(4) As soon as lack of food becomes noticeable and the brood does not grow well enough, the fish are to be removed from the nursery ponds and transferred into the rearing ponds.

(5) The amount of stock for each pond must be carefully regulated. In average, one figures about 50,000 broodfish per hectar (2 1/2 acres), but this is to be so regulated that the brood attains an average length of from 5 to 6 centimeters during the first four weeks. By utmost care as much as 200,000 brood fish can be stored per ha. To merely let the brood slip from the spawning ponds into the nursery ponds is strongly counter-indicated, since this will inevitably lead to slip-shod methods.

With regard to the injurious effects of nursery ponds, formerly and still lately held by many (Schaeperclaus, 1930) only one objection deserves real notice.

It was said that on account of the necessary fishing-out of the brood in June—the most dangerous time for Dactylogyrus affection—the slightest weakening of the brood would expose them to this dreaded disease.

This is easily remedied—where Dactylogyrus occurs notwithstanding the best of care—by rearranging the management of the ponds, i.e. postpone the fishing-out until the end of July or even the beginning of August. This also means that the nursery ponds are stocked somewhat less with brood, in order to provide sufficient food for the prolonged period of stay. Some fishbreeders, on the other hand, obviate the danger of Dactylogyrus affection by advancing the fishing-out time.

But whatever method of "nursing" is employed, the nursery ponds will produce—between June and the beginning of August—relative large broodlings of about 2 to 9 centimeters in length. (At an early date of fishing-out, they will be about 2 to 3 centimeters long, while by fishing them out at a late date they will have reached 7 to 8 centimeters.) In this latter case, it is advisable to use sorting tables which permit the separation of the brood according to size and development of scales (developed already when the fish are only 1.8 centimeters long). By using these tables, one can also separate the broodlings from tadpoles, tench and other fish.

(c) The raising of yearlings.

When raising yearlings, the young carp are transferred from nursery ponds into rearing ponds which can be of most any size. It will facilitate the fishing-out, though, if these ponds are not all too large.

These rearing ponds should have a depth of at least 1 meter in order to avoid—in case of prolonged storing—an over-growing with weeds (see Fig. 20). It is still better to give these ponds a depth of from 1.50 to 2.00 meters, i.e., near the outlet (monk). In this case the yearlings can hibernate in these rearing ponds. It is to be remembered that the broodlings are very sensitive to fishing-out in the fall and are especially in need of food during the winter. The Dubisch procedure surpasses all others by sparing the sensitive yearling carps from the autumn disease favoring fishing-out and the wintering over in small food-poor hibernating ponds. In this procedure, contrary to other growing methods, the autumn fish-out may be omitted because the rearing ponds are already stocked with relatively large little fishes among which losses can hardly occur. The stocking of the rearing ponds can therefore be so planned that in the following spring there will be yearling carps of fairly accurate predetermined size and numbers on hand. The calculated result can also be controlled by repeated weir catches. Surprises are not to be feared in the nursing procedure.

According to prevailing conditions, such as productivity, fertilizing, adopted bottom culture, feeding, etc., the storing of rearing ponds varies, of course. In average, one figures about 5,000 carp per hectar (2 1/2 acres). Proper storage capacity will soon be learned from eventual mistakes made upon this point.

If large yearlings of over 14 centimeters length are desired, the storage should not surpass 1,000 to 1,500 carps per hectar. If yearlings under 10 centimeters length are wanted, the ponds can be stored with 10,000 carp per ha., and under favorable conditions with even twice and three times that number. The losses, generally incurred, from the eighth day to the yearling carp, do not amount to more than 10 to 15 percent in good ponds but can be greater at times.

Yearlings--when sorting them out--are generally graded in three classes, to wit: carp from 6 to 9 centimeters long, from 9 to 12 centimeters and from 12 to 15 centimeters (see Fig. 2).

It is my personal opinion that yearlings of less than 10 centimeters length are inferior in every respect and especially are lacking in resistance to hibernation and to disease germs (the latter attack the brood just at that time). On the other hand, the raising of all too large yearlings has also its disadvantages. Such fish need far too much food for more sustenance in proportion to the food necessary for growth and are therefore an altogether unprofitable stock.

Yearlings bring usually 50 percent higher prices per weight unit than 2-year-old carps.

The nursing ponds, after fishing them out (usually in April) are drained and left to dry until a few days before restocking them. Nursing ponds as well as rearing ponds are thoroughly worked over, fertilized, sown with grass, etc., so as to reach and maintain first class productivity independent from regional condition.

The raising of carp fingerlings and of yearlings in spawning and rearing ponds.

This method according to Schaeperclaus (1930) is used by almost half of all pond fisheries in Northern Germany and is really nothing else but the Dubisch method minus the use of nursing ponds. It is claimed that this method has a particular advantage, to wit: The broodlings are transferred directly from the spawning ponds into the larger and relatively less crowded ponds, whereby the fish are less exposed to contagion from parasites and from disease germs. The fishing-out during summer is thereby avoided.

In reality, it was perhaps mostly scarcity of water and lack of experience, sometimes perhaps more negligence, which led to the introduction of this method. The elimination of nursing ponds makes the work easier for the fishbreeder, but it will invariably lead to more primitive conditions, in short one takes his chances with this method.

Rearing ponds will have to be fished out in the autumn since the actual production cannot be known otherwise. The actual production cannot otherwise be summarized, except that very thorough experiences have been accumulated by means of repeated yearly weir catches, so that the yield may be reliably estimated in advance. Since the losses incurred, by transferring the broodlings directly into the larger ponds are rather great in these ponds, the rearing ponds have to be stocked with about 40,000 fishes per hectar.

Where nursing ponds are lacking but the Dubisch method is preferred, the fishbreeder according to Schaeperclaus can use the rearing ponds as nursing ponds by simply stocking and treating them accordingly. For this purpose they are stocked sparingly and thus handled as nursing ponds.

After four weeks, he fishes them out, refills them and restocks them with nursed brood, just as if he was transferring the brood from a regular nursing pond into a rearing pond. When water is scarce he will have to forego the fishing-out and will then estimate the production results from sample catches. Afterwards, the ponds are filled with the complete amount of water.

The raising of yearlings is handled in all other respects as in the case of the Dubisch method.

The raising of carp fingerlings and of yearlings in larger spawning ponds (also used as nursing ponds) and in rearing ponds.

This method omits, so to speak, the special spawning pond of the Dubisch system. The spawners are set out in nursing ponds of from about 5 to 25 ares (about 1/8 to 2/3 acres), and are left to spawn. After the fishing-out of the parent fishes, the brood is left for 8 to 14 days in the enlarged spawning ponds and is then transferred to the rearing ponds (the broodlings are then about 1 to 2 centimeters long). The losses will be rather constant and the fishing-out of the yearlings can be undertaken with advantage in the spring, omitting the use of special nursing ponds.

Provided that the broodlings do receive the proper care in the spawning ponds, the method can be recommended where water is scarce and spawning ponds are lacking.

Pursuing this idea further, one might arrive at the conclusion that carp could be raised with just one big pond by continually filling and draining it, using it for spawning and nursing and rearing alternately.

This is impossible on account of the quickly accumulating layers of mud and the lack of grass in the deeper parts, near the outlet sluice. But the main obstacle against such a procedure would lie in the great number of spawners required. For 10 ares (about 1/4 acre), one would need 5 to 7 females and 10 to 14 males if the requirement is to be covered by one or two spawning ponds and the spawning is to be successful.

Hatching of carp and raising of yearlings by means of rearing ponds only.

This old method is still applied occasionally today. It is especially to be found now and then in very large fisheries where failures in single ponds do not play so large a role for the entire fishery and where on the other hand there is frequently a lack of reliable working forces which control and carefully handle the nursing method. The spawning carps are placed about 5 sets per hectar into the large rearing ponds where they are to spawn.

I am giving this method here principally to warn against its regular or exclusive application despite a good health condition attained in the yearling carps, because it leads to a primitive management given to chance. The size and amount of yearling carps attained can never be safely estimated in advance. Von dem Borne announces that in such a pond he received yields of 180,000 yearlings and then again of only 8,000 yearlings.

3. The second year, the raising of two-year-old carps.

In the second growth year, the yearling carps (which have been wintered in special hibernation ponds or in rearing ponds) are placed in rearing ponds to grow into two-year-old carps. Only in a year when there is an excess of yearlings it is advisable to crowd these fish (2 to 3 yearlings and more per sq. meter) so their growth remains approximately stationary until the following spring. In the following year they can be used as yearlings. The character of the rearing ponds is the same as that of the normal carp pond. The care and management should be the same as with the masting pond. As the individual losses by diseases and other accidents does not play a decisive part from now on, the time has arrived for a more exact stock calculation on the basis of the local productivity. Normally a stronger more regular feeding is now begun.

In the autumn the rearing ponds are fished out and the two-year carps are placed in hibernating ponds.

4. The Third growth Year, and rearing of market carps.

In the maturing ponds (Fig. 20), which are constructed and managed like normal carp ponds; the market carps are grown to proper size in the third year, in special cases in the third and fourth year.

The feeding and the stock density (number of fish) must be regulated in the third and fourth years even more than in the second year, as the final size and quality of the market fishes depend upon these factors. Both size and quality must correspond to market requirements, and in the interest of good saleability there must not be too much variation.

Fig. 20. 22-acre Carp Maturing Pond in the Lueneberg Heath, in the spring shortly after being filled with water. View from the water inlet; strong formation of earth and water channels on account of flat draining ground in the upper pond.

Since the selection of the spawning carps and their further rearing has already been discussed, it is not necessary at this point to again detail the rearing of spawn carps.

The market carps are fished out in the autumn of the third or fourth growth year, and are either sold at once or after a shorter or longer time of storage. The main demand occurs in the Christmas and New Year season and increases considerably during the Lenten season of the following calendar year. The commercial size classes are designated as 20's, 25's, 30's, 40's, etc., which means that 30 or 40, etc., carps weigh 50 kilograms.

It must be emphasized that the general industry of carp culture as described above is not always completely and purely of that type. Many fisheries sell a part of their fish stock, that is, they only partly rear these fishes. Others again must buy additional carp stock and then keep them only one or two years until they have grown to market sized fishes. The general and partial industry frequently work together.

It is only a small step to the purely specialized industry. The larger special industry is fully equal in its specialty to a corresponding growth division of the general industry. These specialties may be pure fish stock production of carp alevins, yearling carps, or two year carps; or the growing of yearling carps to two year age; or the maintenance and growing of carps for market size production and a corresponding stock production with one or two year rotations; or a maturing industry with a one or two year rotation. A special treatment is not necessary. Only the basic principles of the small pond industry are specially compiled.

C. Side-lines in carp culture.

Value and disadvantages of secondary fishes.

Modern trout fisheries hardly ever go in for side lines, nowadays. On the other hand, few carp fisheries raise carp exclusively. Almost all of them go in for side lines. The underlying idea is to increase business, that is, make more profits, but it must be kept in mind that the culture of side lines makes the raising of carp more difficult and more complicated. Like in agriculture, "mixed crops" increase the returns but complicate the harvesting at the same time. For small fisheries, run upon a simple scale the culture of side lines is hardly to be recommended.

The Tench (Tinca vulgaris)

The most common side line of carp fisheries is tench breeding. So common is this custom that some fisheries are known as "carp and tench fisheries". The tench is (*Tinca vulgaris* Cuv.) (Fig. 21)

The raising of tench is usually done in the carp development and maturing ponds. Several spawning tench are simply placed with the carp. A great evil, justly called "tench mischief" by the tench industry, is the great over-production of small tench brood. The brood is mostly set out year after year and much too abundantly, so that finally from over-aging it again spawns before it has grown to market size.

Because tench are native fishes they are extraordinarily easily propagated, and therefore only one female per hectar should be placed so as to avoid production of too many and too small yearling tench. The females are distinguished from the males by far weaker and shorter developed ventral fins and weaker appearing pelvic bones. (see Fig. 21).

Great difficulties are caused if they are allowed to spawn in special spawning ponds (after the carp in the same Dubisch ponds), because the brood is difficult to fish out. On the other hand, Schaeperclaus (1930) has recently developed another "two pond method" for producing yearling tench: Spawning tench in greater numbers are set in carp nursing ponds (or special tench nursing ponds). By a late fishing out of the nursing ponds in the first days of August, nursling tench about 3 cm. long can be fished out and separated on micro-sorting tables from the carp and tadpoles, and set out in brood nursing ponds. They remain in these ponds until the following spring. This is a great advantage on account of the unusual difficulties of fishing-out tench which like to creep into the mud (use special sieve boxes) and they have very sensitive skins.

Fig. 21. Female Tench. Length 22 cm., 3 summers. In the male the ventral fins are more strongly developed and reach almost to the anal fin.

As already indicated, the culture of tench is generally in bad repute. Only in the pond fishery in Quolsdorf, has systematic selection and constant separation of age classes brought forth outstanding growth results: The Quolsdorf tench which under good circumstances attains portion weight even after two years. According to Nordquist, a good growing race introduced into Sweden surpassed in the second year the old race by 70 to 100 percent. Systematic breeding of rapid growing tench races, according to the same basic principles as with the carp, is therefore the most important task for the tench grower.

The tench, as already stated, is hardly ever grown alone, but rather is used mostly always as secondary stock in carp ponds. At present no conclusive judgement can be formed on the value of this procedure, because it must be also practically assumed that it can be of a different character in individual ponds in accordance with local conditions.

Since the food of the tench is practically the same as that of the carp, the advantage of secondary stock lies only in the increase of fish stock density. Walter rightly emphasizes that this can just as well be attained by the addition of small carps. Not more tench than 10 percent of the number of carps may be added, or else the individual growth of the carps will suffer appreciably. Stronger additions of tench will suppress the individual growth of the carps. However, the growth increase per hectar rises thereby. At the customary intensity of tench additions the number of the carps must be decreased. It has been shown to be advisable in practice, that to a certain number of two-year-carps not more than an equal number of two year tench be added. I have repeatedly found that many pond operators have had special success by setting in only half as many tench as carp, both of the two year age class. To yearling carps there should be added not more than 100 to 200 percent of yearling tench if both fish species are to have satisfactory individual growth.

Formerly, there was a good market for tench, weighing 1/4 to 1/3 of a pound, but today the demand is mostly for 1/2 to 3/4 pounds fish. They bring better prices than carp, but the fishbreeder will make a real profit only then when he properly adjusts his fishery to the necessary alterations.

A 2 years old tench should reach a weight of from 50 to 100 grams. Smaller fish would not reach the proper weight in the third year, while larger ones would increase the costs of upkeep. The percentage individual growth would eventually become too small. Von Milkau has recommended--in order to achieve such results--to stock the ponds with about 200 carp (2 years old) and 200 tench (2 years old) per hectar, or 1,000 carps (yearlings) and 2,800 tench (yearlings) per hectar.

Three year old tench should not possibly be again used as stock tenches, because there is the danger that they will spawn, even if they are small. I have been able to determine that even three year old female tench of hardly 9 cm. length (15 g) were fully spawn mature. In comparison, the largest three year tench of about 400 g weight are used again each year for the production of progeny as a means of producing a good race of tench.

If for any reason, three year old tench must again be set out, they are to be planted with the sexes separated. The sorting (Fig. 21) can be accomplished in the shortest time on the sorting table.

All observers agree that female tench grow better than the males, in average by about 30 percent (Nordquist quotes 35 to 40 percent).

Although the tench goes after food very well and very much better than the carp and the yearling tench eats in cooler weather, a paying "tench masting" cannot be conducted in small ponds according to existing experiments by Walter.

It must also be repeatedly emphasized that the tench, by their moodiness and skin sensitiveness, by the difficult hibernation of the yearlings, by the greater piece-count per hectar, by the greater risk from fish foes and the difficulty of fishing out, often give the pond operator special worry and work. The pond industries today have an important task in providing the lake and river fisheries with tench stock chiefly because in the pond industries the tench can be kept completely free of Ergasilus disease. In non-drainable or strongly weedy ponds the tench takes precedence over the carp.

The Gold Aland (Lenciscus orfus).

This fish is used for "display" in aquariums, in garden ponds and in park lakes. Some carp fisheries raise this fish for such purposes. It is a variety of the aland (Idus melanotus Heck). The gold coloring is due to an almost complete lack of black color cells in the skin. Such "mutations" also occur in carp, tench, crucian, etc. I have bred a pure race of gold colored tench by crossing two such colored fish. They are practically unsuited for the table on account of the faded color of their meat after cooking.

The gold aland is preferred to other gold mutations for "display" purposes since it is a more visible surface fish. Their culture requires hard-bottom ponds, and, as in the case of tench, the breeder puts a few parent fish in the rearing ponds. Not too many, though, in order to avoid a too large progeny of small fish. It is also advisable to use only one pond for their spawning, which occurs in May, in order to facilitate stock regulation. The older age classes, like with tench, may be kept with carps.

The Crucian (Carassius vulgaris Nils).

Fishbreeders, during the last few decades have paid little attention to this fish. But since crucian of about 500 grams weight (about 1 lb.) bring rather good prices, it seems that their culture would be quite profitable, although it offers the same difficulties as the culture of tench. By guarding against over-propagation and introducing rational methods of selection it would be possible to soon develop a race of fast growing, that is, profitable fish.

The crucian is easily distinguished from the carp by a black tail spot and the lack of barbs upon the jaw. It is very resistant, demands even less oxygen then the tench and is free from the oversensitiveness of the skin which is so annoying in tench.

The fish spawns in May and June and glues its eggs to water-plants. The gold variety is not to be confused with the real goldfish (Carassius auratus), a native of China.

The Pike (Esox lucius L.).

The pike has been introduced into pond culture for two different reasons:

(1) The pike shall protect carp and tench from predatory fish (also destroy the brood of such "thieves" and consume any accidental brood of carp and tench, and convert these to usable fish flesh.

(2) The pike has a market value and is raised for market purposes, as nursing pond brood or as stock pike.

In the first case, the fishbreeder keeps a few pike in ponds that are exposed to "wild fishes". Care must be taken, though, that these ponds are stocked only with two-year-old carp, since smaller fish would be devoured by the pike. He is a vorscious feeder, eating up to 30 percent of its own weight. Three kilograms of devoured fish are transformed into 1 kilogram of pike, according to Scholtz.

One figures 10 to 20 pike yearlings per hectar (50 of 10 to 20 cm. length at the utmost). The stronger ones of these fish will even eat up the smaller ones, in true cannibal fashion.

If there is a market for pike stock (line fishers, neighbouring fisheries) it is profitable to set pike brood out in carp ponds. The yound pike feed upon insect larvae during the first summer and by fall reach a length of from 10 to 30 centimeters.

Due to the great demand for pike brood, some fisheries are raising it but special provisions have to be made for this purpose. In the spring, spawners are brought into rather large ponds (of some 100 square meters) where they will soon begin to spawn. Immediately after the spawning, the parent fish are removed through drainage of the pond.

The young brood (first clinging to grass) is able to eat and to swim on the third day; after two weeks, the broodlings are about 2 to 3 centimeters long and after six weeks reach a length of about 6 centimeters. At that time the brood must be fished out, otherwise the stronger ones will devour the weaker ones. This voracity also increases the difficulties of transportation. Always, upon the arrival of such brood their number has usually decreased by 50 percent, and the tail of a smaller fish dangles out of the mouth of a larger one.

The Perch-pike (Lucioperca sandra).

The perch-pike also is a predatory fish, that is from its first to the second year, but less adept in hunting. It only catches very small fish and even those only in turbid waters. It is therefore unsuited for "police duty" in ponds but the increased demand for perch-pike stock for lakes is being met by the pond industries.

Wiedener has recommended to bring one set of spawners into a pond of over 50 centimeters depth.

Here the fish, at a water temperature of about 12 to 14 degrees centigrade will deposit their eggs in grooves, in the deeper places of the pond. It is customary to line spots (nests) with spruce or juniper twigs (in Hungary, bundles of millet are in use) upon which the spawners deposit their eggs. The separated twigs, with their eggs packed in moss can be shipped, if necessary.

The eggs are then spread out along the shores of carp ponds and protected with other branches or screen-covered boxes. After about 5 or 6 days in April or May, the brood emerges from the eggs. By fall, the broodlings will have reached a length of about 10 centimeters. The fishing-out can be done without difficulties before the carps are fished out, especially when using a "fishing box" or seine.

During the first year, the perch-pike feeds exclusively upon plankton; its rearing in combination with carp and tench is therefore clear profit. The perch-pike prefers by nature turbid waters, rich in plankton and of a hard bottom. It thrives well in only feebly eutrophic ponds.

The Trout

Trout as a side line is significant only in smaller carp ponds, and the rainbow trout, of all species is best suited. But, even rainbow trout requires not too muddy ponds, due to its great demand for oxygen, in order to avoid considerable losses by fishing them out. The fishing-out must be done with a "fishing box" or a seine.

The trout breeder can raise his spawners to advantage in carp ponds. Rearing ponds for carp are occasionally also used for the rearing of trout fingerlings. Good results will only be had, when the carp are already big enough so that the trout will not catch up with them, since they would simply eat them up.

Rainbow trout are of no use for "policing" carp ponds.

Other fish, like Whiting (dace) and eel are of no consequence as side lines, although they are raised occasionally in nondrainable ponds, which are difficult to fish out. The eel, at present, do certainly not belong in drainable ponds.

Chapter V

TROUT CULTURE

A. Characteristics of the different varieties of trout and environmental requirements for their culture.

1. General

Just as carp fisheries raise tench and other fish as side lines, so do trout fisheries. They also raise other fish but especially various trout "species" or rather varieties. These different varieties are of different economical value and also differ in habits and requirements for existence.

Since trout breeders have to adjust the management of their fisheries to the habits of the specific variety, we will discuss here the characteristics and habits of the three foremost varieties, cutivated at the present times.

It is of course not always possible to adjust the conditions of pond fisheries completely to the most preferred natural conditions, but at times, fish will even grow better under "unnatural" conditions. Still, the environmental conditions must be such as to facilitate proper adjustment to the changed conditions and artificial feeding on the the part of the fish. This question must be briefly investigated for each trout species as given in the following text. Other fishes occasionally raised with trout, such as graylings, maranes, pike, salmon, etc., cannot be especially discussed here.

2. Brown Trout, or Brook Trout

The brown trout (*Salmo trutta forma fario* L.) is at present the only important native trout variety of all Middle Europe. To trout breeders, it is *the* trout, for short. It was the first Middle European trout species to be artificially grown.

Like all other salmonids, the brown trout has a second dorsal fin, a "fat fin". Orange-red spots, surrounded by blueish and white rings distinguish the brown trout from the sea trout (*Salmo trutta* L.), and from the lake trout (*Salmo trutta forma lacustris* L.) (see Fig. 22). Coloring and bodily form are changeable, though, especially through feeding. Even the red spots may be lacking but the silver glow of sea and lake trouts is always absent.

During the first and second years and until the fish is about 14 centimeters long, the brown trout wears the so-called juvenile coat. It consists of from 10 to 13 large, oval black spots upon the sies (see Fig. 70). While very sililar to young salmon, at that stage, the brown trout is recognizable by 5 smaller black spots upon the rear gills covers. Young salmon have only two such spots and very large ones.

Some scientists, and especially Englishmen and Norwegians like Kyle and Ehrenbaum see in lake, sea and brown trout only different representatives of one and the same species. Brown trout and lake trout have presumably evolved from the sea trout (as evidenced already by their Latin labels). Proof for this hypothesis is seen in the fact that sea trout, raised in fresh water acquire the characteristics of brown trout. Marked brown trout, planted in the Baltic Sea revert back, in appearance and growth, to sea trout. It is also presumed that after the glacial period sea trout evolved from the brown trout.

From the exclusively natural presence of the brook trout as suggested in a "Trout Brook" occurring in the uppermost region near the source of flowing streams of the central mountain zone as well as of the plain, the trout is a fish which has a comparatively small power and latitude of adaptation. It embodies the "Stenotype" in contrast to the pike, which on account of its greater power of adaptation is a "Eurytype".

Fig. 22. Brook Trout (Brown Trout).
16 cm. length fish, not artificially fed, from a large pond.

The trout favors cool waters and does not tolerate great changes in temperature ("Stenothermic" cold water animal). Trout also like clean water with a "through current" or "through flow" (reophil). They favor oxygen and are sensitive to pronounced fluctuations in the oxygen rate of the water "stenooxyybiontic". Cornelius has demonstrated that brown trout assimilate natural food better and artificial food less well than rainbow trout.

These especial environmental demands are the reason that brown trout is more difficult to domenticate than rainbow trout.

On the other hand, one should not underestimate the assimilative possibilities of brown trout, as shown by the possibility of a brown trout to become a sea trout. But the trout must become accustomed to changed environmental conditions at an early stage in life in order to thrive and to subsist.

I have raised especially large fingerlings in the carp ponds at Eberswalde, for instance, from self-feeding brood. The ponds were 50 to 100 centimeters deep, the water temperature (in May and June) constantly 20 degrees centigrade and later on, on the surface, repeatedly as high as 28 degrees. The fingerlings from these ponds in the fall were 200 percent heavier than fingerlings of the same hatch raised in trout ponds, of a water temperature of never more than 18 degrees, but for most of the time only 13 to 14 degrees centigrade. The losses in the carp ponds were 48 percent as against losses of 80 to 90 percent in the trout ponds.

Under intensive feeding conditions, water temperatures of less than 20 degrees centigrade are naturally recommended, since this makes for better hygienic conditions. But aside from this, the optimal food assimilation, under similar temperatures, is seemingly the same for brown trout as for rainbow trout. Temperatures over 10 degrees centigrade will provoke faster growth but not better food assimilation, i.e. do not lead to economy in food.

In trout ponds where the brown trout lives together with minnows, Willer's Thumb (Cottus gobio) and with groundlings, it is extraordinarily hypogynous. Even when feeding, it clings closely to the bottom, which distinguishes the brown trout immediately from the rainbow trout.

The brown trout is a winter spawner, spawns in currents and in pairs. From October to January, but mostly in November and December, the brown trout goes up the brook. The females, followed by a like number of males (Scheuring 1929/30) spawn their eggs in spots of clear water of from 20 to 30 centimeters and in scooped hollows from 5 to 15 centimeters deep. The pea-sized eggs are deposited into these holes.

The flesh of brown trout and of all other trout varieties can be of salmon color; their eggs can be full red if the food contains the red coloring matter (carotene), present in gammarus and shrimp and in some mollusks.

While brown trout, and similarly rainbow trout, possess relatively little capacity for adaptation and domestication, they can nevertheless be raised profitably by means of intensive culture. Numerous hatcheries have demonstrated that brown trout may be raised exclusively or in greater part through intensive artificial feeding. The excellent showing made by some hatcheries in this respect are centainly the result of planned culture.

In one respect, the brown trout surpasses the rainbow trout, to wit: in its relatively greater resistance to Gyrodactylus. On the other hand, brown trout is more apt to contract furunculosis than rainbow trout. With regard to growth, brown trout, from my own observations and those of various trout fisheries, is not lacking behind the rainbow trout, under like conditions, of course.

3. The Rainbow Trout.

The rainbow trout is a native of the California mountain regions. The fish was first brought to Germany in 1880 through the German Fishbreeders Association, and through von dem Borne. For the introduction of fresh blood these importations were repeated from time to time, and 13 such importations were made between 1907 and 1926.

Ehrenbaum has pointed out that the imported stock differed greatly in varieties. Aside from the fixed-form dweller in mountain brooks (Salmo Shasta, Jordan), different crossbreeds and especially steelhead (Salmo irideus, Gibbons) came to Germany.

The steelhead is supposed to have come by its name on account of the great resistance of its head. This fish comes originally from the lower stream regions of these American rivers which shed their waters into the Pacific Ocean.

From here, the steelhead was distributed in the rivers of eastern North America. Although the steelhead still spawns in cooler waters, it is nevertheless really a fish of the mouths of great rivers, i.e. used to warmer waters.

It is reasonable to assume that rainbow trout as well as steelhead retain these characteristics in Germany. The introduction of the steelhead, at least, has fostered the belief that rainbow trout is fundamentally not suited for planting in trout brooks.

If certain hatcheries, especially in Bavaria report good results from the domestication of these fish, we presume that none but rainbow trout (Salmo Shasta) were used in these cases.

The Shasta trout is supposed to have from 145 to 160 scales along the lateral line and to have 63 vertabrae, as against 135 scales and 60 vertebrae in the steelhead.

According to most fishing laws, in force in Germany, the introduction of rainbow trout, char (Salmo salvelinus) and other foreign species for distribution in open waters requires a Government permit.

During the last decades, the different forms (varieties) of rainbow trout and steelhead have been crossed so frequently that a distinction between them (in Germany) is today almost impossible. Ehrenbaum maintains that the differentiating characteristics are now obliterated in Germany. Under these conditions, the question about preferences for or against one or the other species is an idle one from the viewpoint of the industrial fishbreeder.

Ehrenbaum rightly warns not to discriminate against the steelhead (or against the Shasta trout) since it is not at all proven that the steelhead fares worse under intensive culture than the rainbow trout. According to American experiences, the crossing of both varieties has occasionally even counter-acted certain degenerative tendencies.

All that remains to be said with regard to characteristics and life conditions of the Salmo Shasta also pertains to the rainbow trout, as encountered in German hatcheries (see Fig. 23).

The juvenile coat of this, German, rainbow trout is very similar to the juvenile coat of the brown trout, minus the red spots. Along the sides, one finds a row of from 11 to 13 large black spots, in the intervals of which may also, upon occasion, occur one or two rows of smaller spots (Fig. 70).

These spots have disappeared when the fish are about 15 centimeters long, i.e. one or two years old. At that time, the silvery background becomes more pronounced, upon the back appear numerous small black spots and a red line (ribbon-like) appears along the sides. This red stripe is especially pronounced in males during spawning times. The coloring is more vivid under natural feeding than in case of intensive artificial feeding. Like in brown trout the coloring varies very frequently.

In Germany, the spawning season is between January and May. In colder waters spawning maturity is always somewhat retarded. In Denmark, the spawning season is somewhat later than in Germany, while the spawning process is similar to the spawning process of brown trout.

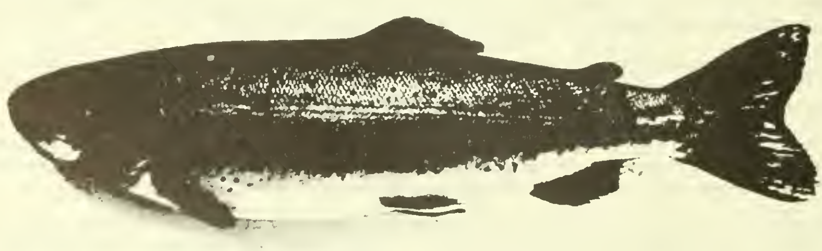

Fig. 23. Rainbow Trout. 2 years old,
230 g. weight, strongly artificial feeding.

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With regard to water temperature the same applies to rainbow trout as to brown trout. I have experimented with thousands of trout fry and which I raised to fingerlings in carp ponds. The surface temperature of these ponds would reach at times 30 degrees centigrade, still the losses (without artificial feeding) were only from 32 to 52 percent.

In a large hatchery I found rainbow trout placed (for prophylactic reasons against gyrodactilus) in small, shallow ponds without any through flow and under intensive feeding conditions. The temperature would rise at times to 24 degrees centigrade (and even more) and about 150 broodlings were counted per square meter. No ill effects whatsoever were observable.

It may well be said that rainbow trout are less "stenotypical" than brown trout. Their adaptation latitude and power is even greater, but as to oxygen requirements rainbow trout are on a par with brown trout.

Notwithstanding these findings, I am—together with Buschkiel—of the opinion that the water temperature for rainbow trout should be kept at from 5 to 15 degrees centigrade, that is, under conditions of intensive culture and for the same reasons as in the case of brown trout. This applies especially for the intensive breeding of adult fish.

If the most rapid growth is desired, the upper point of this temperature range should be maintained since the temperature reacts strongly upon the growth of trout. Carefully conducted experiments by Cornelius have shown that the rate of highest food absorption occurs at temperatures of 19 degrees centigrade.

Best food assimilation and lowest food quotient have been noted (in the case of rainbow trout) at a water temperature of 9 degrees centigrade.

Feeding with fish, at a temperature of 10 degrees centigrade showed a food quotient of 2.9, and of 6 at a temperature of 17 degrees.

The ratio between anabolism and metabolism is therefore best at a temperature of 9 degrees while a temperature of 10 degrees assures best food assimilation. Of course, feeding under lower temperatures requires greatly prolonged work since the fish grow slower under temperatures of 9 degrees than under temperatures of from 15 to 20 degrees.

The great preferences for rainbow trout (over all other varieties) under intensive culture conditions and which have made rainbow trout THE fish in trout fisheries are based upon:

(1) Its adaptation capacity to environmental changes (with especial regard to intensive feeding) and domestication in general.

(2) Its resistance against certain diseases, furunculosis, for instance.

(3) The possibility of speedier hatching at higher temperatures in the spring, hatching after typical winter spawners and shorter terms of incubation.

As disadvantages we list its susceptibility to Gyrodactilus, straying from natural habitats and the alleged lower quality of its meat.

In my opinion, the latter is not at all proven as compared with brown trout and char. Quite often this is merely prejudice, since fish under artificial feeding conditions (rainbow trout are mostly fed thus) do not taste as good as natural feeders. This inferior taste disappears gradually, though quite slowly by keeping the fish in clean water.

I have made an experiment along these lines: I served trout to unprejudiced persons (some of the fish were naturally fed, others had been artificially fed with a mixture of fish meal, meat meal, spleen and shrimp). When served right after drainage of the ponds, the difference in taste was pronounced. The artificially fed fish tasted dry, mouldy and muddy. Their flesh was white and less tender than the reddish, juicy and clean tasting flesh of natural feeders. Twelve days later, the difference in taste was less marked although still noticeable. Only 27 days after drainage (and after the last feeding) had all differences in taste disappeared. The flesh of artificially fed fish was still white, though, but the skin not lighter than the skin of natural feeders.

4. The Char.

The Char (Salmo fontinalis, Nitsch)--also introduced from America--has lost in pond-industrial importance during the last decades. One reason for this lies in the fact that char die easily in their second or third year during the spawning season. It is said of the char that it thrives better in shelterless brooks than brown trout and also requires less oxygen. For these reasons it thrives in oxygen-poor spring regions which are its natural habitat.

The char is a winter spawner, spawning from October to January.

Char are distinguished by the marbled designs upon their backs, the black, ribbon-like stripes upon dorsal fin and caudal fin and the white, black and red stripes upon the pectoral, ventral and anal fins.

B. Artificial Fish Breeding.

1. Significance and Development.

The trout "industry" undoubtedly owes its great importance to artificial breeding. Numerous waters would have been depleted, long since, of their stock of salmonoids if artificial breeding methods had not been introduced. Brood for ponds would be lacking and actual fish "culture" would be impossible without rational selection of parent fish.

By the term "artificial culture" we do not understand rearing of fish in small ponds and by artificial feeding but the manual stripping of the male and female sex products and after artificial fertilization, the brooding of these eggs.

This "stripping" process was first described by Jacobi, who published an article in the Hannover Magazine in 1765. But it was only from 1850 on, that this method was really introduced upon a large scale and accepted in France and Germany, thanks to the efforts of the French fishbreeder Coste.

2. Selection and rearing of parent fish.

The principle to keep spawners separate from marketable fish is more important still with trout than it is with carp. It was found again and again that the ovaries of trout--under intensive artificial feeding--degenerate and produce few usable eggs. Only by natural feeding--or alimentation as nearly natural as possible--and by proper care, approaching natural conditions will the eggs retain their red and transparent appearance. The amount of milt may be increased in males through intensified feeding, but the quality will suffer.

It is quite possible that the chemical properties of fats containing less olein, and of proteins, contained in artificial foodstuffs differs from those of natural foods. This in turn may react upon the composition of the roe, which according to König and Grossfeld is mainly composed of the proteins ichthuline and albumin (both rich in sulphur and phosphorus), while its fats contain as much as 59 percent of lecithine and up to 14 percent of cholesterine. On the other hand (Schaeperclaus) has demonstrated that even whitish and opaque eggs, from intensively but carefully fed fish can produce efficacious brood. The productivity, and not any other characteristic, or the appearance (even when it is unnatural) are the final determining factors.

For the benefit of new rules in the interest of rational feeding, the demand that eggs must be gotten exclusively from parent fishes grown only on natural food or from "wild fishes" which are caught just two months before stripping and have received no artificial food, should not be so strictly enforced. This demand actually has seldom been and frequently cannot be followed.

But aside from this, the rearing of broodstock in brooks and open ponds through natural feeding, exclusively, offers other difficulties and disadvantages.

(1) It is practically impossible to ascertain the hereditary traits of each spawner with regard to growth and resistance under customary, ordinary pond conditions.

(2) The selection of a broodstock of best food assimilative qualities is also not possible since feeding (then) did neither take place nor was it supervised.

(3) Diseases (even Gyrodactylus) can be easily brought in.

(4) It is difficult altogether to raise broodstock to a desirable spawner size on a food supply of micro-organisms alone.

These viewpoints lead me to the conviction that every possibility of raising spawning trout, particularly brook trout, in natural waters should be fully used, and along with this a rational feeding of the spawning trout (especially of rainbow trout) must be considered advisable. The main object is to obtain the largest possible, not too old, spawning trout whose progeny will be good food evaluators. Therefore, there must be an increasing demand for rational feeding. It must begin in the earliest youth, for whatever is missed in early youth cannot be regained later in spite of the best feeding.

The nutriments should preferably consist of life-fresh and uncooked food, such as snails, frogs, (Ahrens states that the ovaries are to be removed.) fresh shrimp, mussels, really fresh sea fish, etc. Reduction by meat chopper, if necessary. An occasional feeding with substitutes, but as rarely as possible, will then be tolerated with less danger.

Strictly to be avoided are irregularities in feeding! Also, sudden changes in the diet, and worse still, a sudden change from natural foods to artificial food or vice versa.

I have found, upon occasion, that 3 year old rainbow trout would be sterile or produce small and unusable eggs. These fish had subsisted for one year upon natural food, were then intensively fed (artificially) and then again returned to open ponds where they were left to natural feeding.

Trout spawners are best kept in larger ponds. I have often seen that breeders kept as many as 200 young spawners per are (1/30 acre) and with good results, but it is really better to store not more than from 1 to 10 per area, especially in the case of spawners of pound weight and over.

Under good pond conditions and in not all too muddy ponds, trout broodstock may be kept in large carp ponds and together with carp. In this case, though, the ponds have to be fished out with the fish box outside of the pond. In this way the trout will be caught cleanly and without loss before the carp mature.

But once again and in order to avoid any misunderstandings, I wish to emphasize that natural pastures are for trout broodstock of the same importance as for carp and should be available for them as much as possible. They provide, and without any effort on the part of the breeder, what artificial feeding will provide only by greatest care and with much work, to wit: Vitality, resistance, fertility and good health of all organs. In the case of brown trout--far more resistant to domestication--this is especially to be remembered.

The importance of "natural pastures" finds expression even with the fishing laws of the different countries. The laws permit catching of trout broodstock even during closed seasons. Most trout breeders, for like reasons, rightly try to lease valuable neighboring trout brooks in order to use them for the rearing of their broodstock.

One or two months before the spawning period, the breeder begins with a reduction in feeding. It is best stopped altogether when the spawners begin to go upstream to reach their spawning grounds. In this way, any injuries to either roe or milt of the fish will be avoided.

I will mention, though, that trout never stop eating altogether. This is proven by the presence of feces during the stripping process.

With the beginning of full maturity, the special demands for existence on the part of brook and river dwellers come to the fore, so to speak. The most perfect eggs and the most prolonged movements of the spermatozoids are observed in waters with a strong current (Scheuring). For this reason it is to be recommended to get the broodstock out of the larger ponds and transfer the fish into such waters. Where broodstock is kept in natural waters (brooks), it is best fished out already during the summer months and brought into special ponds. The females, especially, should not be fished out too late.

At least once every eight days, the stock ponds or tanks are gone over with a small drag net and the trout are examined as to their full maturity. This has been reached when the milt and eggs exude upon a slight pressure and the eggs are felt loose and moveable in the female. Milt which only exudes upon hard pressure or is mixed or colored with blood is still immature. It is over-ripe, when a watery fluid precedes the issuance of milt and the milt itself is thin and watery.

If not resorted to already, the different sexes are now best separated and brought into separate ponds or tanks. Keeping trout in tanks has no disadvantages as Scheuring (1928) has proven again through milt tests.

Males of the rainbow trout are easily distinguished from the females through a vividly red stripe upon their sides. Their belly is usually somewhat darker than the belly of the female and the lower jaw, in older males show a typical hook form. One also notices upon them so-called "spawn rinds", i.e., a thickening of the upper layers of the skin along the fins, especially around the tail fin. The females are easily recognized, and at an early date, by their embonpoint and the somewhat protruding red "vulva".

The males will attend to their reproductive functions repeatedly during one spawning period. This especially the case when the males are kept in ponds (or tanks) whose water is the overflow from tanks, plentifully stocked with females.

As a rule, males can be stripped from 3 to 8 times at intervals of from 8 to 14 days, with a rest period of at least 70 "day degrees" (4 hours) between two strippings. It takes that long for spermatozoids to ripen. As a rule, repeated stripping stimulates the development of spermatozoids. Scheuring was able to obtain from one male an amount of milt equivalent to 8.89 percent of its body weight. For these reasons the number of males ought to be only 1/4 to 1/3 of the number of females. In order not to exhaust the males, many fishbreeders see to it that their ponds are not at a lower level than the ponds of the females, nor do they keep them together with the females. But in case of immaturity of the males it is recommended to bring them together with the females.

The full maturity of the female is of short duration. As a rule, it lasts not more than 8 days . Mature eggs, carried for more than 8 days in the belly of the female show signs of overripeness (degeneration). Mrsic found another disadvantage with regard to overripe eggs (although still incubatable) inasmuch as such eggs will produce a progeny of 86 percent of males as against a progeny of only 50 percent males under normal conditions. And the same may be said with regard to immature eggs (proven for frogs by Hertwig). If the brood is to be later placed in natural waters or to be raised into spawners, that kind of material (overripe eggs) would cause a highly disadvantageous shifting of the sex ratio. Also, the number of malformations and of freaks increases with overripeness of deposited eggs.

The start of sex maturity during one spawning period depends upon various factors:

(1) Upon the variety of fish (brown trout, char are winter spawners, rainbow trout spawn in the spring).

(2) Upon the hereditary traits of the existing race and the characteristics and deviating traits of certain individuals.

(3) Upon the water temperature and the modus of changing the water; also upon the regional climate and other local conditions (brown trout will come sooner to maturity the sooner lower winter temperatures follow the warm summer days, while rainbow trout mature earlier the warmer the water during winter and spring).

(4) Upon the movement of the water. According to Ahrens, free-water fishes mature earlier than pond fishes.

(5) Upon their state of nutrition. Under-nourishment retards maturity.

Perhaps other environmental factors are also of influence, the presence of the opposite sex, for instance. Ahrens claimed that from the 4th year on, the spawning period will occur at earlier dates but my own experiments with the same stock of rainbow trout (over a period of 3 years) did not confirm this. Table 12 is based upon these experiments. At the same time it explains the rule given in 3, thereby giving a summary on the average water and air temperatures for each year.

It shows that the spawning period is seemingly retarded when the month, preceding the spawning (in this case February) is too cold. The broodstock used for my investigations came from eggs, hatched in 1928 in a fishery with spring water supply. The climate there is mild and the fishes had been stripped on the 10th of February. My investigations also did not allow to formulate the rule that either larger and smaller fishes attain maturity at an earlier date.

Table 12.

Dependence of spawning periods (of rainbow trout) upon the temperature.

		1930				1931				1932			
		January	February	March	April	January	February	March	April	January	February	March	April
Atmospheric temperature in centigrade.	Average	2.0	0.1	3.8	8.9	0.0	-1.4	-0.4	5.7	1.4	-1.7	0.4	8.1
	deviation from many year average	3.2	0.0	0.5	1.3	1.2	-1.5	-3.7	-1.9	2.6	-1.8	-2.9	0.5
Average water temperature (trout spawning pond) in centigrade.		4.4	3.3	3.9	7.4	3.0	2.9	2.7	5.9	4.0	2.6	3.8	7.1
Duration of spawning period.		Mar. 18 to Apr. 17				Apr. 10 to Apr. 22				Apr. 16 to May 7			
Age of trout (in years).		2				3				4			

One should not underestimate the possibility to make practical use of certain rules concerning maturity with regard to early spawning. Early feeders among the fingerlings of rainbow trout, for instance, are superior to others in many ways, such as better acclimatization, longer growth duration, complete accomodation to food at the beginning of the main period of growth during summer, less inclination to contract Cyrodactilus etc. The differences are at times quite marked.

I know of a trout hatchery in Central Germany. There, the brood (from Danish eggs) began to feed on May 26, while brood from their own eggs began to feed already on April 1, i.e. almost two months earlier.

With regard to the appearance of sex maturity for the first time in individual fish, I would like to say that two years old females bring forth eggs for the first time. According to Wohlgemuth males can become sex-mature already in the first year.

If mature fish are not stripped or do not spawn, their eggs and spermatozoids are converted back. The egg shells remain in the "ovarian pouch" and are expelled at the next spawning. First year females are seldom fit for stripping, they are not large enough and their state of nutrition is often under par.

Certain paratypical factors play an important role in the evaluation of spawn trout to be used for stripping. Size, state of nutrition and perhaps even age. These factors influence the sex, the number and the growth of the progeny. The size of the parent fish is the determining factor. Upon it depends:

(1) The absolute and relative amount of eggs in the female and of milt in the male.

(2) The size of eggs.

(3) The proportion of sexes among the progeny in relation to the mating of differently sized parent fishes.

Age and state of nutrition seem also to exert some influences, although to a lesser degree. They will influence the procreative functions of males and females. Young males, 3 to 4 years old, subsisting upon natural aliments will produce a better milt, according to Scheuring, than older ones. These latter are frequently sterile. Well nourished males--even those subsisting altogether upon artificial food--produce more milt than badly nourished ones.

Diseases and injuries are injurious to both, males and females. A more than normal loss of scales may cause sterility in females and may cause water disease of the vitelline sac of their brood. Injuries through fishhooks, though, have no noticeable bad results.

All of these things have to be considered if first class spawn-trout is the attempted goal.

Females of 1 kilogram weight produce an average of 2,000 eggs. In smaller fishes, the number of eggs is offhand absolutely less but relatively greater. In very small females, their number drops absolutely as well as relatively, as may be seen from table 13. The figures in this table come from well nourished trout, raised by me at the Academy of Eberswalde.

Table 13.

Weight and number of eggs of brown trout of different sizes, but of same age.

Weight of mother fish, before stripping.	Weight of an egg after fertilization.	Number of eggs.	Calculated number of eggs per 1 kilogram of trout.
282 grams	51.8 milligrams	768	2700
235 "	63.5 "	588	2500
205 "	57.5 "	444	2170
162 "	57.6 "	218	1350
90 "	53.9 "	144	1600

The weight for an egg represents the average weight, as calculated from all of them, and from one and the same female. Aside from these test fishes, numerous others were also investigated. Isolated cases of exceptions always occurred.

Similar regularities, based upon practical experiences with rainbow trout were found by Quirll. In table 14, I record his findings.

Table 14.

Number of eggs from rainbow trout of different sizes and ages.

Weight and age of the individual female.	Number of eggs	Calculated number of eggs per kilogram.
1650 gr. 5-6 years	2900	1750
875 " 3-4 "	2400	2750
750 " 3-4 "	1900	2540

Mast also has demonstrated that the number of eggs per kilogram drops when the weight of fish rises over 200 to 250 grams. Unfortunately, he did not properly segregate age and weight in calculating his findings.

But from all this we derive the practically important knowledge that eggs from larger and older fish (i.e. larger eggs in general), cause substantially greater outlay than eggs from young and smaller broodstock.

The size of eggs is important for the fishbreeder since larger eggs produce a larger fry than smaller ones. Sklower confirmed this law through experiments with brown trout and also demonstrated that the size of parent males, used in stripping has no influence whatever upon the size of the progeny. Fry from small eggs remained smaller all through the first year than fry from larger eggs. In this respect is must be remembered, though, that the size of the father fish depend upon hereditary good food assimilation. Their progeny can therefore only be judged after they begin to feed and after eventual unfavorable paratypical influences (size of eggs) have disappeared. I have had the same experiences as Sklower with rainbow trout. In this case, the mortality among fingerlings from very small eggs was very high during the first summer.

Table 15 shows conclusively that the size of eggs* (and consequently of alevins) is functionally depending upon the size of the mother fish and not upon their age. The

* Measurement of eggs by ocular micrometer, "egg pincettes" are unusable.

table lists the size of eggs of a stock of uniform rainbow trout, uniform genotypically and paratypically. The enumerated groups are comparable among each other since frequently only one factor, i.e., age or size differs, while all other factors were kept alike (compare groups 1 and 2 and 4; 7 and 8 with 5 and 9; 6 with 9 and 10; 2 with 7 and 10).

The similarity of hereditary characteristics is guaranteed, since the table deals with a small and isolated stock, whose progeny underwent examinations from year to year. Only the fish in groups 7 to 10 were so kept as not to increase from the 3 to the 4 year, i.e. their nutritional conditions were therefore bad. Their eggs, for these reasons were smaller than in the previous year, i.e. when the fish were a year younger.

Table 15.

Relations of the size of eggs of mature mother fish of rainbow trout (kept under like conditions) to the size and age of the mother fish.

Mother trout					Diameter of the eyed eggs.	
No.	Genealogical relations and state of nutrition.	No.	Age Years	Individual weight grams	Average	Fluctuation
1	Same broodstock as No. 2 but undernourished.	69	4-6	1000	5.12	4.5-6.9
2	Prima paras, well nourished.	23	2	1000-1250	5.25	4.2-6.9
3	Progeny of Nos. 1 & 2; not fed.	30	2	145	5.7	3.1-4.1
4	" " " " " "	5	3	210	4.6	4.0-5.7
5	" " " " " "	5	3	172	4.4	
6	" " " " " "	2	3	155	4.2	
7	" " " " " "	4	4	215	4.2	3.5-4.9
8	" " " " " "	2	4	248	4.3	3.8-4.6
9	" " " " " "	1	4	185	4.1	3.7-4.5
10	" " " " " "	1	4	190	4.2	3.7-4.4

These investigations, conducted at the Forest Academy at Eberswalde show that the conclusions, arrived at by Sklowers can be misleading. He formulated the theorem: "From young mothers small eggs, from old mothers large eggs". In the case of rainbow trout, at least, this is not so at all. Sklower made his observations upon materisl, varying in age as well as size and also perhaps in varying stages of nutrition.

But there are still other factors which determine the size of eggs. Mrsic (according to Neresheimer) for instance found that overripe eggs become reduced in size on account of resorption. Also, the oxygen content of the water in which spawning takes place can later on, seemingly, influence the size of eggs. In my investigations as reported in table 15, these factors have been kept alike.

It results from all this that for practical purposes the fishbreeder must strive to raise the possibly biggest but not oldest mother fish. By avoiding extremes, the fishbreeder is sure to have large and well performing eggs and without lowering the amount of eggs obtainable. He will thus also be protected against disorders in later stages of development and which are of common occurrence in brood from very old mother fish. It is for these reasons that I recommended earlier rational feeding of spawners, since large sized fish will only then quickly be raised (as in table 15, No. 2).

There remain still two more questions with regard to size and age of spawners and which are of importance to the breeder.

There is first the question of age and size of the male. It is a somewhat common practice to use young and small males for the fertilization of eggs. Scheuring has demonstrated that the spermatozoids from 3 to 4 years old males are most lively (motile) and retains their motility the longest. Sklower found that the size of eggs is not influenced by the size of the males. From these findings, there seems to be no objections to the common practice referred to above. But I would like to call attention to certain disadvantages, pointed out by Thumm. Thumm found that with fish it is also the rule that mating of small, young males with large and older females will produce a predominantly male progeny. Persistent use of small and young males will by and by react upon the sex proportions, the "sexual figure", i.e. the number of males per 100 females.

Another question is to the effect if the elimination of older trout does not represent "waste of brood stock"? This is the contention of Sklower. These fish certainly produce large eggs, which in turn produce large sized offspring.

But it is known, on the one hand, that greater losses in eggs occur from older females and on the other hand, we observe over and over again a greater percentage of sterile fish among them.

Rainbow trout females, which could be stripped 100 percent during the 2nd and 3rd year showed 64 percent of sterile fish in the 4th year. (Material used in table 15.) A smaller sterility figure is certainly possible under more favorable conditions and by better feeding, but in practice it has been found that spawners are best eliminated after the age of 7 years. Scheuring made the observation that even among males, sterility increases, relatively, with age.

After this discussion of the care and rearing of trout spawners with regard to paratypical factors, and which predetermine from the egg the size and quality of the offspring--independent of possible hereditary characteristics--I turn now to the subject of "genotypical" factors, i.e. to the subject of planned rational selection for the production of trout of commercially profitable hereditary characteristics.

The aim of selection and of selective breeding is to produce a race of highest standards. I understand by "race", in this connection, the definition of the term as given earlier. The progeny shall reproduce hereditary characteristics, i.e. under like conditions of existence. If these conditions differ, the paratypical modifications of hereditary characteristics can be greatly variable (especially "physiological" characteristics, including growth characteristics). This does not impair the "racial fixation". To the contrary, the adaptability of the races to special conditions is of commercial value. A lack of adaptability causes severe failures in the transplantation of races.

But an absolutely perfect adaptability can never be attained. For this reason it is wrong to continually experiment with the introductions of "original forms", so-called, and so often done in the case of rainbow trout. Breeders should abstain from trying to improve their races by attempts to emulate the types of some other localities. In this respect it is worth noting that the recent importations of rainbow trout from America were a disappointment from the viewpoint of quality (Jaisch).

It is far better--as Kronacher has pointed out--to develop and to perfect the races through selective breeding of offspring--as in the case of higher animals--from the best and best performing trout, adapted to local conditions and according to the principles as set forth for carp.

When fishing out ponds it becomes apparent that the fish, that is, the production abilities of fish vary even among trout. It is erroneous to presume that a continuous selection of the largest and most resistant fish for reproduction is superfluous, because planting experiments in the Baltic Sea have shown that the growth ability of trout is actually greater than is made use of in pond fisheries. It is a fact that brook trout planted in the Baltic Sea increased to 1500 grams (3 lbs.) within two years. It follows that the growth ability of the individual trout must be very great. But that is not the only point to be considered. Food assimilation, resistance against disease and pond conditions are of no lesser importance. It is to be presumed that the precociously growing fish is more endowed with these qualities than its retarded mates. Many trout in the Baltic Sea were finally just as much retarded in their growth as pond fish. Selective breeding must for ever remain the most important factor in trout culture. As a matter of fact, one finds today in German trout fisheries especially well performing "breeds" of broodstock obtained through selective breeding and which may well be spoken of as "races".

I wish to mention here that the variety question played a certain role in the importation of rainbow trout from America. Originally, these importations were designed to combat certain symptons of degeneration through the introduction of fresh blood. Such symptoms of degeneration are closely interwoven with the problem of race development. In themselves they do not represent anything homogeneous. Probable causes for degeneration may be:

(1) Genotypical factors, inbreeding for instance, facilitate the reappearance of recessive and undesirable hereditary characteristics.

(2) Paratypical factors, to which belong bad care, improper food and feeding, etc., that is, bad management.

It is obvious that the ravages enumerated under 2 can be avoided. Their prevention is the most important means to avoid degenerative symptoms altogether. Inbreeding does hardly any harm in trout culture, since the number of offspring is really enormous. And according to the laws of heredity, only a small proportion (up to 1/4) can be afflicted with undesirable, recessive characteristics. Such fish are easily eliminated or eliminate themselves. The loss on the basis of enormous quantity of progeny is really not great, since young fingerlings, altogether, are of little commercial value.

The large number of offspring makes speedy development of favorable hereditary factor combinations possible and at the same time facilitates the elimination of badly endowed individuals from the field of reproduction, and precisely by means of inbreeding.

Inbreeding in fish culture is therefore of really positive value, as is shown by well managed fisheries.

The great advantage of a numerous progeny has, on the other hand the disadvantage that fish mature relatively late. The number of fish generations within a certain space of time is smaller than in domestic animals.

Ehrenbaum has rightly emphasized that degeneration or degenerative symptoms, caused through inbreeding are negligible in trout culture. In America such symptoms occur at all times, the steady supply of fresh blood notwithstanding.

Nothing special needs to be said regarding the supply of spawners of other kinds of fish such as salmon, graylings, maranes and pike for artificial culture. As a rule they are stripped immediately after they are caught. Pike and also maranes must not be stored for any length of time, because the sex products repidly become unusable. Tomuschat, to be sure, announces good storage results with small maranes. With maranes, but particularly with pike, the use of a relatively larger number of males (which mostly ripen before the females) is advisable to insure fertilization. Here the possibility of obtaining artificial brood depends upon the simultaneous catch of ample amounts of fully ripe milters and spawners.

3. Artificial Extraction of the Sex Products.

We distinguish between "wet" and "dry" fertilization. In "wet" fertilization, roe and milt are stripped from the fishes right into the water. By using the "dry" method, water is added only after the stripped sex products have been thoroughly mixed. "Dry" stripping is based upon the observation that milt, so stripped, remains fertile for a number of days, while the resulting motility from the addition of water lasts only a short while. (According to Scheuring, 1928, milt from rainbow trout—at a temperature of from 4 to 8 degrees centigrades--remains usable for ten days, milt from brook trout for only one to two days and the not stripped milt in dead fish only from 12 to 24 hours.

Scheuring also found that the motility of trout milt lasts as long as 90 minutes, intensive motility up to 30 minutes.)

The relatively small and flaccid eggs, when stripped, will swell within a few minutes. The spermatozoids enters the eggs through a small opening, the micropyle. After the absorption of water, this opening is blocked and a fertilization is no longer possible. As a matter of fact, "dry" fertilization gives extraordinarily good results, although--or rather because--it is an unnatural method. Almost every egg becomes fertilized by this method.

In German trout fisheries the "dry" stripping method is almost exclusively in use, although I have found "wet" stripping occasionally in the Central Mountain regions. If quickly done it gives just as good results as "dry" stripping, which certainly goes to prove that elaborate and much detailed directions for stripping--quite often given--are really superfluous.

With the sticky eggs of certain fishes (pikes) the "wet" method has many advantages, according to the experiences of breeders and I agree with them upon the basis of my own experiences. The reason for it may lie in the fact that by "dry" stripping of pike, the spermatozoids become enveloped in the slimy exudates and thus deprive them of their motility.

I had success here with the "wet" method by gathering the sperma of a number of males in a water-filled bowl, into which I then stripped the eggs. The procedure in both methods is otherwise alike as seen from the following description.

Before beginning with the stripping, one has to have handy, at least, two dry and clean enameled bowls of about 25 to 30 centimeters diameter. Also some cloths, some chicken or goose feathers and a pair of egg tweezers.

The female is best caught by slowly gripping her with both hands. The neophyte in this business should use a towel or cloth until some practice is acquired. The fish is to be caught by the head--to be kept upward at all times. Water clinging to the fish is blotted with the cloth. Then turn the fish with belly upward, the cloth to cover the head only but not the body. Hold the fish in the left hand so that the tail hangs down, closely to the rim of the bowl. The biolent resistance of the fish ceases after a few seconds and it will remain limp in the operator's hands.

Fig. 24. Stripping of a Female Trout.

The stripping is done with the thumb of the free hand which massages the eggs out, so to speak, by following the middle line of the belly. In order to ease this process for the fish, one should begin to strip first the eggs from the rear end, coming slowly nearer

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the opening. At the end of the process, the abdominal cavity of the fish appears entirely empty and collapsed but by careful handling the fish suffer no ill effects.

All eggs can be removed from the female at one stripping, since there are no differences as to maturity or development between the forward and the rear end eggs (according to Mrsic). Repeated stripping over a number of days would distress the female unnecessarily. It is not advisable to strip the eggs into sieves so as to drain off the amniotic fluid, since the presence of this fluid increases the motility of the spermatozoids (according to Scheuring).

It was presumed in former days that stripping of salmonoid species was so relatively easy--as compared with other species--because these fish are minus tubes. Newer investigations by Leach and Kendall have shown this to be an error. The mature eggs in trout--according to these authors--are dropped into pseudo peritoneums, into an "ovarian pouch", as it were. This pouch will tear only through rough handling and the eggs will then drop into the abdominal cavity. This will also occur if the head of the female is kept downward. The eggs will then fall into the abdominal cavity through a fissure (a cleft) in the rear end of the pouch. This can be harmful to the fish.

The process of stripping is now repeated with some 2 to 4 females until the bowl is 1/3 or 1/2 full of eggs.

Now, a male is caught in the same way as described for the female. In difference to the female, he is held with belly downward and in such a way that the body opening comes over the middle of the bowl. With thumb and index finger the milt is stripped from the fish. The fish practically "slides" through the hand of the operator. (In some case of very large and active fish an assistant may be necessary to hold the fish by the tail.) The amount of ejected--odorless--milt is very small but is sufficient to fertilize a large number of eggs, since it contains large quantities of spermatozoids (in rainbow trout 32 to 39 (1 eq. 1/1000 mm)). Since sterile males are rare among trout, it is sufficient to strip just one specimen. For the safety of greater quantities of eggs, 2 males may be stripped. (Among maränes and pike, immature males are frequently found. In their case it is best to strip more males than females.)

Lehmann has pointed out that the use of inferior oil cloth aprons, worn by the operators may cause considerable losses among the parent fishes. A bad oil cloth fabric often contains acids which are injurious to the skin of fish, and it is unavoidable that they come into contact with the apron.

According to Scheuring, the good quality of the milt of trout is recognized by:

(1) Good milt is cream-like, while inferior milt is curdly, watery or flaky.

(2) Good milt has a chloride content of from 0.26 to 0.34 percent and a pH rate of from 7.3 to 7.6, while bad milt or overripe milt shows lower rates. Immature milt can have higher rates.

(3) Good milt furnishes spermatozoids of long-lasting "motility" and in fish of the same stock of even duration and of great intensity of movement.

I have to state, though, that so far it is not at all proven that these enumerated qualities are identical with a high virility. Neither is the vivid coloring of a male proof for the good quality of the milt. On the other hand, males (of rainbow trout) whose silvery glow of the belly extends beyond the lateral line, so-called shiny fishes, are almost always sterile and therefore should be eliminated.

The stripped-off milt is now thoroughly mixed with the eggs by means of the feather (see above), and all foreign matter removed with the tweezers. Only then is water added to the bowl, and eggs and milt are again thoroughly stirred with the feather. After this, the bowl is left alone for about 20 minutes while the operator proceeds again with the stripping of new fish.

After this period of rest, the now fertilized eggs are dumped into the brood receptacle. During the first few hours after fertilization the eggs are very resistant and will even stand transportation. With eggs of maranes and pike such a transportation is almost always necessary. (For shipments it is best to use white metal cans, not "galvanized" sheet iron or otherwise zinc-coated metal cans.) These cans are filled to 1/4 with eggs and then completely filled up with water. Before this is done, the eggs have to be thoroughly washed, in order to free them from all dirt, slime and now superfluous spermatozoids. For at least 15 minutes, the eggs are rinsed and stirred with ever renewed, clean water. Stirring up will bring eventual scales, even feces to the surface. These are removed with the forceps. During shipment (which I have successfully done for a period of 12 hours), the water is not to be renewed. As mentioned before, it is also possible to ship eggs and milt in dry state, best in thermos bottles, but this is seldom done in practice.

4. The Construction and Arrangement of Brood Apparatus for the Artificial Hatching of Fish Eggs.

The importance of proper incubation of trout eggs cannot be overestimated from the economical viewpoint (Fig. 30). And since trout eggs are relatively large, about the size of a pea, the process of their incubation is quite easy. Among the many specially constructed apparatuses or those with unimportant modifications, only the California incubating apparatus (under current apparatus) and the long current apparatus have maintained a considerable use in practice. I will describe here the mode of their construction, and which from my experiences appears to be the most practical one.

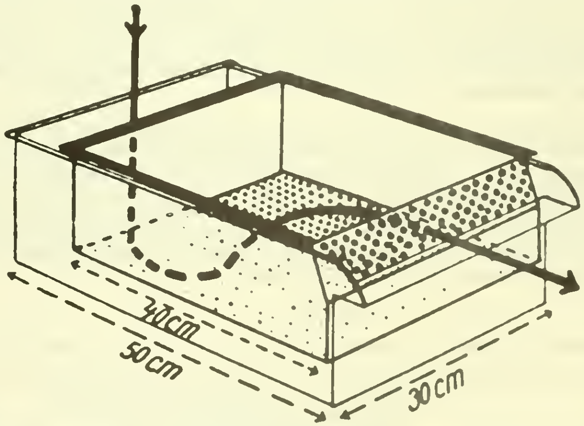

Fig. 25. Undercurrent Apparatus (California Incubator) for the incubation of trout eggs. The inner sieve box, for the sake of clearness, has also been drawn into the covered portion. The sieve box is covered with a lid during the incubation (30 cm. x 40 cm.).

The construction of the California brood basket--an "undercurrent" device--is seen in Fig. 25. The eggs rest upon a sieve-like frame and the water washes them from below. The result is that oxygen and fresh water supply are especially good, and any mud present in the water will settle at the bottom of the baskets. The baskets should not be much longer than about 30 to 40 centimeters, in order to have an "even undercurrent". The wider the apparatus, the more attention must be paid to an even water current all through the baskets. In the sketch (Fig. 25), it was attempted to achieve this by an outflow from the <u>whole</u> <u>width</u> of the basket instead of through a pipe in the middle of it. An even inflow and an even distribution of same is assured through installation of a number of faucets, or through the insertion of a distribution plate. The frames should not be deeper than about 15 centimeters and not wider than from 30 to 40 centimeters, in order to assure a good view of the eggs at all times. On the other hand, one should not go below a certain minimum size of these baskets. Willer has shown that a small volume and a small amount of water interfere somewhat with the growth of the embryos in the eggs (excretion factor, mentioned before). The surface size of the baskets greatly influences the growth of the alevins (outflow factor). It was found that brood from a basket of 1925 square centimeters, one hundred forty days after fertilization had grown to 25.02 millimeters in length, weighing 112.4 milligrams. On the other hand, brood from a basket of only 565.5 square centimeters of size was only 24.47 millimeters in length and weighed only 111.2 milligrams.

If feeding of the brood is intended in the basket (the "understream" basket is less adapted for it than the "longstream" apparatus), the suspended removable sieve is taken out and a smaller otherwise similar sieve is suspended before the outflow. The inner side of the sieve is best painted white (to facilitate the view), and all the rest can be kept black. Special waterproof, quick drying paints for incubators may be gotten from G. Korn (G.K. Farben) in Dresden. Wooden parts are best painted with tar; asphalt lacquer is just as good but dries very slowly. All zinc parts must be especially well painted over as they will otherwise bring about highly toxic zinc combinations (chloride of zinc, etc.). The inserted sieves can be easily darkened with well-fitting lids.

On account of the shortness of the undercurrent incubator, several boxes are mostly placed under each other. For this purpose a relatively large fall is necessary, or there must be a very long inflow channel, in order to accomodate the installation of a larger number of boxes. Too many boxes must not be placed under each other, or else the fresh water supply to the lower boxes will be insufficient, and the amount of water to be run through will become too large. It is better to form the front wall of the sieve box into a protective sieve, rather than to suspend or insert special protective sieves which mostly do not shut off safely.

Egg losses during the incubation are essentially determined by the kind of support, that is, by the sieve surface of the insertion. The sieve surfaces used in individual establishments vary greatly. In order to determine the suitability of individual sieve types, I have conducted experiments in the hatchery of the Forestry School at Eberswalde, upon white metal (tin) sieves with slits (2 x 20 mm.), round perforations (2mm. diameter, Fig. 13), wire screen (1.3 x 1.3 mm. mesh, 0.5 mm. wire diameter), and round rods (10 mm. diameter, 2 mm. separations). The results shown in Table 16 were obtained by covering the sieves with single layers of rainbow and brook trout eggs.

Table 16.

The influence of different frame materials upon the loss of trout eggs.

Year	Species	Brood stage	Number of eggs per frame 40x40	Losses in percent			
				Wood Rods	Wire	White metal (slits)	White metal (holes)
1929	brook trout	eyed eggs (nonfeeding)	505	5.8%	3.2%	67%	5.7%
1930	rain-bow trout	hatched, able to feed	1563	19.1%	18.5%	20.8%	19.9%
1931	brook trout	eyed eggs, able to feed	3000	0.7%	0.5%	0.8%	0.7%
	Passage space of frames:			16%	57%	28.8%	40.0%

As seen from this table, wire-mesh frames give the best results and the space for the passage of water obviously determines the final results. The relatively good results obtained from wooden frames are only due to the small number of eggs per frame. On account of this, each egg rested automatically upon a slit, that is, was directly in touch with the water current. In order to avoid any eventual blocking of the water current the breeder should not make use of especially reinforced frames, while in order to avoid "air pockets", the meshes should be bossed somewhat downward. This will not interfere with the eggs. The troughs can be made of either wood or white metal. Industrial manufacture, like in the long stream apparatus, is not customary on account of the small demand.

The "long stream" apparatus consists of a long trough of at least 1.50 meter in length. Material as well as width vary according to conditions. For smaller hatcheries wooden troughs (Fig. 26) are recommended, while large breeding plants will mostly use stone or cement troughs. The frames ("boats", "cradles") are simply set into these troughs, sometimes even in layers, one on top of the other, and must be wide enough to completely fill the trough, somewhat above the water level.

This arrangement forces the water to flow through the transverse sides of the frames. All interference with a free current is scrupulously to be avoided. The "boats" had best be formed as shown in Fig. 26, the feet are made of tin. The suspension of the sieves from a higher edge or setting them on points in the side walls is impractical. All that was said with regard to "under current" apparatus is also to be taken into consideration here.

A great advantage of the "long stream" apparatus is that it requires only a low degree of inclination, and secondly, very important, after removal of the "boats", the spaciousness allows its use for brood feeding.

In order to avoid an eventual escape of the fry, the transverse walls should be raised by frame screens (wood frames holding sheet metal with 2 mm. perforations setting in slots in the side walls). The lower frame, if placed somewhat slanting will act as an automatic stream cleanser.

I estimate the minimum of necessary inflow--when using California baskets-- at 0.4 liter per second and per square meter of egg resting place. The frames can be stocked with two layers of eggs in any of these apparatus. More than two layers are not advisable on account of the excretion factor mentioned earlier in this book. Trout eggs of 5 millimeters in diameter can be placed up to four per square centimeter in one layer and up to eight when stocking the frames with two layers per frame. From these figures the required dimensions can easily be determined in case of new installations.

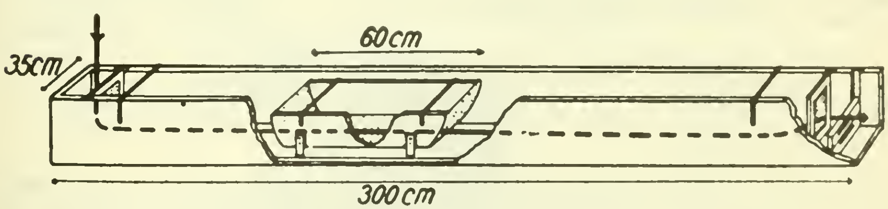

Fig. 26. Long-stream Apparatus for the Incubation of Trout Eggs. Only one of the four sieve insets is drawn. The framed screens at the inflow and outflow are set in place only when the box is to be used for feeding the brood. The water level is regulated by a small sluice board. Covers are placed on during incubation.

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<u>The method of gravel-bed hatching</u> is popular again in the Rhine and Moselle regions in Germany, also in Holland. Trout, and above all salmon, are hatched in this way. The method was widely discussed in Germany, at the turn of the Century as the method nearest to natural salmonide hatching conditions. Alternating layers of gravel—2 to 4 centimeters thick—and of freshly fertilized salmonoid eggs were than put into large "long stream" troughs of either wood or cement. The gravel had to be coarse enough so as not to press upon the eggs, filling the spaces between the gravel and allow for a free play of the water. The resulting brood is unusually strong and healthy but the losses of eggs are relatively higher than in other methods. The gravel beds remain completely undisturbed until the brood begins to feed. They are than removed by means of hands or of dull forks from the troughs. One advantage of this method is that bad eggs have not to be sorted out.

At the hatchery of the monastery of Maria Laach, I came across a somewhat peculiar hatching apparatus. It was a closet-like contraption with doors, designed to darken the incubator. In the Harz mountains, I found large, water-filled wooden boxes. Here, the eggs were hatched upon layers of stone splinters, sprinkled with water from a fountain-like contraption.

The most simple of all hatching apparatus is the "hatching pot" and which is practically nothing but a stew pot or sauce pan full of holes and which, when filled with eggs is simply set into a brook or into a wooden pipe with running water. All of these "incubators" are of course designed for "home use" only, and have no place in industrial plants, nor are they to be compared with any modern apparatus.

Eggs of maräne, pike and many other fish cannot, on account of their small sizes, be hatched in trout incubators. From my own experiments, I recommend for them such apparatus as the so-called "Zuger glass" and the "von dem Borne" apparatus made of tin.

The "Zuger glass" (to be had at Bartsch, Philipps & Co., Berlin NW 40, Doberitz Strasse 3, or at the Ver. Lausitzer Glasswerken A. G., Berlin SO 36, Lausitzer Strasse 10) consists of a glass cylinder with a funnel-shaped opening at the bottom. It is from 50 to 65 centimeters high and contains from 5 to 9 liters. The glass is fastened to a small white metal box (see Fig. 27).

The difference between the water level of the conduct pipe and the upper rim of the glass—the so-called pressure—is best 1 meter. A conduct pipe with an inflow opening into the glass of 9 millimeters will provide for a through current of from 0.07 to 0.1 liter per second, which is sufficient for all practical purposes.

The <u>whole</u> pressure, that is, distance from conduct pipe to bottom of the box is therefore about 1.80 meter. By lack of pressure, I recommend the "von dem Borne" apparatus and which has given as good results as the "Zuger glass" at our hatchery at Eberswalde. Also the idea, underlying the "Macdonald glass" is practical from the fishbreeder's viewpoint. I must also recommend that larger establishments seek the advice of specialist fishery biologists to conform with local conditions.

The above named apparatus are filled to not more than half with freshly fertilized eggs. The brood is caught in especially constructed white metal boxes which are placed under the outflow opening of the "Zuger glass" (see Fig. 27). These boxes are best covered with a soldered-in screen of finest hair sieve in order to avoid an escape of the very small broodlings.

The incubator may be installed outside (see Fig. 28) or still better in a hatch house or hatch room. A cellar, or a wing at least half sunken in the ground (see Fig. 29), or a special small house may be used. Most important in every case is the level trough (Fig. 28) made of wood, strong tin or masonry, through which water runs continuously and flows out through an overflow. The incubator apparatuses on bucks or similar supports are placed under the faucets connected to the level trough or are connected to the faucets by means of pipes and hoses (Zuger Glasses, see Fig. 27). In recent, more wastefully constructed incubator houses, the long-stream apparatuses are often firmly set in masonry. In every case, care should be taken that the outflow water does not run on the floor of the incubation room, but through special outflow channels.

Fig. 27. Zuger Glass Incubator (Self Selector) for the incubation of small fish eggs. Catching boxes (painted white inside and barred by a hair sieve) are placed under the outflow for catching the hatched brood.

Fig. 28. Incubation Plant of a large central German Trout Fishery. Front right the filter, behind this the level trough. In the front center undercurrent apparatus, behind this the feeding boxes. The arrangement of the incubation houses is essentially similar. In the background, a trout spawning pond.

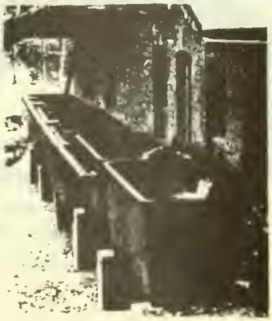

Fig. 29. Filtering arrangement of a hatch house. Front, 2 pre-filters, behind 3 filters.

It is also very convenient if the hatch house contains large and small containers for the spawn trout and for grading food trout. Larger plants also require a packing room and a shipping room. It may also be advantageous to have the food kitchen in the same building as the hatch house and to arrange storage and cooling rooms for the food. Filter arrangements may be placed inside before the level trough, or outside (see Fig. 29) to save space, as freezing of running water will not occur.

The water for the hatch house must not be drawn from stocked ponds, in order to avoid Gyrodactylus and other injuries. It is best to draw from an oxygen rich spring brook. If springs and brooks of various winter temperatures are available, it is advisable to provide a regulation of water temperature. If the brooding water contains much suspended matter such as flakes of iron hydroxide, leaf particles, etc., it must be filtered, especially when hatching is done in "self selectors". Formerly, deep walled concrete chambers in whose center a horizontal grate supported a layer of gravel, were used for filtration. The water ran alternately through one chamber from above and through the next from below and finally into the level trough.

In the fish hatchery of the Eberswalde Forestry School, I have recently had a filtering arrangement constructed (Fig. 29), which has given excellent results. From the storage pond a pipe protected of a sieve on the inlet end leads the water into two pre-filter basins. They are strong rectangular iron vessels, such as are used in industry. The basins are placed on two steel rails which rest on brick pedestals. The basins are wide to provide ample filtration surface, but not too deep for the best service to the arrangement. A wooden grate is set in about 20 cm. above the bottom to hold the filtering material, excelsior or gravel. In the pre-filter, coarse gravel is used, and in the filter finer gravel is used. A vertical pipe which opens close to the bottom leads the pre-filtered water into a pipe which conducts it to the three actual filters. Here also the water flows in at the top, so that the top sand layer takes up most of the dirt and can be easily cleaned. Further upright pipes conduct the completely filtered water into the hatch house and into the level trough with overflow. Each chamber can be cut out separately and drained by an outlet in the bottom.

The provision of good daylight illumination and a water proof electric lighting arrangement in the hatch house deserves attention, so that all tasks, particularly that of selection, can be at all times carried out with necessary care.

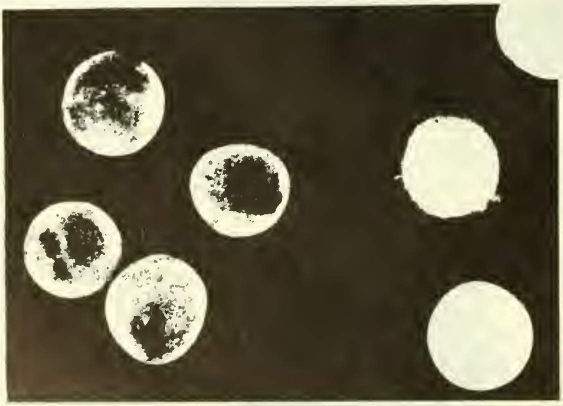

Fig. 30. LEFT. Living brook trout eggs in eye point stage.
RIGHT. 2 dead, white and one moldy dead trout egg.
2 x natural size.

Fig. 31. Living brook trout brood (vitellin sac brood) immediately after hatching. Also two empty egg shells. 2 x natural size.

5. Artificial incubation, shipping of eggs, counting of eggs and brood.

In artificial incubation we distinguish between two stages:

(1) The pre-incubation period, that is, up to the time of the development of the two black eye spots (Figs. 30 and 34). One of these spots--in trout--lies somewhat deeper and is not always clearly perceived.

(2) The incubation period, that is, from the eyed stage to the moment of hatching (Fig. 31).

The period of incubation of trout eggs is dependent upon many factors, not fully understood as yet and differing in practically every case. The hatching period of eggs from one and the same mother fish will at times stretch over a period of more than a week.

Willer and his pupils have ascertained that entry of light, and also a low oxygen content of the water will delay hatching for almost a week. Haempel and Lechler found the reverse to be true when exposing eggs to ultra-violet rays. Sklower notes a shortened hatching period in eggs from older fish. I have observed that insufficient maturity increases the incubation period. But the most influential factor is the temperature, of course. It is imperative for the fishbreeder—who has to know the hatching time in advance--to know the approximate influence strength of temperature.

As a rule, the incubation period is figured by "day degrees", that is, the total of the daily averages. For example: 5 degrees at one day and 6 degrees at the next are equal to 11 day degrees and so forth.

Observations made at the incubator house at Eberswalde—the temperatures were measured to 1/10 of degrees--gave the following results:

Eggs from 3 and 4 years old rainbow trout, about 330 day-degrees; at an average temperature of 9 degrees centigrade.

Eggs from 3 and 4 years old brook trout, about 460 day-degrees; at an average temperature of 4 degrees centigrade.

Eggs from marane, Coregonus lavaretus, about 360 day-degrees; at an average temperature of 4 degrees centigrade.

Here, the time is figured from fertilization to beginning of hatching. The hatching was mostly finished after 50 day-degrees. But the number of day-degrees changes with changing degrees of temperature, as Ainsworth (according to von dem Borne) already mentioned with regard to brook trout. Quite recently, Leiner (according to Lange) found that in the case of the stickle-back, the number of day-degrees will drop evenly from 230, at a temperature of 8 degrees, to 110 at a temperature of 28 degrees.

Since my own observations are in accordance with those of Ainsworth, I give here a chart, concerning the incubation period of eggs from brook trout at different temperatures. The dotted line in this chart pertains to rainbow trout and is sufficient for all practical purposes. Since slight changes in temperatures occur constantly, and other factors also vary slightly, it is impossible to predict with utmost exactness the moment of hatching. The eye spots in eggs of rainbow trout become visible shortly after the first half of the development stage is reached.

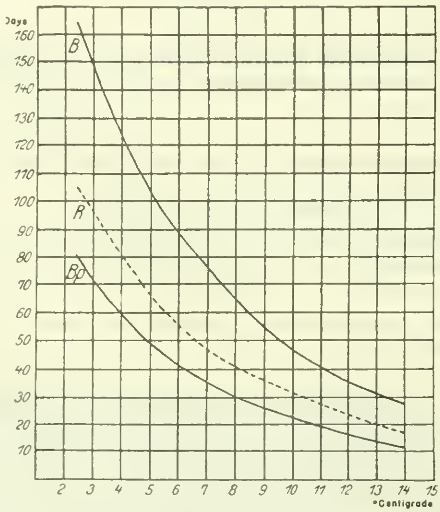

Fig. 32. Developing period of brook and rainbow trout eggs in different temperatures.
Bp: Development period of brook trout up to development of eye points and red blood.
B: Development period of brook trout eggs up to moment of hatching.
R: Development of rainbow trout eggs up to moment of hatching.

One day after stripping, the percentage of fertilized eggs can be tested by placing the eggs in Hoffer's solution (1/4 percent of chromic acid..3 parts; 10 percent nitric acid..4 parts; 96 percent alcohol..30 parts). In the fertilized eggs a separation into 2 or 4 parts of the white germ field become clearly visible within a few minutes. If the test is made 8 days after fertilization, a streaked outline of the embryo becomes visible.

The following work is to be done during the incubation period:

(1) At short intervals (about every two days) the died-off eggs (Fig. 33) are to be removed, in order to prevent contamination of healthy eggs through their decay. This is best done by means of the Lietmann forceps which

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allow to get hold of 5 or 6 eggs at a time. The average losses--from good eggs--are about 5 percent but will be as high as 20 percent in the case of rainbow trout. Too great losses make the work unprofitable and the whole crop of eggs may as well be dumped.

(2) Eggs as well as newly hatched brood has to be protected against light. Exposure to dazzling sunlight is liable--from my own observations--to kill off the eggs. According to Haempel and Lechler, freshly fertilized eggs are very sensitive to ultra-violet rays, eyed eggs somewhat less. The sensitiveness varies with the different trout species and varieties. Moderate exposure to these rays is said to be beneficial but will provoke premature hatching.

(3) The oxygen content of the water, used in incubation is to be kept as high as possible. Experiments by Willer and his co-operators have shown that eggs in water, rich in oxygen (under otherwise like conditions) and if kept in darkness will produce a feeding brood by 58.7 percent greater in length and by 21.5 percent heavier than those that were kept in water of 66 percent less oxygen and were exposed to light. Care must be taken that the screens, upon which the eggs rest, are bent downward so as to prevent the occurrence of air bubbles.

(4) Accumulating mud or slime is to be removed by slowly raising and lowering the screens in the water. After the eye spots have become visible, this can also be done by raising the screens out of the water and douse the slime off with a sprinkling can. Altogether, great care is to be taken to keep the water free from dirt particles and--worse still--dissolved impurities.

(5) Only moderate movements of the eggs are permissible until the development of the eye spots and they must not be shaken violently. From experiments by Hein, it can be presumed, though, that pressure, blows and falls do not injure the eggs as greatly as was previously assumed. The eggs are least resistant during the second fifth of the incubation period and very resistant during the fourth fifth of the period.

Work connected with the "Zuger Glass" and with the von dem Borne incubation apparatus consists chiefly in the regulation of the through-flow, the maintenance of the filters and the sorting out of the eggs. The term "self-sorting" (of these apparatus) is really misleading. Died-off eggs are not automatically eliminated by the water flowing through the apparatus. Only when the loss of eggs is less than 33 percent can the results of this method of incubation be considered satisfactory. The sorting-out is best undertaken after the appearance of the eye spots. Bad eggs are sucked out with a hose and any good eggs, adhering to them are put back into the water, but should be touched as little as possible.

The eggs will stand shipping, as soon as they are clearly eyed (Figs. 30 and 34), but this must be terminated 5 days before hatching in order to avoid greater losses, which are unavoidable if the shipping is delayed. Small amounts of eggs can very well be shipped in thermos bottle or packed in moist moss. Large consignments of eggs are usually shipped in "frames". Such shipments can stand from 2 to 3 days more of transport without any great injuries. The "frames" were recently standardized by the German Trout Breeders Association.

The "frames"--in shape similar to picture frames--consist of wooden moldings, 6 millimeters thick and 20 millimeters wide and are joined together to form a frame of 22 by 32 centimeters. One side of the frame is then spanned with cheese cloth or some similar fabric. A thickness of the moldings of less than 6 millimeters may injure the eggs which are often over 5 millimeters in diameter.

Fig. 33. Sorting out dead trout eggs from the under-stream apparatus. To ease the work, the inset sieve is slightly lifted and firmly clamped.

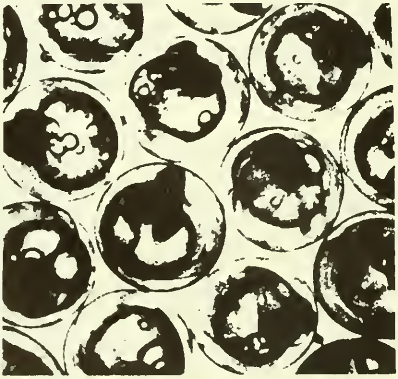

Fig. 34. Living eggs of the small maräne (Coregonus albula) in the eye-point stage. Diameter 2.2 mm.

The fabric covering the frames is well moistened and packed with a layer of eggs (in case of maränes with two layers) in so close a fashion that a rolling of the eggs is hardly possible. The frames are stacked one on top of the other and an empty frame is inserted between each pile of five frames. A few empty frames--or moss-filled ones--form the bottom of a pile which is topped by an empty frame of somewhat higher molding. This frame has a lattice bottom packed with ice.

The whole stack of frames is then carefully wrapped up in paper (impermeable one, if possible). This package again is packed into a large wooden box, sufficiently large to allow stuffing (all around) with chaff or sawdust or excelsior to a thickness of at least 7 centimeters. The box to be marked - "Live Fish Eggs", "This end up", "Do not expose to heat or frost", "Handle with care". In this way, eggs from rainbow trout were safely shipped from America to Germany.

When unpacking the box, the eggs of each frame are first carefully sprinkled with water in order to accustom them to the new water and a different temperature. Only after 15 to 30 minutes are the eggs transferred to the incubators.

Formerly held opinions with regard to an excessive sensitiveness of the eggs against changes in temperature have been found to be unfounded, according to Hein.

The counting of the eggs in the incubator is always easier than the counting of the broodlings. And since losses are negligible in eyed eggs it is of advantage to divide the brood among the different incubators while still in this stage, but not all too shortly before the time of hatching.

The following four methods for counting eggs are simple and practical:

(1) Weigh out 1000 eggs upon an apothecary scale, using this weight as a unit for larger amounts, weighed out upon a larger scale. Since the weight of eggs is variable, on account of the different sizes of eggs, I abstain from quoting figures, but emphasize that the unit weight has to be ascertained from the eggs of different stocks.

(2) Measure (in a gradnated glass) the cubic volume of 1000 eggs and then count the eggs out with larger measures. The advantage of this method is that the eggs can be siphoned out. While the cubic unit has also to be measured for each separate stock, I found that with small eggs the differences are negligible. For marine eggs I found almost invariably the following figures per 1000 eggs:

Coregonus generosus: 25 cubic centimeters.
" albula : 9 " " .
" lavaretus: 40 " " .

For trout eggs there is also a cup measure of about 50 ccm. in use, with a wire-screen bottom. The counted-out number of eggs from the first serves as unit for all further measurements.

(3) By means of the overflow apparatus (Fig. 35) may be determined how much water is displaced by 1,000 eggs which are transferred without water into the funnel and sink into the lower vessel filled with water. The eggs are transferred with a spoon net. The Schillinger Measure Glass works on the same proncinple. To lessen the manipulation, a rubber hose may be connected to the overflow tube and held high until the end of the filling. The water displacement (true volume of 1,000 eggs) may also be easily found from the third power of the egg diameter in centimeters by multiplication with 524: True Volume (water displacement) of 1,000 eggs = $d^3 \times 524$. Finally to be regarded is what has been said in methods 1 and 2.

(4) By means of a hard rubber plate (Brandstetter Counting Plate, obtainable at F. Greiner, Munich, Mathilden Strasse), which has a definite number of hemispherical depressions with bottom perforations. The depressions are the size of a trout egg. The plate has a handle and can transfer a definite number of eggs. The great advantage is independence of individual size of an egg. Only eggs the size of trout eggs can be measured.

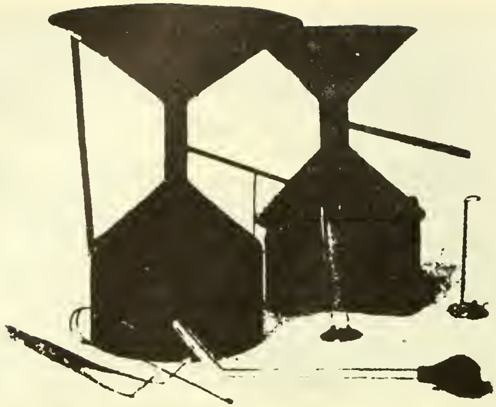

Fig. 35. Overflow apparatus for counting fish eggs and brood, egg pipette and egg pincettes for sorting out dead eggs.
For counting eggs or brood the apparatus is filled to overflowing with water. After the water flow stops, a measuring cylinder is placed under the overflow tube, and the water running off from the filling of eggs and brood is measured. A soldered-in sieve prevents the entry of brood in the overflow tube.

Fig. 36. Brook trout fry capable of eating and swimming. About 150-200 day-degrees after hatching, 24 mm. length. One third of the vitelline sac remains.

C. Production of fingerlings and of adult fish (trout ponds).

1. Rearing of trout fry and fingerlings.

In general, fingerlings are divided into the following four classes: One summer old fingerlings; yearlings; 3 to 4 months old June fingerlings of brook trout; September fingerlings of rainbow trout.

June fingerlings and also September fingerlings are about 3 to 7 centimeters long; one summer old fingerlings from about 5 to 15 centimeters and yearlings (spring yearlings) from about 10 to 20 centimeters.

The fingerlings are raised by the two methods of:

(1) Raising them in larger natural ponds without artificial feeding and at a low rate of stock per pond.

(2) Raising them in smaller ponds, heavily stocked and feeding them.

The fry should not be brought into ponds until they are able to eat and to swim (see Fig. 36), since otherwise, and from my own experiences, greater losses are sure to occur. To retard the transfer of the brood into the ponds will also adversely affect the later development of the fish. The date for such transfers is practically of no importance. There is no lack of food in trout ponds, not even in winter. Contrary to the findings of others, I have found that water fleas and insect larvae are plentiful just in winter.

Ability to eat and to swim is best recognized by the attempts of the brood--after the loss of the greater part of their vitelline sacs--to stand up at the bottom, rise to the surface of the incubators and their attempts to swim freely about. This occurs, according to conditions at about 120 to 200 day-degrees after hatching. The vitelline sac is then still present to about 1/3 of its size (see Fig. 36). But the fish already require food and if none is forthcoming, the later development will be adversely affected, as Hein has demonstrated in 1906.

In both transfer methods the time between stocking the ponds and overhauling them is of importance. In order to avoid an accumulation of brood enemies, the ponds should be overhauled just before stocking them. The same applies also to natural rearing. An interval of 5 days is about the optimal time according to my own series of experiments along these lines. This interval is apparently sufficiently long for the production of natural food stuffs in the ponds.

In practice, good results are obtained if the brood has been fed before their transfer into the ponds. Such brood is generally stronger, hence better protected against natural enemies, and above all will then have already outgrown the risky stage of an infection from Lentospora. A further advantage is that brood, fed in the incubators will be already accustomed to feeding when brought into the ponds, as mentioned earlier.

The first feeding is frequently done in special "nurseries", for example, in boxes swimming in the brook. These boxes have walls of wire mesh or of perforated metal. It may also be done in water current brood boxes. It is simplest to feed in the long-stream apparatus after removing the hatching boxes. Here is the best protection against diseases (as Lentospora cerebralis) and goes, and the best attention will be possible. Small ponds of about 30 square meters, stocked with 1,000 fry per square meter, are usable if they are free of disease producers. I cannot directly share the view that ponds are preferable to "nursery" boxes for the first feeding. The pretext, that the brood in the pond is better protected against hunger by sudden suspension of feeding, can hardly be tenable in a well managed industry.

Experiments which I had conducted by the forestry student, Mr. von dem Borne, in the hatchery of the Eberswalde Forestry School have shown similarly to researches of Willer and his co-workers, that the size of the brood boxes, the stock density and the strength of current are of great significance in nursery feeding. With a stock density of 128 trout per liter (1.7 fish per square centimeter) and 64 trout per liter (0.85 trout per square centimeter) in two identical long-stream boxes (160 x 30 x 13 centimeters water space), the denser stock showed about 15 percent better growth in two months, than the weaker stock in three months. A corresponding picture was given by experiments in various sized boxes with the same number of fish. Of course, the "outflow factor" shows its influence here. A box with 400 square centimeters of surface, in contrast to one with 1,453 square centimeters of surface, both stocked with 200 fish, showed about 26 percent poorer growth after 29 days. Thus, the following rule may be stated: In the early development stage the density of stock must not be too weak, with larger growth a lower density of stock is more favorable. Accordingly, in case of longer term "nursery feeding", the brood should be sorted and distributed in larger space. In every case, the "nursery boxes" should have ample surfaces, not less than 1500 square centimeters.

Experiments with a through current of 12 liters per minute (in a box of 80 x 30 x 13 centimeters water space) showed a superior growth in the fry as compared with fry, kept in boxes with a through current of only 6 liters per minute. The fish had grown by 41 percent better within 29 days. The current must not be strong enough to press the brood against the outflow sieve.

The influence of light upon the growth of the fry is also noticeable. We experimented with fry in nursery boxes kept in the open and in houses, exposed to light and to darkness. Best results were shown by boxes kept in the open. Equally good results were noted with boxes (kept in houses) that were painted white on the inside. The results were less good by 24 percent with boxes, painted black on the inside and by 34 percent less good with boxes kept in the open but completely darkened.

In addition to the action of light, the better visibility of food--in light exposed boxes--plays undoubtedly a great role.

Within 2 to 3 weeks (at a temperature of 12 degrees centigrade) a differentiation in growth becomes noticeable. If the "nursing" is continued, a sorting out of the broodlings becomes necessary. Sorting apparatus or nets of different sized meshes are used. Individuals, large or small, may be selected by hand.

The "nursing" of the brood has its decided advantages as shown by numerous experiments. In a hatchery under intensive culture, the losses among unnursed fry amounted to 62 percent as against 48 percent in the nursed stock (under otherwise like conditions).

In experiments at the Forest Academy in Eberswalde with fry from brook trout, kept in natural ponds, I had losses of only 40 percent with nursed fry, as against losses of 80 percent of unnursed fry. Losses among some 1,000 "nursed" fry (in various natural ponds) amounted--in the fall of 1931--to 33 percent among the non-sorted stock, to 52 percent among especially small selected stock and to 32 percent among especially large selected stock.

There now remain for brief discussion, both of the named methods of fingerling rearing in ponds. In the first method, the natural rearing, about 2 individual broodlings per square meter of water surface are set out. Besides larger natural ponds, carp nursing ponds are advantageously stocked with rainbow trout brood along with carps. In case of long "nursing", only half the stock is set in. If the pond is too fished-out after three to four months, then three broodlings per square meter are set in. These figures are average values. Naturally, fertility and local conditions must be considered. In the Trout Fishery at Fuerstenberg in Westphalia, it is customary (according to Schaeperclaus) to first stock the ponds with brook trout brood, then to fish these out as 4-6 cm. length "June fingerlings", and then from June to September to grow similar rainbow trout fingerlings in them. No "nursery feeding" is done, and the average loss is 60 to 70 percent, according to Schaeperclaus.

In the second method, the "nursed" or feed competent brood is set in small ponds (Fig. 37) of 0.75 to 1.00 meter depth, not too strong flowing if there is danger of gyrodactylus, at a density of about 100 fry per square meter. Artificial feeding, mostly with spleen is begun at once. The ponds must be very well planned, somewhat sloped to allow thorough cleansing, and have water flow over the entire extent. Under favorable conditions and with two sortings in the first summer, the number of fish can be increased right in the beginning from about 1,000 to 1,500 fish per square meter. I recommend, however, if possible to fish out rainbow trout for the first time in September about four months after stocking and then set in 100 broodlings per square meter. The majority of the fish attain in September, a length of 7 to 11 centimeters. An infection with gyrodactylus is not now to be feared, as the development of resistant gyrodactylus spores (which inoculate the bottom and infect brood ponds) has not yet taken place. The trout are sufficiently differentiated in growth so it is advisable to grade them. Lastly, in September the weather is so cool that fishing out and prolonged grading can be undertaken without injury.

The sorting and separation of rainbow trout according to size must not be postponed beyond September. The larger fish will crowd the smaller ones too vigorously from food and even attack them. Also, the larger fish can now be fed with other food (marine fish, meat). The expensive brood feed can then be entirely available to the small fish.

The losses up to the fishing out amount to about 60 percent on the average; in case of diseases they are much greater, but under favorable conditions—especially by setting out "nursery" brood, losses may drop to 20 to 30 percent.

Fig. 37. Nursing Ponds of a large trout fishery of central German lowlands. The ponds are connected successively in small series by means of overflows. Inlet conduit in foreground, outflow ditch in center.

With regard to sorting out, Buschkiel has recommended the following classifications:

Size	0	below 5	centimeters.
"	I	5 to 7.5	"
"	II	7.5 to 10	"
"	III	10 to 12.5	"
"	IV	12.5 to 15	"
"	V	above 15	"

2. The culture of adult trout.

The fingerlings, during the first year, over the winter and according to weather, feeding and local conditions, have grown on the average to about 25 grams, 100 grams or in rare cases even to 150 grams. They are separated into size classes and placed in so-called "mast ponds", fingerling ponds, or maturing ponds (Fig. 38). If the maintenance during the fingerling growth has been unsuitable, in too narrow ponds and too great a stock density, in consequence of more unfavorable conditions of the space-factor-complex, then maintenance in the mast pond is even more so. Over the winter the trout fingerlings can still be kept pretty densely stocked in individual ponds, but beginning the spring of the second year they will grow well only in larger ponds of at least 100 square meters surface with steep banks, and a depth of 1.5 to 2 meters in a strong through current and a stock density of about 25 to 50 fish per square meter. In order to simulate the trout brook as much as possible, the mast ponds are elongated (for instance 4 x 25 meters). The water flows in and out through the narrow ends, so there will be no dead angles where dirt can accumulate and decompose.

The Schnede Trout Fishery, in order to emphasize the brook-like character of the ponds, has arranged three trenches each 800 meters long and provided with strong currents for masting. The trenches are separated in single divisions. This arrangement is not always standard. It is probably better to construct the "brook" units shorter and as individual ponds, because in case of disease occurrence or accidents each pond can be kept individually. Of course separate inflow and outflow is advisable. Obviously, much water is required if the trout are to have several ponds even without serial connection (Fig. 37) and the same water velocity as in the brook. In Schnede an entire small river can be run through the trenches, the velocity is therefore strong. If each of the 800 meter long trenches were divided into 32 ponds, the velocity in a single pond could only be weak. The living conditions, corresponding to the velocity of water would vary more from the "natural". The hygienic conditions would, however, be more favorable, and that must in the final analysis be the deciding factor.

The rearing at a definite temperature is the more economical the quicker it succeeds, since the consumption of maintenance food is so much greater the longer the rearing time lasts. Accordingly, feeding must be done as frequently and constantly as possible to the complete satiety of the trout. With rainbow trout, the faster growers can be used for eating after a total rearing time of 16 months in the summer of the second year under normal conditions in Germany. The last one quarter to one third pound table trout should normally be "finished" after two to two and a half years. In pond fisheries infected with gyrodactylus I have frequently observed that the last stragglers weighed only 50 grams after two years. Thereby the worst of the rainbow trout had already been eliminated.

With so long a time of rearing, the loss of individuals (which in the second year should not be over 5 to 10 percent), and also losses of maintenance food are too great. With the appearance of spawning maturity in the second winter the individual losses often suddenly increase strongly. The further rearing of these not even one-third pound poor food evaluators into large fish, is mostly unprofitable. In fact the rule to be regarded is: The rearing of sickly or weakly animals is unprofitable. The quicker they are eliminated, the more is spared on work and food.

Brook trout are best mixed up to 25 percent with rainbow trout, as they will then go after food better. They can then be distinguished as in the first year from the rainbow trout at a glance, because they like to remain in the depths of the ponds.

The trout fishery's immediate rearing goal, according to Jaisle, is the production of three sizes of table trout:

Dinner - or menu trout of .... 130 to 170 grams.
Portion - or a la Carte trout of .... 200 to 500 grams.
"Salmon trout" or "Pond salmon" of .... 500 to 2000 grams.

It might at first glance be surprising, that the trout growers today, especially prefer to raise large fish, which in addition are somewhat lower in price, and that the tendency in this direction has become ever stronger. This is partly for the reason that the single fish, as such, represents a particularly high value in the trout rearing. The production of fingerlings is very difficult on account of the many brood diseases and enemies. The quarter pound trout, however, can be grown to essentially heavy trout easily, quickly and with hardly any losses, while one to one and a half years are required for the raising of these fish. Expensive brood fodder and high individual losses must be taken into account. In accordance with what has been stated earlier, I maintain it is not out of the question that the food quotient is more favorable in that kind of fishes than with smaller gradings, so that it would signify a waste for the fish grower if he did not evaluate these favorable possibilities. Unfortunately, as in so many fields of fish growing, exact experiences are not available.

Divisional management in trout rearing, just like in the carp pond industry, is an optional part of the larger industry. Even more than in the carp growing, its from is conditioned by the multiplicity of local conditions.

3. Size and Division of Pond Surfaces of Trout Fisheries.

The entire pond surface of a single trout fishery in full operation is real small in comparison with a carp fishery, which fact has been repeatedly emphasized. The largest German and European Trout Fishery in Schnede has only 37 acres (15 hectars) of pond surface: In the Secondary Mountain Range where good water conditions and favorable locations are available, there are many fisheries which possess scant 1 hectar (2.4 acres) of pond surfaces, in which 50 and more double hundredweights of trout are produced and which very well support the proprietor and his family. Trout growing, as regards evaluation of surface, far surpasses the most intensive remaining agricultural industries like poultry farms, more intensive hog growing, etc. Hardly any other agricultural industry brings such high gross yields per hectar surface as does trout growing. It has therefore been justly designated as a highly industrial and social task to maintain and advance Germany in her prosperity by continually improving the management of these trout growing industries. Naturally it is always to be considered that the intensive production of food trout, similarly to goose masting, presents a refinement industry which is indeed bound to the soil whose yields are in part natural yields but for the greater part are fodder yields. The required fodder is produced on foreign soil.

Since trout growing operates more continuously than carp growing and the commerce in food trout is not seasonal like carp selling, either in a technical operative sense or relative to commercial customs, the result is that trout growing has not developed an outspoken biennial rotation. Since the height of stock density is permitted to vary between pretty wide limits, the ratio of the ponds for growing of fingerlings to the masting ponds need not be definite. The surface proportion of good brood ponds to the total surface must naturally not be measured too closely. Obviously, it is variable locally according to the fingerling business and the water conditions. With a normal full management without a larger fingerling sale it should comprise at least 30 to 50 percent of the total surface as growing and masting ponds (that is, without trout-spawning ponds). Production of fingerlings can, however, be very considerable and can become almost the main thing. It is stated that Prussia alone produces about 1 million fingerlings annually for the stocking of natural waters. In pond fisheries, which participate in this production, the ratio of pond surfaces naturally must be shifted.

So much for the size and division of the pond surface of full managements of trout growing. With partial or specialty management such manifold conditions can occur that it is impossible to make universally valid statements. On the applicability of trout in the small-pond industry, will be discussed in a later chapter.

Fig. 38. Group of step-like mast ponds arranged on a flat slope in a trout fishery of the West German Secondary Mountains.

Chapter VI
NATURAL PRODUCTIVITY OF PONDS, THEIR STORAGE CAPACITY AND THE STOCKING OF PONDS.

The aim of stock regulation is to bring the number and weight of stock into proper relations to the given chemical-physical and biological conditions. It is today one of the most important means by which to increase production in quantity as well as quality.

First of all, stock regulation shall bring forth a perfect adjustment of the stock to the existing natural food conditions in carp and tench ponds. This even in case of artificial feeding, the more so, since the amount of food, given to carp and tench is depending again upon the natural food, available in a given pond. Only under intensified culture is the adjustment of trout to pond conditions more in the nature of an adjustment of chemical-physical-hygienic factors. The production rate is than chiefly determined by the intensity of feeding.

As mentioned already, the exact amount of stock per pond is to be calculated by the weight and size of the fish, i.e. by the more nearly marketable sizes of fish, especially for large carp extending and maturing ponds. And since through such calculations pond conditions shall approach the gross natural productivity of ponds as closely as possible--feeding in carp and tench fisheries is based upon this natural productivity--it becomes necessary, of course, to first ascertain the natural productivity of a given pond.

The gross natural productivity, namely the yearly weight increase of fish without additional feeding can be estimated from previous experiences. (It is to be remembered that new ponds are by 100 percent more "fertile" than older ones). Exact estimates of the really available natural food (aquatics) will have to be done by the fish biologist. The experienced fish breeder can only guess--more or less correctly--what the natural productivity of a pond may be, taking into consideration the information in chapter IE enumerating physical, chemical and biological factors, etc. (It is now generally agreed to divide ponds into four classes from the viewpoint of productivity.)

Fisheries in moors and in heaths usually belong in the 3rd and 4th classes (also lime poor ponds), while fisheries upon light soil and lime rich ponds usually fall into the second class.

From the available literature and from my own experiences, I will quote here the natural pond productivity--per annum--of certain fisheries and localities. These figures are based upon the observations of many years.

Berneuchen (Neumark)............... about 100 kilograms per hectar.
Spechthausen (near Eberswalde)..... " 100 " " "
Wielenbach (Upper Bavaria) .... " 100 " " "

In the fisheries in the "Lüneburger Heath" and in Lower Lusatia about 50 kilograms per hectar.

In the "Uckermark" with good water but changeable soil, from about 100 to 350 kilograms per hectar.

Stadtforst in Saxony .... 100 kilograms per hectar.
Militsch .... 65 " " "
Geeste in Westphalia .... 50 " " "
Dulmen in Westphalia .... 60 to 100 kilograms per hectar.
Gemen in Westphalia .... 50 to 110 " " "

In Upper Saxon Lusatia (with water of an A.C.C. of from 0.1 to 0.45) 2.5 to 90 kilograms per hectar.
In Upper Saxon Lusatia (with water of an A.C.C. of from 0.1 to 0.95) 25 to 135 kilograms per hectar.
In Upper Saxon Lusatia (with a constant A.C.C. of at least 0.5) 135 to 210 kilograms per hectar.
Scheyern (Lower Bavaria) .... an average of 317 kilograms per hectar.
Rampsau (near Regensburg) .... an average of 117 kilograms per hectar.

The classification of ponds (on productivity) is bound up, of course, with stock conditions. Just as the returns of a field depend upon quality and quantity of seed, so the productivity of a pond depends upon the species, and "race", the state of health, the number and the size of fish.

Tables 17 and 18 will better illustrate the points that have been discussed.

Table 17.

Classification (on productivity) of carp ponds, stocked with 2 year old carp of normal weight (350 grams) and increasing in weight as listed under B.

	1. Class	2. Class	3. Class	4. Class
A. Natural increase in kilograms per hectar.	400 to 200	200 to 100	100 to 50	50 to 25
B. Normal basic weight increase per fish (in grams).	1000 to 1250	1000	1000 to 750	750

By exclusive stocking with carp yearlings (weight increase 300 grams) the natural productivity is in average about 40 percent higher, by stocking with brook trout or rainbow trout (weight increase 120 grams) in average by about 40 percent lower. Mixed stock and deviation from the normal weight (at time of stocking) will change the rate of natural increase (A) per hectar and annum.

The influence of the amount of stock and of the density of stock within a given pond have been discussed already. Thanks to the valuable investigations of Walter, Nordquist and of Contag, this influence has been more exactly defined, and for the first time.

With regard to other factors--species, stock combinations, etc.--we will establish here the respective rules. Weather changes, changes in cultivation, etc. will bring about yearly variations in the productivity of ponds.

The "stock figure", that is, the proper number of fish for a given pond is found or estimated through the computed total increase. In case of feeding the fish and by fertilizing the pond this increase is the total of natural increase through feeding plus increase through fertilization. Without feeding and fertilizing the total increase is just natural increase. The computation can be done through the following, simple formula:

$$\text{"Stock figure" eq. } \frac{\text{total increase kg}}{\text{Increase in number kg}} \text{ plus allowance for losses.}$$

The allowance for losses has to be based upon local experiences. Average figures for same (in percentage) will be found in table 18. The increase in number (weight of fish taken out minus weight of fish put in) is at the discretion of the fishbreeder, of course. For normal estimates see table 18.

Table 18.

Normal average weight (per fish) of added stock, yearly weight increase (per fish), and losses of different classes (age) of pond fish.

Species and age.	Normal weight of stock (per fish). grams	Normal weight increase (per fish). grams	Normal losses.
Carp (1 year)	35	315	10%
" (2 ")	350	900	2 to 5%
Tench (1 year)	6	44 to 64	20%
" (2 ")	50 to 70	150 to 200	2 to 5%
Rainbow trout (yearlings)	30	120	2 to 5%
Same, but fed	25	160	2 to 5%
Brook trout (yearlings)	20	120	2 to 5%

Example for "stock computation".

A pond of 2 hectar (about 5 acres) of second class productivity (table 17) has an increase per hectar of about 150 kilograms of fish (non fed) and a total increase, that is, natural increase of 300 kilograms altogether. It is to be stocked with 2 year old carp of a weight of 350 grams per fish. The carp shall be fished out at a weight of 1350 grams.

The desired stock increase (individual weight) is therefore 1000 grams. Losses are 5 percent. Hence: Stock figure $\frac{300}{1}$ plus loss allowance $300 + 15 = 315$.

It follows that 315 carp of a weight of 350 grams are to be set out in this pond.

If stocking with mixed stock (yearlings and 2 year old, for instance), the total increase can be divided, so to speak. One can figure, for example, 200 kilograms increase for 2 year old and 100 kilograms increase for yearlings. Or two yearlings with a weight increase of 350 grams per fish are figured per each 2 year old with a weight increase of 1000 grams.

We have then the divisor 1000 + 2 x 350 = 1700 grams and have thus the quotient of $\frac{300}{1.7} = 177$. Hence, the "stock figure" is 177 x 1 for 2 year old carp and 177 x 2= 354 for yearlings.

As seen in table 17, the increase per hectar changes immediately upon deviation from 2 year stock with normal stock weight and ditto increase. This allows the fishbreeder to better the "hectar increase" through rationalization in stocking, proper choice of added stock (from the viewpoint of weight) and use of mixed stock, according to general requirements.

Highest results will not be achieved under conditions as enumerated in table 17. The figures in table 17 are rather a compromise between market demands, technical possibilities and attempts for possible best results.

The possibilities of a still better utilization of the natural foodstuffs, present in a pond, depend upon the following fundamental principles, casually mentioned before:

(1) Ponds will yield profits (per hectar) in correlation to the number of fish per hectar (density of population) and according to the diversity of their number as to quantitative and qualitative utilization of food, that is, to the diversity of their size and characteristics. These factors will foster proper food utilization.

(2) The rate of profits per hectar will vary according to the rate of upkeep (expenses for food). The cost of upkeep mounts in proportion to the number of fish per space unit and decreases in relation to their more or less speedy increase in growth.

It follows, that from the practical viewpoint one must strive to raise the possibly greatest number of fish per hectar (density) but exercise the greatest possible economy in the matter of upkeep. Too small a number of fish per hectar (low density rate) will quickly increase in size and weight but at a disproportionally high rate of upkeep. Fullest utilization of a pond's productivity calls for corresponding number of good eaters. It is from this viewpoint that we arrive at the following rules for proper stocking, and which ought to be kept in mind at all times.

(1) At an expected high increase in weight, the number of fish per space unit (density) will have to be correspondingly low. In less productive ponds, the demands for weight increase should be low with a correspondingly low density rate.

(2) All too big 2 and retarded 3 years old carp do not repay the costs of upkeep, since their necessary sustenance is out of proportion to their increase in weight. This is particularly true for poor ponds.

(3) The more favorable the natural food conditions, the easier can larger stock fishes (despite their high maintenance requirements) find so much natural food that they will reach an individual increase of 200 percent, which alone guarantees a good food evaluation. Walter has shown that the piece weight of set-in fish can be greater, the more fertile the ponds are.

(4) A mixed stock of carp and tench and of various age classes has, on the one hand, the purpose of better evaluation of natural feeding by enlarging the extent of nutrition. On the other hand, the addition of younger age classes to older ones in the large maturing ponds increases the number of feeders per hectar or maintenance requirement without strong increase of the total set-in weight. By this means an increase of the surface yield is achieved especially in the more extensive surfaces.

(5) Under mixed stock conditions (2 year old carp and yearlings) the weight increase of the minority grade is greater, and the increase of the majority class is less, that is, in comparison. Tench stock, when added to carp stock will bring down the increase of carp through lowering the rate of increase per space unit. If more than three 1 year tench are placed to one yearling carp, any advantages of tench stocking are lost. True, the weight increase of carp is raised but the increase per space unit is lowered below normal (according to Walter).

(6) Overstocking increases the yield per surface unit but the individual weight increase naturally is considerably retarded. With an eight-fold over stocking with yearling carp, the surface yield increases three-fold and it was found by Walter, that the individual growth, which normally should be 400 grams, was only 164 grams. The application of this rule can only pay practically when carp are artificially retarded for three years and used in the fourth year as three year olds weighing about 350 grams, and used like two year old stock. After effects on food animal production do not occur in the following year with overstocking, which has been revealed to me by experiments in the fishery of the Forest Academy at Eberswalde. Theoretically such an undesirable after effect would be thoroughly conceivable.

(7) The increase of stock density resulting from feeding in carp ponds with stock food causes a considerably better evaluation of the available natural food. The success of the feeding does not ultimately depend on this. One half to two thirds of the total nutrition in this way is represented by natural food in the feeding management. Only under such conditions is the food well evaluated. The yield increase by pond fertilization is also largely due to the increase of stock density by means of the food stock.

The number of stock for carp ponds with feeding is calculated in the same way from the total growth increase (table 20), which in this case equals the sum of the natural growth increase and the food growth increase.

For cases where no special calculation of the stock figure is to be carried out, I have elsewhere given guide figures. I shall again give them in Table 19, and also average stock figures for carp ponds. These figures may be valuable to the small pond operator and to the beginner who wishes to avoid calculations by the stock formula. I must emphasize that Table 19 deals only with approximate average figures.

In setting up the stock plan it is obviously necessary to consider the characteristics of each pond, its freedom from pike, the possible penetration of wild fishes and all other factors which would make a stock regulation illusory. Each pond must have its own most suitable stock. The technique of stocking is extremely simple. Previous determination of the number and weight of the fish to be placed is obviously necessary after what has been said and in the interest of good bookkeeping, which alone allows the collection of experiences.

The ponds must be amply covered at the right time before the fish planting. Large ponds in some circumstances are kept closed for weeks before the planting of fish. Stock to be purchased should be ordered in the previous autumn, and the transportation should be well prepared so that no unpleasant surprises can occur. The only thing remaining to be watched, is the avoidance of temperature differences, especially with the youn brood, and thorough distribution of fishes (especially brood) is setting out at the shore.

Larger fishes are most conveniently transferred to the pond with a wooden or better a galvanized iron slide. In this way barrels can be poured out from the top of the dam. By using sack-linen hoses, the barrels can even be tipped over on the wagon. The fish are carried unharmed through the hoses into the pond. A distribution of larger fishes during the setting out is generally superfluous.

Table 19.

Directions for the stocking of carp ponds, trout ponds and of holding ponds, based upon average production, normal stock weight and normal stock increase.

Abbreviations - B: brook trout; C: carp; R: rainbow trout; T: tench.
B_0, R_0, C_0, T_0: fish with vitelline sac.
B_1, R_1, C_1, T_1: yearlings of respective species.
Figures 2 to 6 below letters B, R, C, T mean 2 to 6 years.

C Kind of ponds or tanks	Number, kind and age of fish to be set out.
C spawning pond	2 females, 4 males
C nursing pond	50,000 broodlings per hectar (2½ acres)
C rearing pond	5,000 fingerlings " "
C holding pond (non-fed).......	500 yearlings " "
C " " (fed)	(1,500 " " " or mixed stock: (1,000 C_1 plus 2800 T_1 per hectar.
C adult ponds, non-fed	100 C_2 per hectar
C " " fed	(350 C_2 " " or mixed stock: (200 C_2 plus 200 T_2 per hectar.
C winter ponds	1 C_2 per square meter
C fish tank	100 C_3 " " " (150 kilograms per cu. meter)
C earth ponds	10 - 20 C_3 " "
T rearing ponds	2,500 yearlings per hectar
T holding pond (non-fed)	650 T_2
T " " (fed)	2,000 T_2
C holding Pond) or T spawning ")	1 T_3 female plus 2 T_3 males per hectar
(Incubation pond)	2 B_0 or R_0 per square centimeter.
(Brood pond (natural)	2 B_0 or R_0 " " meter.
(" " (feeding)	100 B_0 or R_0 " " " .
Trout: (Fattening ponds (intensive feeding)	25 B_1 or R_1 " " " .
(Spawning ponds)	1 to 10 B_4 to B_6 or R_4 to R_6 per are (1/100 hectar)

Chapter VII
FISH FEEDING

A. Importance of feeding. The food quotient as standard of good results.

The profits to be derived from pond fisheries are greatly increased through the feeding of fish. In trout ponds, the fish—through feeding—become independent of the natural catabolic cycle of the pond. In carp fisheries, additional feeding allows greater stock density and stimulates the fish to a better utilization of the natural food. Under the climatic conditions of Germany, it would almost be impossible to produce carp for the market, upon a profitable basis without the aid of feeding.

Qualitative differences of the food, in relation to the differences in age are seldom made, since there is no difference in fish between a period of mere growth and periods of fattening them; like in the case of cattle.

In carp culture, where natural food is such an important factor, only the form of food is adjusted to the size of fish. All other adjustments are superfluous, often even with regard to proportional issuance of rations.

The composition and theoretical physiological values of artificial foodstuffs has been dealt with in table 4, but aside from some especial factors, it is not so much the physiological food value as the price of food which is of interest to the fishbreeder. Fish food must be cheap.

The pond manager uses the food-quotient in order to calculate relatively, the price value of a food. The food quotient is the figure which indicates how many weight units of food are required to produce a weight unit of fish growth. The older expression food coefficient means the same as food quotient. Since the calculated figure is not of invariably constant size, but as shown below is a highly variable ratio figure, I consider it more correct to speak not of a "Coefficient" but rather of a "Quotient". The food quotient permits judgement of the commercial value of a food.

In carp culture, the food quotient is easily determined by dividing the amount of food issued through the increase of natural food in the ponds. The so calculated figure is the "absolute food quotient" (Walter).

Unfortunately, some fishbreeders are still accustomed to figure out the food quotient according to the formula of: Food plus increase through fertilization - or - Food plus fertilizer plus increase in natural food. The food quotient so arrived at, is spoken of as "relative food quotient".

In order to avoid misunderstandings I wish to point out that in this book the "absolute food quotient" is meant whenever the word is used.

It must never be forgotten, that the "absolute food quotient" in the carp-pond fishery is only a commercial measure and does not express the purely physiological activity of a food. In its calculation the individual losses of fishes are neglected. Besides, as I repeatedly emphasize, a stronger evaluation of natural food results from the stock increase, due to feeding. The height of the food quotient for a food depends also on the kind of stock.

In trout feeding in intensive operations, the food quotient is determined simply by dividing the weight of dispensed food by the total growth weight. Since the trout in the feeding pond take up additionally, only relatively small amounts of natural food, the resulting error here is not all too large. Besides, it is partly offset by the neglect of the losses.

Above and away from the sum total sources of error, even the "physiological food quotient" for one and the same food is no completely fixed unalterable size. Theoretically, it could be assumed that it depends on the size of the fishes because the ratio of maintenance food requirement to growth food requirement would not be constant in variously sized fishes. Cornelius, however, has found no differences in food quotients in various sizes of rainbow trout. The food quotient for the same food was approximately equal for brood weighing 100 milligrams each, and for fingerlings weighing from 5 to 100 grams.

On the other hand, Cornelius found that with trout there exists a dependence of the food quotient upon the temperature. Furthermore, according to Cornelius, the food quotient drops as the oxygen content increases, until it reaches the lowest value at an oxygen content of 17 milligrams per liter. The food quotient of a food for every kind of fish naturally also depends upon the health status of the fishes (gyrodactylus!) and upon the kind of feeding. Cornelius found that with rainbow trout, the food quotient requires at least a thrice daily feeding to reach the same value given by uninterrupted availability of the food.

Which brings us to the conclusion that <u>the food quotient of a certain foodstuff and for certain kind of fish is not to be considered as generally characteristic and invariable. The food quotient depends upon the biological conditions of the pond, upon various environmental factors, upon the modus operandi of feeding and upon the general conditions of the fish.</u>

The influence of the foodstuffs themselves upon the rate of the quotient is explained by the varying caloric values of the divers foodstuffs. The desirable rate of the quotient will be discussed later.

B. The most important foodstuffs for carp and trout.

For reasons of profits, the breeder of carp and tench will choose simple and cheap foodstuffs for his fish. The foodstuffs used for the large carps, exclusively fed, in the aquarium in Berlin--merely kept for educational and show purposes--would be far too expensive for commercial fisheries. Instead of seeds, such fisheries use mostly chopped up fresh fish, fresh mussels, earthworms, lettuce, etc.

Some of the main foodstuffs for carp and tench are lupine and soya bean groats. Almost equally good are rye, barley and maize. Less good are the various animals flours, such as fish flour, meat flour, cadavre flour, blood flour, etc. Very useful, in many cases are vegetable waste products of not too great a water content. Animal fresh waste products are also usable. Of less value are potatoes and all waste products of high water contents. The same foodstuffs can be used for the brood of carp and tench, if they are fed at all.

The chief nutriments for trout fingerlings are fresh sea fish, slaughterhouse wastes, knackery wastes and horse meat. The most important nutriments for trout fingerlings is spleen. Substitutes are dehydrated small fish, animal meals (dehydrated), such as fish meal, meat meal, etc. Less good or too costly but usable are liver, brain, blood and curds. Highly nutritious but relatively costly for use in small scale feeding and growing of spawners, are fresh sweet water fish, shrimps, fresh mussels, snails, frogs, cockchafer (Melolontha vulgaris), etc. As fillers diluters, and binders are in use fish flour, meat flour, dehydrated shrimps, blood flour, rye flour, rice middlings, wheat middlings, potatoe pulp, beechwood sawdust, poplar sawdust and of late--for reasons of vitamine supply--yeast and blood yeast.

The importance and the commercial value of the different foodstuffs were previously discussed.

C. Preparation of the food and the compounding of food mixtures.

1. Food for Carp.

Special preparation of the food for carp is often not necessary at all. To soak the foodstuffs and to chop them up is usually sufficient. For smaller fish, the breeder will crush or grind up the larger seeds (lupines, beans, maize). Since middlings deteriorate by and by, only a sufficient quantity for short periods should be kept on hand.

Two year old carp of 250 grams and over and older fish will feed upon the whole seeds.

Rye is usually crushed and only the smaller maize kernels are given whole to the fish. Investigations by Walter (over a period of many years) have proven that lupines seeds are just as effective in whole as in crushed form. It has also been shown that whole seeds are quickly reduced to a mush in the intestines of fish.

Middlings is soaked in water to prevent it from drifting off upon the surface of the water. It is not necessary--although often done--to soak whole seeds, since the seeds will swell quickly when merely thrown into the water. In Hungaria, the soaking of maize kernels is done since oldest times as a matter of course. The only advantage of it lies in the stimulation of germination and of vitamine activity.

According to Hempel, the use of pre-germinated and afterwards crushed lupines seeds makes for better food utilization and the food quotient will drop from 4 to 2.5 (Sklower, lately, found the opposite to be true).

The bitterness of lupine seeds does not react unfavorably upon the fish and has therefore not to be extracted. Soya beans are always fed the same as middlings. What has been said of lupine is also valid for soya bean middlings, legume seeds, grain seeds, corn, and oil fruits, etc.

Animal flours have to be boiled before use and are mixed with vegetable flours into a stiff mush. Prevention of scattering and leaching out of food is at least as important as favorable composition of food in the growing of carp.

Dehydrated lupines and likewise horsechestnuts are nowadays a market commodity, a "staple," sold under the trade name of "Lupiscin." Mixtures with flesh-bone flour "Lupiscin I" are also on the market. Walter has 10 percent better results with "Lupiscin" than with lupines. The manufacturer of "Lupiscin" states that the processing of this product does not affect the digestibility of the so treated lupines.

The better results with "Lupiscin" are probably simply due to its low water content. Kellner has rightly said that digestible matter is lost in the roasting process of foodstuffs. On the other hand, the dehydrating process makes for better food preservation, while at the same time certain unpalatable components of lupines and horsechestnuts are destroyed through roasting.

2. Foodstuffs for Trout.

Foodstuffs for trout in the intensive feeding operations, most always require a special and careful storage and preparation. There must be a cooling or icing room available for the storage of fresh sea fish and fresh meat. It can be built in the brood house. It may be helpful to store cases of food by suspending them in conduits which are mostly cool. The flesh of warm blooded animals which is frequently obtained in frozen state can be conveniently thawed here and remains well preserved so the food needs be drawn upon only two to four times per week.

Another special small room or one in a small building in the vicinity of the pond serves as a "food kitchen", food room, or food house. This room must be kept scrupulously clean and well ventilated. The kitchen must contain a meat chopper, not too small a model, in which fish can be ground head and all, also a special table for butchery, and cooking or preferably steaming facilities. The chopping machine may be hand powered in small fisheries, or for larger operations may be driven by turbines or water wheels run by storage water or by sufficiently strong motors outside of the kitchen (Fig. 39). Warning! Meat grinders, next to vehicles have caused the most accidents in the pond industry, as shown by statistics.

The flesh of warm blooded animals to be used for food must be freed from fatty tissue, large bones and very coarse sinews, and after immediate addition of dry flours or other supplementary foods (fish meal, shrimp meal, wheat bran, rye flour, potato pulp, mashed potatoes, beechwood sawdust, also clay, food lime, etc.), the mixture is put through the chopping machine. If small-holed plates are to be used, it is better to grind twice, the first time without adding the supplementary food. Short firm noodles should be formed. 10 to 20 percent of the food must consist of binding additions. In my experience I find that smaller amounts of sinews are not harmful, even if they hang out of the fish's vent for some time after feeding, as we are dealing with very soft "filling" ingredients. Smaller bones (especially after previous steaming) can be ground through. They enrich the food by their mineral content and as "ballast".

In the preparation of fresh sea fish, particularly strong skeletal parts may be removed. All too great an anxiety is out of place, since predatory fishes naturally devour the bones of their prey, and a good breaking up of bones occurs in the meat chopper. Grinding through, is done as with fresh meat of warm blooded animals. For binder materials for fishes, only good fish flours, rye flour and similar material is to be recommended. Spleen, the principal foodstuff for broods is scraped for the very young brood. It is nailed upon a board and scraped out till only the membranes are left. For larger brood the spleen can be ground through, but the perforated plates must not be too fine, in order to avoid stopping up. Additions at the beginning of feeding are mostly never made or only in narrow limits (best salt-free fish flour, fresh sea fish or shrimp meals). Dead fresh water fish and unremoved sea fish, if they are not absolutely fresh, must be removed before the preparation. According to Buschkiel, two dozen food-fishes can be mixed with dry food and chopped and ready for feeding in one hour with a strong chopping machine.

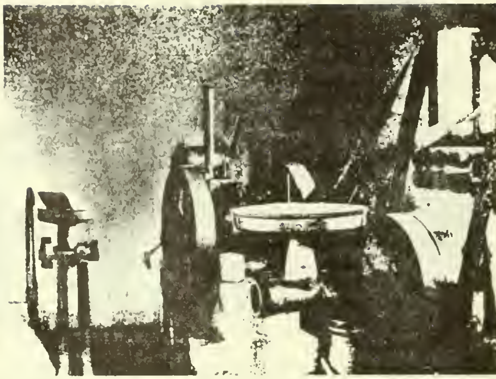

Fig. 39. Meat chopping machine with "crude oil motor" drive in the feed-house of a large trout fishery. Left, a small chopping machine for hand power.

The cooking or steaming of large sea fishes and bony meat of warm blooded animals is often done only to ease the screw turning through the chopper. The bones are softened by steaming, and coarser bones can easily be removed. In cases where there is no good reason for heating, cooking and steaming is only justified when the food is no longer fresh enough or when the flesh of sick animals is being fed. Slaughter house waste today is largely ob tainable only in the cooked condition and after veterinary inspection and through the mediation of "Utilization Associations for Slaughterhouse Waste". Unfortunately a two to three hour cooking is required for softening bones. The shorter the time, the better it is. Unnecessary heating, cooking or steaming of foodstuffs is most certainly to be avoided, because heating will not unlock the food substances or increase the digestibility. On the contrary, the utilization value of crude protein is lowered in heated meat. At the same time vitamins are destroyed, nutritive substances are leached out, and by the decreasing of food volume the nutritive substances are concentrated. The concentration acts very unfavorably on the digestive organs of trout. On the contrary, the object must be to suppress too large a concentration of foodstuffs by the addition of ballast substances. Finally, according to Schaeperclaus (1931), there is no danger whatsoever, that the feeding of uncooked sea fish will cause the entry of the gyrodactilus infection. Also the entry of other diseases by means of fresh sea fish is not to be feared. If the food must be cooked, it is recommended to change off with fresh food.

If heating of the food is to be done for any of the reasons given, that is, to destroy putrefactive bacteria and their toxins, or to ease the preparation, then steaming is to be preferred to cooking. Although steaming occurs in some circumstances with somewhat higher temperatures, yet the necessary heating time is shorter. The food can be "dry cooked", and will not therefore be leached out. The fat, which is undesirable in trout feeding, is separated off by steam and may be saved and sold to soap factories. The salt in salty foods should be extensively removed by the steaming.

For steamers a large variety of apparatus may be used, especially hinged steamers which are used in agriculture. Even better are special fish food steamers (Fig. 40) manufactured by Gotthardt and Kuhne, Lommatzach, Saxony. They consist of two separated parts: - a steam generator, which can also be used for heating and hot water appliance, and the actual steam hoods. The steam is piped into the hoods. The hoods, built similarly to a gas oven, contains removable sieves. The capacity varies according to size of the apparatus, from 15 to 40 pounds of fish food.

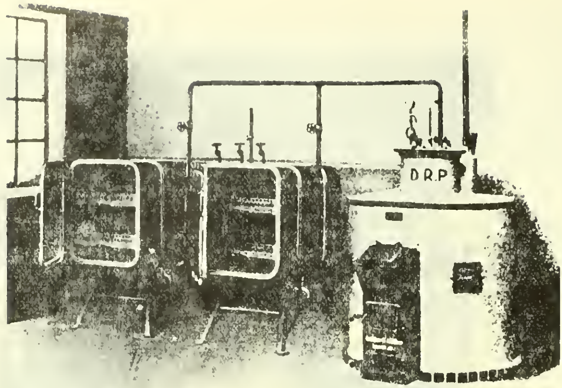

Fig. 40. Fish food steamer of the firm Gotthardt and Kühne.
Left - 2 steam hoods, Right - steam generator.
D.R.P. = German patent.

There are almost unlimited possibilities for the preparation of trout food mixtures. A great number of variations are possible merely by changing the ratio of main food to admixed food. Even more variety may be gotten by a greater variety of admixture foods.

For example, I shall give only three trout food mixtures here:

(1) 67% of slaughter house wastes and
33% of fish flour and rye flour in equal parts.

(2) 50% of fresh sea fish
30% of fish flour
10% of shrimp middling
10% of rice flour (food flour)

The different flours are first mixed together and may be moistened with blood. The mixture is then passed through the meat chopper, together with the sea fish.

(3) Ahren's mixture.

25% of rye flour
25% of shrimp middling
25% of fish flour
25% of meat flour (fresh salt water fish or fresh meat can be substituted).

Skimmed milk can be used to mix all this into a mush and the mixture can be recommended even for young broodlings. An addition of blood improves the mixture.

"Salmona", a dehydrated trout food has lately appeared upon the market. Here is the formula:

Make a dough of 1 kilogram of "Salmona" and of 1 liter of water.
Let the well mixed dough stay for 30 minutes, then work it over again, and feed it to the fish.

According to Lehmann, "Salmona" contains 1.4 percent of salt and no bone flour or any kind of flour from warm blooded animals. The food quotient varies between 2.7 to 6, according to varying temperatures and the variable size of test fish. Lehmann states that

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a lately much praised trout food (presumably Salmona) consists of a mixture of fish flour with about 15 percent of grain flour. He considers the price far too high. Ready made mixtures are preferred in the small fishery because the manager saves the effort of selecting good quality foods and the work of mixing them.

All warm foodstuffs have to cool off again, and of course, before they are given to the fish. It is recommended to leave them over night in a most possibly germ-free cool room or refrigerator after mixing and chopping.

D. Characteristics and uses of the different foods.

1. Vegetable Foods.

Lupine. They are the ideal food for carp and tench. Their issuance is simple and they are very nourishing without reacting unfavorably upon the quality of the produced fish meat. Their average food quotient is 4 and should not vary more than between 3 and 5. There is hardly any difference between yellow and blue lupine.

Walter's experiments have also shown better results some times with one variety and again with the other. Lower quality is usable but of poorer activity. A disadvantage of lupines is their poor storage ability. In recent years lupine has often been too expensive in regard to table carps; the ratio of lupine purchase to carp production price (as introduced by Brüning), has become too unfavorable. The lupine price must be at most one eight of the carp price in order to maintain profitability. The well storable dry preparations like "Lupiscin" on account of their low water content, often have a high food quotient, but are also higher priced.

Soya bean middling extract. It has become a good substitute for lupine in recent years. It is a by-product of oil extraction, contains only 1 to 4 percent of fat and is generally known as soya middling. The food quotient as well as the food value are about the same as lupine. It is easier to keep in storage and ready to serve--even to younger carp--without first putting it through the mill. "Vita Middlings", a light-colored variety showed a high food quotient in the hatcheries at Wielenbach, while "Vita-Molasses Bricks" were less satisfactory.

Other legumes are also good but too high in price.

Horse Chestnuts. Precaution necessary. Can lead to saponine poisoning.

Maize can be used in a similar manner as lupine. Due to its high fat content and variable food ratio it produces soft fish, lacking in resistance and the flesh will taste of maize. In holding ponds, "maize carp" lose considerably in weight, hence, maize feeding should be stopped a few weeks before marketing the fish. Altogether, not more than 50 percent of maize should ever be added to any food mixture. Its food quotient is somewhat higher than the food quotient of lupine (averaging about 5). Despite its broad foodstuff ration, maize and also maizena are very good in the feeding of brood over 5 cm. in length and of yearling carps. The natural nutrition can of course completely satisfy the metabolic and therefore also the protein requirement.

Maize is rich in vitamin A and if not too plentifully given during the second part of the summer will aid the carp to store away a food reserve for the winter without fattening them all too much.

If used for broodlings, 25 percent of fish flour is usually added. For trout, up to 20 percent of Maizena is often added to their food as a by-product, although it is not a good "binder".

Rye, Barley and other grains, are given whole or crushed to carp and tench. Boiling, often recommended, is not necessary.

According to Mehring, grains--on account of their high mineral contents--aid in the fertilization of the ponds via the feces of fish. Their food quotient is from 4 to 6. In difference to maize, these grains do not react upon the taste of the flesh. The possibilities of their uses is a question of price.

Barley and barley middlings have an especially favorable food quotient and are widely used--notwithstanding their hard shells--for carp broodlings and younger carp.

In Thüringia, according to Kamprath, barley is served out to larger carp (after soaking it in tepid water for 12 hours) in the belief that it produces a finer and tastier flesh.

Flours, ~~bran,~~ brewers grain and distiller's wash from rye, barley, oats, wheat, rice and maize can be given to carp and tench without further preparation. The food quotient is from 4 to 6, at times below 4. Very fine flours like rice flour, rice bran (1930 about $1.62 per 100 pounds) obtained from polishing rice grains and containing according to law not less than 22 percent of protein and fat, can only be used profitably in the food cycle by feeding in lumps made by water admixture or after hot preparation or in briquette form. For carps, the fine flour form is the most unfavorable, often giving food quotients of 10 and over in the case of rice feed flour, but with proper distribution only 4-5. All flours, especially rye flour, rough wheat bran and rice feed-flour are important as binders for trout food and are then added to the main foodstuffs (meat, fish) in amounts up to 35 percent. Rice feed-flour is especially noted for a high protein rate, a high rate in vitamin B and is normally free from chaff (chaff contents of over 13 percent must be indicated). Haempel, on account of its high vitamin rate, considers it especially valuable as binder in trout culture.

Wheat bran, according to the experiments of Gaschott and Probst and from all practical experiences also rates high as a by-product for trout food.

Waste products from oil extractions (sunflower seeds, pumpkin seeds, palm kernels) can be similarly used as maize but impart a still stronger taste to the flesh than maize. They are low in vitamins. Food quotient about from 5 to 6 (according to Klee). They may be fed to yearling and two year carps, but must not be given shortly before the fishing out time.

Potatoes are not very well suited for carp and tench. Their food quotient is 20, even 30 or more. They are usable to some extent only when cooked and mixed with animal flours. Steamed mashed potatoes--and dry potato pulp in amounts of from 10 to 20 percent--make a good binder with sea fish or with meat for trout food.

Waste cookies and other bakery wastes may be used for feeding. This kind of food cooky, which was prepared with cacao butter contained 6.33 percent crude fat, of which 3.34 percent consisted of free fatty acids. The air dry feces of carps, feed in the winter pond, contained 32.9 percent crude fat of which 42.1 percent consisted of free fatty acids (calculated as oleic acid). Accordingly, the fat of the cake seems to have been hardly digestible, at least in the winter. Waffle waste in Wielenbach 1931 had a very good reaction, the food quotient amounted to only 3.1.

Beech and poplar sawdust is used as a cheap binder and "ballast" for fresh trout food. It lowers the dangers of indigestion and of losses quite perceptibly (demoll). A food mixture of 75 percent of salt water fish and of 25 percent of sawdust had a food quotient of 4.9, salt water fish alone had one of 5.3. All too large doses of sawdust are detrimental, though, sawdust added to fattening food of cattle lowers the effects of these foodstuffs (Kellner).

Dry yeast has of late been introduced into trout culture in order to enrich the vitamin content. Some fishbreeders consider it a prophylatic against lipoidal degeneration of the liver. Gaschott and Probst, experimenting with exposures of dry yeast to violet rays have demonstrated that a more than 4 percent addition to trout foods does not repay. Dry yeast (Genovitan) is composed of 50 percent protein, 2 percent of fat, 24 percent of carbohydrates and 3 percent of phosphatic salts.

2. Animal Foods.

Fresh Marine Fish (54 to 65 cents per 100 pounds in 1930), in a fully unspoiled raw state form the most natural bulk food which the fish breeder can offer his fishes. Fatty marine fishes like herring and smelt are excluded, but haddock, codfish and coal fish (Gauds virons) with and without head are usable. Small fishes like gurnard (Trigla hirundo), small flounders, also fish heads (for their high content of small bones) can be of great value when the remaining food is poor in minerals.

On account of easy spoilage and high freight costs, fresh marine fishes can only be considered by trout fisheries near coasts (North Sea) or by fisheries having good railroad connection with North Sea Fishery Ports (Geestamonde, Wesermuende and Cuxhaven). The purveyors for marine fishes are the large wholesale fish dealers of these fishery ports. As a rule those fish which have become damaged and unsightly in the loading room of the fishery steamer or in reloading, are sold cheaper. Fishes which have been too plentifully left at the auctions, consequently reek with a strong ordor and are usually taken at once to neighboring fish meal factories and can be used only (after previous steaming) in very nearby fisheries. It is very important to safeguard a most regular supply throughout the year by means of definite agreements. Strong, ventilated boxes, baskets, or food tubs are used for transportation. Only fish in exceptional (good) condition may be transported.

In trout feeding the food quotient for marine fish is very variable, corresponding to the kind of fish to be fed, the age and growing power of the trout, the height of losses occurring, the kind of dispensing and preparation of the food, perhaps the height of the temperature and of the oxygen content. A quotient of 5 in the dispensing of raw sea fish is very good and mostly represents the highest performance in practical management. On the average 6 to 8 must be figured. In the experiments of Riggert, as in most experiments, the natural nutrition probably played a role. If there is an occasional food shortage or if the fishes for other reasons grow to table size only after two years or later, then the food quotient probably still lies over 8, namely at 9 or over. Brood may receive, after two months, additions of faultless sea fish to the spleen; after three months the addition may be as much as 50 percent.

Dried Fish. This fish food (consisting chiefly of Chatoessus nasus) has been imported from East India, during the last few years. In 1930, the cost was about $4.55 per 100 pounds. The fish are air-dried and their price is only slightly higher than the price of fish flour. Before use, the food has to be soaked in tanks when the sand, clinging to the fish will fall to the bottom. According to a letter from Professor Brühl, these fish are predominantly Chatoessus nasus.

Fish Flours (costing about $4.11 per 100 pounds in 1930) are made predominantly from easily spoiled wares as already mentioned, from de-fatted fish residues in the cod liver oil industries, and from fish heads. The "steamed flour" is prepared by comminution, drying with steam or flue gases, grinding and sieving. If the starting material consists entirely or predominantly of herring, then the produced flour is very fatty and must be labeled "Herring Flour" according to the German Food Law. Good fish flours must not have been overheated. In this case the protein is altered and cannot be decomposed by pepsin into peptones and albumoses, or by trypsin into aminoacids, and is therefore indigestible. Heated flours should actually be dried in the absence of air, since only then are vitamins preserved. Good, are most flaky, lighter "air dried codfish flours" (which are sometimes also re-dried by heat action) as in the best quality coming from Norway, and all others which are light colored, flaky, not too fatty (less than 3 percent fat), salt poor (under 3 percent, for brood under 1 percent), not too rich in bones (less than 30 percent calcium phosphate), and which are not protein poor "Fish Flours", "Codfish Flours", "Lean Fish Flours", "White Fish Flours", "Whitefish Flours". According to Lehmann, among a larger number of analyzed fish flours, 77.1 percent contained more than 3 percent of fat, 41.4 percent more than 3 percent salt, and 18 percent more than 1 percent of sand. One contained up to 23.5 percent of fat and one a salt content up to 12.2 percent. Moldy, too watery (containing over 12 percent water) foods occur, also food adulterated with sack fibers, sawdust, etc. Mach and Claus who, in the years 1930-1931, tested the composition of the fish flours in commerce, place the main value on testing the flours for cleanliness and freshness. The expensive chemical analysis can in some cases be omitted, since cleanliness and freshness are more important than the amount of foodstuff content. Care is very advisable, and doubtful flours should be analyzed, as bad fish flours most frequently cause intentinal inflammations.

Fish flours belong to the most important foods. Special success is gained in the feeding of carp brood and yearlings by adding 23 to 35 percent of fish flour to the main food. These successes with carps are partly traceable to the high vitamin A content, which, however, disappears in overheated flours.

I was told by one certain fishbreeder that from long experience he has come to the conclusion that mixing the main foodstuffs with fish flour will prevent "white spot" (Ichthyophthiriasis). Since water and soil of this particular hatchery are very poor in lime, it is not at all impossible that the high content of calcium phosphate in fish flour, in combination with the high content of content of animal protein and of vitamin A really do give good results in this particular case.

According to Haempel, it was Aulde who found that lack of calcium (lime) counteracts the effects of vitamine A, while on the other hand the storage of calcium (lime) depends upon same.

In trout culture, fish flour is used as a supplementary food and in emergencies even as main food, to which some vegetable flour is then added. Food quotient--as far as known as yet--is from 1.5 to 3 (for carp and trout).

Roe of salt water fish is often offered as foodstuff for trout fingerlings--especially between January and April--but is not all too highly valued by fishbreeders. It is mostly far too salty, even if labeled "mildly salty".

Fresh Freshwater Fish are exceedingly valuable food for trout growing. Ever increasing numbers of fisheries endeavor to get a supply of cheap and otherwise not valuable bleak fish, red eyes, roaches, blays, etc. Unfortunately deliveries can not be maintained steadily throughout the year. In exact aquarium feeding experiments on 10 to 100 gram rainbow trout on a diet of "white fish", Cornelius found at 10° an average food quotient of 2.9, and at 17° one of 6. Fish flour from freshwater fish, which are not marketable on account of too low prices, is now being manufactured (especially in Hungary), and naturally it may be used under the same conditions as flour from sea fish.

Fresh meat from warmblooded animals. The production of many trout fisheries in Northern and Southern Germany depends preponderantly on the feeding with this meat. This includes beef and horse meat, which fish growers buy directly, meat and organs from slaughterhouse waste ($1.52 per 100 pounds in 1930) and meat from flaying establishments. Unfortunately in times of stress available amounts are always smaller. The shortage of available meat is increasing also on account of stricter veterinary police rules. Where veterinary police restrictions are not in effect, it must be remarked or rather advised to cook the meat and organs (in many localities much lung is fed) of tubercular of otherwise diseased animals before feeding it, on account of transmission danger, unless already cooked meat has been purchased. Regarding the preparation, methods were discussed earlier. The total requirement of food flesh is often very considerable. A fishery which produces 10,000 pounds of trout a year, requires in the summer a whole beef or horse daily.

But while feeding of these materials is of sheer necessity, they are inferior to salt water fish and in every respect. They also impart a bad taste to the flesh of trout and their mixing with by-products is absolutely necessary in order to avoid intestinal disorders in trout. Spleen and yeast (both rich in vitamines) should also be added to the flesh from warm-blooded animals. Especially when cooking has destroyed vitamins and made the protein more indigestible. Feeding with salt water fish, at least once a week will somewhat improve the otherwise bad taste of trout. I recommend to stop altogether with feeding meat from warmblooded animals 4 to 5 weeks before bringing the trout to market.

The food quotient varies greatly. The quotient of very sinewy pork without by-food in the case of pond feeding--hovers around from 4.5 to 5.7. The average is about between 5 and 8.

According to Buschkiel, the food quotient rises to 10 when boiling the meat. It is erroneous to believe that the flesh of warm-blooded animals is made more digestible through boiling. One has to remember that boiling destroys all vitamins and makes the protein more indigestible.

Flesh forage flour. These foodstuffs play a less important role in carp and in trout culture than fish flours. They are a by-product of mostly foreign meat packing plants and of meat extract factories. Only healthy meat from beef, lamb and horse--free from bones, sinews and fat--is used. To the lixiviated meat is added some calcium chloride, some sodium phosphate and some calcium salts. Adulterations are rare.

Meat flour is prepared from healthy meat, meat scrap, and bones. The protein content is only about 50 percent. If the flour contains more than 12 percent of calcium phosphate, then according to the Food Law it must be labelled meat-bone flour.

Animal flour, animal body flour, cadaver flour is similarly prepared in the interior from the bodies of fallen animals, meat from flaying establishments, etc. The composition is therefore similar to meat flour. It is mostly unusable for trout feeding.

Feed lime is a by-product of glue manufacture and contains 37 to 38 percent of phosphoric acid, since it consists for the larger part of calcium phosphate. Adulterations, among others with arsenic, suggest caution. Feed lime serves for addition to every kind of calcium-poor food. The amount to be added is about 1 to 5 percent. Instead of feed lime, about 2 percent of prepared (levigated) chalk or powdered limestone (marble) may be given.

Spleen, Liver, Brain and Blood. These parts are the most valuable trout food substances of slaughterhouse waste. Spleen, especially in consequence of its not too high price ($4.33 per 100 pounds in 1930) has become an ideal feed for brood. Even when it is at times slightly expensive in some places there should be no occasion to substitute with essentially poorer foods. It must be considered that spleen serves not only for the production of flesh mass, but also of healthy fingerlings. Under normal conditions the net food costs up to the production of a 10 gram fingerling are at most 7/10 of a cent. After three months, 50 percent of sea fish may be added to the spleen. The best fish flour, 3 to 5 percent of shrimps and similar foods may be added on. The spleen is especially active on account of its valuable protein and high vitamin content. A regular supply of spleen has become almost indispensable for the mass growing of trout brood. Since it is difficult to obtain larger amounts of spleen for the summer only, it is advisable to make agreements for the entire year and to feed spleen during the winter to the fingerlings as a valuable addition food.

Spleen is too expensive for a trout mast. The fish prefer spleen from calves and beef rather than from pigs. In a large fishery, I was able to estimate that 1,210 pounds of fingerlings were grown from brood with about 9,900 pounds of spleen. The food quotient was practically about 8. In this case, however, the losses of over 50 percent of connective tissue occurring from preparation and sieving of the food, and the brood losses of about 50 percent were not considered. The purely physiological food quotient, in which food waste and the losses in food and fishes do not falsify the calculation, is naturally much lower. Cornelius determined, for rainbow trout brood of less than 1 gram at 13°C, a food quotient of 3.2, for fingerlings at 14°C, a food quotient of 2.9.

Liver from beef, calves, and hogs is relatively too expensive. In several regions of Germany, however, on account of the low price it is said to be fed to a large extent. In America liver of beef and sheep is fed to trout broodlings. In comparative food tests which were carried out for me in the fish hatchery at Eberswalde, the brood fed with liver showed a growth 18 percent better than brood fed with spleen and about 10.5 percent better than brood given spleen plus natural nutrition. These tests were on rainbow trout brood. In Wohlgamuth's experiments, trout brood digested liver in 7 to 8 hours, and spleen in only 6 to 7 hours. Liver is therefore a very good substitute for spleen.

Brain is also usable, but it is less valuable than spleen. Similarly, the undoubtedly vitamin-rich kidneys and hearts may be fed, but they are mostly too expensive. Blood given raw is a valuable addition to iron-poor curds or to plant flours, as it contains all the necessary proteins and mineral substances, but lacks filler substance. This lack can be compensated by suitable additions. Carps are at times fed with blood which has been cooked and put through the meat chopper. In this way food quotients of about 3 are said to have been achieved. From other sources it is suggested to completely absorb the blood in bran. This mixture is said to be durable when pressed into barrels.

Dehydrated Spleen has very recently appeared on the market at acceptable prices ($4.11 per 100 pounds, fresh spleen $4.33 in 1932), and it has been tested by Probst on its applicability in trout growing. From this it was found that brood which was fed half and half fresh and dried spleen thrived as well as those fed only with fresh spleen. Rearing only with dried spleen failed. But in the mast equally good results were achieved as with sea fish, and with almost equal costs. It is to be noted, however, that Probst is reckoning fresh spleen very high, at $9.74 per 100 pounds. The food quotient for a food, consisting of 80 percent dried spleen, 12 percent sawdust, 4 percent rye flour, 4 percent wheat bran amounted to 7, but by miscalculation of losses only 5.1.

Blood Flour is made by drying and grinding the blood of slaughtered animals. It is to be used like meat flour. Overheated, blackish flours occur frequently but should be rejected for trout growing, on account of indigestibility.

Blood-Yeast was introduced into trout feeding by Johansen. It consists of a mixture of beer yeast and blood. In manufacturing the dry preparation, temperatures up to 100°C are used only, so that the protein is not made indigestible as in the case of other dry flours. On account of the low price (1930, $6.27 per 100 pounds) it is used to stretch spleen. Larger additions to the masting food do not pay.

Curd is a relatively one-sided food, and also does not contain all of the "building stones" of protein. Besides it is very poor in iron and in vitamins. A one-sided feeding with curd leads very quickly to blood impoverishment. Many remote fisheries are dependent upon curd feeding to trout brood. In such cases, it is advisable to improve the food by admixture of blood, spleen, raw eggs, natural food and other substances. If possible the giving of curd should be avoided at least during the first six to eight weeks of the brood feeding. The food quotient is given as about 10 to 15. With carps, a food quotient of 2.8 was achieved by Klee. Curd is today too expensive as carp food.

Occasionally, other milk products, like centrifuge slime and dried skim milk come into consideration, if only they are cheap enough and do not have too high a fat content (often over 25 percent).

Poultry Eggs are occasionally mixed raw with the brood fodder of trout, and serve to improve the quality of the proteins in the fodder.

Shrimps. Dried shrimps, also erroneously called crabs, shrimp grist and shrimp flour are valuable addition food, rich in mineral and protein, for fresh trout foodstuffs (fish, meat). They are, however, not exactly cheap (1930, $4.98 per 100 pounds) and have therefore been more and more crowded out of trout feeding by other foodstuffs. Lately in fisheries near the coast, fresh shrimp form a very excellent food (1930, $5.19 per 100 pounds) for spawning trout. Unfortunately the shrimps can only be kept one or two days and can be shipped only short distances. Shrimps form one of the few abundant foods closely approaching the natural nutrition of trout and which can be fed completely, viscera and all. Fresh shrimps are available principally in the summer and autumn from August to September. There are fisheries, for which a coast fisherman exclusively catches shrimps at this time. According to Roehler (1928), Riggert announced a food quotient of 4 for shrimps. According to Heiderich the catch of shrimps, also called crab gammel, took a perceptible upturn after the war due to the introduction of drying. Air drying has only been preserved in small individual enterprises, which in the interest of trout growing, is very regrettable. The crab gammel (shrimps), after separating the food crabs, is cooked, (often on board the ship on account of easy spoilage), treated with steam and dried with cold and hot air (180-200°C). The weight shrinks about 23 percent. Naturally in the strong heating the protein becomes difficult of digestion, vitamins are destroyed.

Shrimp flour and grist is also subjected to adulteration. At times carapace fragments from table crabs are added. Many flours are contaminated by sea stars and fishes. Other flours are much too salty. I have often investigated cases where severe intestinal inflammation had occurred from salty shrimps. It is advisable therefore to purchase dried shrimps in natural form, to always taste it, and to personally run it through the chopper with the main food. Many growers scald the shrimps in advance with hot water. Additions of dry shrimps should not be too generous on account of high prices. Shrimps, for a long time, have been too expensive a component of food mixtures. On the other hand, I consider it wrong to regard shrimps as "crude fiber" and to compare its food value only to the action of sawdust.

Wollhand Crab Groats has been placed on the market, since the abundant occurrence of the Wollhand crab in the lower Elbe River, by a firm under the names "Egeo-Groats" (100 pounds about $3.03) and "Egeo-Flour" (100 pounds about $3.23). The following analysis is given:

Protein (including chitin, therefore only 22.2% digestible ...	38.22%
Fat	9.94
Calcium phosphate	4.24
Calcium carbonate	27.72
Silicic acid (Silica)	0.58
Sodium chloride (salt)	0.95

An experiment which I made with slaughterhouse scraps (pork scraps) plus 18 percent of Wollhand crab groats on rainbow trout fingerlings with one feeding per day gave a food quotient of 5.25, whereas the parallel experiment with slaughterhouse scraps only, gave a quotient of 5.7. A second experiment with an addition of 20 percent Wollhand crab groats led to a food quotient of 5.2 and a piece loss of 7 percent. The comparison experiment with pork scrap gave this time an even more favorable food quotient of only 4.5, the piece loss 0 percent. It was apparent that the food with Wollhand crab groats was more poorly digested than the food without addition. Possibly the product available up to now is capable of improvement. Quite good results are said to have been gotten here and there by feeding fresh Wollhand crabs.

Mussels and Snails. As a mass food material for trout growing, sea mussels which can be obtained in the live state by the grower, should be mentioned above all. They are a highly valuable food material which should be reserved primarily for spawning trout, inasmuch as it causes a fine color in the eggs. The shells gape after a brief dip in boiling water and the animal can be removed. The yield of flesh is not very large so that even this food is not cheap. If the mussels are to be used only as addition food, they may simply be put through the chopper and fed, in the same way as edible snails and other land mollusks. The shell fragments act only advantageously in the total food. Trout under natural living conditions also eat larger amounts of snail shells.

Frogs may be fed to trout or after suitable preparation also to carps. Spawn ripe female frogs should first have the ovaries removed. As to tadpoles, see Chapter XIV. Living tadpoles are very seldom eaten.

Leafchafers (Melolontha vulgaris), June bugs. Their use for feeding pays only in swarming years, and for small pond management. This feeding was first recommended by Eckstein. The beetles are killed by scalding, put through the chopper and mixed with meat flour, until a mass like mashed potatoes is obtained, and then fed to the trout. For carps a mixture is recommended of 50 percent leafchafers and 50 percent lupine groats, which later may also be replaced by barley, potatoes with 2 to 4 percent of feed lime, etc. If larger amounts of leafchafers are available, they can after scalding with hot water be placed in sacks and dried on a baking oven (for the small fishery). In this connection, I shall mention also that chopped earthworms are a good food for the smallest broodlings.

Natural Small-Animal Nutrition. The feeding of natural small-animal nutrition only comes into consideration in the growing of trout brood and of course in fattening. Although we could hardly succeed in giving all food in the form of natural food, yet a portion of natural food can greatly improve the total food. Experiments in the fish hatchery at Eberswalde showed that the addition of about 20 to 40 percent of natural food to spleen caused rainbow trout brood to grow about 7.5 percent better, healthier, and more resistant, than those in a parallel experiment which received only spleen. In general, only water fleas (Cladocerae), copepodae and chironomus larvae are suited for dispensing. All other water animals had to be disintegrated. This food is best grown in small stagnating, sunny exposured fish-free ponds which are organically fertilized, before or after filling with water, by distributing a wheelbarrow full of cow dung for each 10 square meters of surface, or about 3 to 5 kilograms of meat flour or with liquid manure, etc. At water temperatures below 10°C, of course, the growth has little success. The food is fished out with fine nets, washed out, and distributed in small portions in the brood apparatus during a temporary halt in the through current. There will be no danger of carrying in disease producers if the ponds are really free of fish and have been thoroughly disinfected before their first time use as a food pond. Cornelius, using Daphnia on trout brood, determined a food quotient of 5.1 (13°C). With fingerlings he found the following food quotients:--For flea crabs (Gammarus) 3.9 at 9.2°C, for Chironomus larvae 4.4 (9.3°C).

I must also mention, that in the Agricultural Institute for Fishery in Berlin-Friedrichshagen there were repeated occurrences of intestinal inflammations in trout fingerlings (Miegel), whenever flea crabs and sewage water Chironomus larvae were given. Therefore even the use of natural food is not an absolute protection against digestive disturbances, as has been assumed up to now.

E. The Giving of Food.

1. Carp and Tench Feeding.

An exclusive feeding of carps and tench is not possible in an economic way, as has been fully explained in numerous places in this book. Carps and tench always require for a good evaluation of the food, a simultaneous assimilation of at least 50 percent of natural nutrition. The carp pond can not only be a "stall", it is always "stall" and "pasture" in once.

The individual growth of the fishes in general should be equally great with feeding or without. Therefore in carp ponds in which feeding is to be done, more carps must be set in, than when no feeding is done. In good ponds the number of stock can be doubled without the feeding becoming unprofitable. The pond then contains 50 percent natural supply, 50 percent food supply. Actually therefore 50 percent of the fishes, or better said, 50 percent of each individual carp should be grown by feeding.

But this calculation also does not agree completely. By the doubling of the fish, stock-density, of the number of eating mouths, the using up of the natural food supply becomes greater. The non-eaten portion of food fauna of the pond becomes smaller. In reality, therefore, over 50 percent of the nutrition is covered by natural nutrition. In this lies the main advantage of the carp feeding. These actual conditions are not to be overlooked in the individual case, and therefore, must be schematically calculated in practice. To be noted is simply:--A first class pond which has a natural growth increase of 300 kilograms per hectar (266 pounds per acre), can with profitable management achieve a food increase of 300 kilograms, so that the total growth increase amounts to 600 kilograms.

Since poorer ponds possess a lower natural growth increase, and a somewhat lower piece growth (see table 17), the fish shock-density is much smaller, the utilization of natural nutrition with natural stock much poorer, the non-eaten part of natural nutrition is percentually much greater than in the first class pond.

The consequence is, as first clearly expressed by Walter (1928), that in the poor pond the total increase, with equally profitable feeding, grows more strongly in relation to natural increase than in the case of the good pond. The "food increase" in a purely mathematical sense is therefore relatively higher in the poorer pond than in the good pond. The ratio of pure mathematical natural increase (natural stock) to mathematical food increase (food stock) can (without the utilization of the food becoming appreciably poorer or that the natural nutrition portion of the total nutrition really sinks below 50 percent) be shown for the individual yield classes as follows:

CLASS	NATURAL INCREASE	FOOD INCREASE
I	50.0%	50.0%
II	33.3	66.6
III	25.0	75.0
IV	20.0	80.0

I have accordingly compiled the yearly natural food, and total increase for the four yield classes in Table 20, as was similarly done in Table 17 according to Walter's procedure.

Table 20.

Natural-, Food-, and Total-Increase in Carp Ponds of the Ist to IVth Yield Classes (Compare with Table 17).

	CLASS I	CLASS II	CLASS III	CLASS IV
A Natural increase, kilogram/hectar	400–200	200–100	100–50	50–25
B Food increase, kilogram/hectar	400–200	400–200	300–150	200–100
C Total increase, kilogram/hectar	800–400	600–300	400–200	250–125
Normal basic piece increase, grams	1250–1000	1000	1000–750	750

As examples and proofs for the basic correctness of this compilation, I am giving in Table 21 the yield values from seven pond fisheries with varied, regionally conditioned, but typical features. These figures correspond to the actually achieved natural and total hectar yields and represent averages which are achieved in similar conditions of climate, water and soil in the rest of Germany.

Table 21.

Total Hectar Increase and Natural Hectar Increase of Several North German Pond Fisheries.

No.	POND FISHERY	A TOTAL INCREASE Kg/HA	B NATURAL INCREASE Kg/HA
1	L. Luneberg Heath	100–120	30 (27 % of A)
2	A. " "	240	60 (25 % of A)
3	Z. Lower Lusatia	150	50 (33.1 % of A)
4	T. " "	150–200	50–100 (33 % of A)
5	B. Neumark	300	150 (50 % of A)
6	R. Havelland	250–300	50–100 (20–33 % of A)
7	G. Uckermark	Is not fed	200

It is to be considered that Table 20 gives figures to be achieved. These values naturally, can only be achieved by prescribed and faultless management of the ponds. The calculation of the yearly total amount of food for a pond can be immediately obtained by multiplying the food increase per pond by the food quotient. The necessary yearly amount of food for one hectar is calculated by multiplication of the food increase per hectar by the food quotient of the distributed food:

FOOD QUANTITY/Ha = FOOD INCREASE/Ha X <u>Food Quotient</u>.

Example:—In a pond of 2 hectar size of the second yield class the feeding shall be with lupine. The food increase can be estimated at about 300 Kg/Ha, or 600 Kg per pond. The yearly amount of food for the pond then comes to about 600 x 4 = 2400 Kg.

In the actual distribution of food, it is the rule that only so much food may be given as to have been completely consumed by the fishes before the next feeding. More or less feeding is to be done according to the temperature. At temperatures below 13°C, the feeding in nursing and growing ponds should be suspended. About feeding in winter ponds see Chapter X. Caution is also in order with very high temperatures in late summer, for then the oxygen content can be very low. When diseases are present, feeding should be suspended at once. This is especially necessary when gill rot occurs. In times when strong demands are being made on the resistance of the fishes, this should not be further reduced by the considerable work of digestion.

These summarized rules are sufficient for the food distribution in the small fishery operation. With larger ponds, an exact plan must be set up to include a division of food for the individual months. It must be noted that in the summer the most food is to be given on account of the higher water temperatures. Besides this the heaviest feeding must be shifted to late summer and autumn, because (1) in the autumn, the fishes are at least twice to twenty times the size they were when planted, and therefore have a higher food requirement; (2) in the spring the fishes must become accustomed to take up natural food, otherwise they would neglect the taking up of natural food. Therefore, they must receive little or no artificial food in the spring.

As a guide for the food distribution for the variously high percentual piece increase as used for yearling and two year carps, the formulation of Walter (1932) is given in Table 22.

Table 22.

The Distribution of the Total Amount of Food in the Carp Pond in Individual Months at Variously High Percentual Piece Increase.

		RATIO OF PIECE WEIGHT AT PLANTING TO WEIGHT AT FISHING OUT AS 1:					
		2	2.5	3	4	10	20
	: May	15	13	11	9	--	--
PERCENTAGES OF THE	: June	20	18	16	14	10	--
TOTAL YEARLY FOOD WEIGHT	: July	25	24	23	21	20	25
TO BE DISTRIBUTED FOR	: August	30	32	33	36	45	50
	: Sept.	10	13	17	20	25	25

Obviously this kind of a plan can never be exactly adhered to, however, it is a guide which gives protection against gross errors. All schematic and rigid summaries are only to bring order in the complexity of production questions of the pond fishery. These plans, however polymorphic they may be, cannot fit into the smallest details and into every special case.

The feeding should most preferably be done in the morning hours, since the work of digestion increases the oxygen requirement of the fishes, and the oxygen content of ponds is as a rule higher during the day than at night. With carps the frequency of feeding has but little influence upon the action of the food. According to the experiments by Walter in 1927, the peak of success was achieved by daily feeding (except Sundays) in which a food quotient of 3.0 was obtained. By feeding three times a week the quotient was 3.4 with twice weekly 3.3, with once weekly 3.6. According to the expenditure of time and labor caused by the feeding, therefore, a three times weekly feeding can be more profitable than a six times weekly feeding. The question must be decided for each case. A similar series of experiments by Walter in the following year, shows how very much more powerful other unbounded and non-regulatable factors are then the method of food distribution, from which it may be concluded that other factors are so strong that the weekly food distribution is indifferent in comparison.

Since carps and tench--hardly according to nature--only accept food when it is offered very conveniently, the food is poured in heaps in the pond. Four food places per hectar are arranged well distributed so that smaller fishes are not crowded away from food and so that, on the other hand, the fishes are repeatedly directed to the natural nutrition.

The food places must be easily supervised and on firm not muddy ground. They are to be changed repeatedly so that no putrid spots occur. The food places are marked by inserting poles which project above the water surface, and in some cases they are provided with brush roofs to protect against the inroads of ducks. The use of horizontal wooden food tables on the pond floor, whose rim is surrounded by a high standing lath, is both expensive and superfluous. It has even been frequently observed that the hard wooden base is unpleasant and injurious to the soft fish mouth.

The food is carried to the food places by means of a flat food boat, which is filled from food stalls erected at large ponds or from the soaking box (Fig. 41).

A change of food should never be sudden, or the fish will easily refuse the new food. This disadvantage may be avoided by a gradual change.

Fig. 41. Food boat for the distribution of food at the food places in the carp pond. The boat is built light and flat, and it contains a middle section for lupines. In the foreground is a box for the soaking of lupines. (From the picture archive of the Prussian Agricultural Institution for Fishery in Berlin-Friedrichshagen).

2. Trout Feeding.

Trout take up food before it sinks to the bottom of the pond. Since trout exist upon feeding practically altogether, it is far more easy to calculate their necessary rations. On the other hand, their feeding requires greater care than is the case with carp and tench. It must be done more often and more regularly.

The amount of food may be determined most simply by feeding each time so long as the trout take up the food well. From the calculation of food requirement, it may be assumed in feeding fingerlings at a water temperature of 10 to 15°C, that the daily food requirement per pond is about 5 percent of the total weight of fish present in the pond. The "daily food weight" (the food percent) amounts to about 5 percent of the weight of the fish to be fed. The weight of fish in a pond can be estimated by a sample catch, determination of the average piece weight and multiplication by the number of stock.

The given value of the daily food weight is naturally of only approximate size. The daily food weight is largely dependent on the temperature, the size of fishes to be fed, and the kind of food.

When feeding with fish food, fingerlings of rainbow trout, at different temperatures require about the following rations:

at 5 degrees centigrade	about	2 % of their weight.
at 7 to 10 degrees centigrade	"	3 % to 5% of their weight.
at 10 to 15 degrees centigrade	"	5 % to 7 % of their weight.
at 15 to 18 degrees centigrade	"	7 % to 8 " of their weight.

According to Cornelius, rainbow trout reach the maximum of their food requirements at a temperature of 19 degrees centigrade.

For rainbow trout broodlings under 0.5 gram weight, Cornelius calculated their food requirements as follows:

At a temperature of 13 degrees, when feeding spleen ... 16 % of their weight.
At a temperature of 13 degrees, when feeding daphnae .. 22 % of their weight.
At a temperature of 17 degrees, when feeding daphnae .. 38 % of their weight.

It follows that the smaller the trout (to be fed) are, the greater must be the daily weight of food measured out.

With regard to the kind of food, Cornelius found that fingerlings of rainbow trout require the following rations:

At a temperature of 10 degrees centigrade, feeding upon whiting---- 4.2 % of their own weight.
At a temperature of 14.1 degrees centigrade, feeding upon spleen--- 10 % of their own weight.
At a temperature of 9.2 degrees centigrade, feeding upon Gammarus--- 3.7 % of their own weight.
At a temperature of 9.3 degrees centigrade, feeding upon Chironomus--- 7.4 % of their own weight.

The total amount of food for a pond within a definite time period is to be calculated similarly as with carps by multiplication of the estimated total increase in this time, by the food quotient of the food given. The distribution of the total amount of food during individual months in the normal growing of one year fingerlings into table trout, is somewhat as follows:

March	1%	June	15%	September	17%
April	4%	July	16%	October	14%
May	7%	August	18%	November	10%

It must be remembered that the temperature differences in the trout pond in the course of the year are not so great as a rule as they are in the carp pond and that the "daily food weights" diminish somewhat with the growing up.

During the first few weeks, trout broodlings should be fed four times daily, at least. Older trout are fed from 2 to 4 times daily, according to the amount of food given at each feeding. During the cold season, it is at times sufficient to feed just once per day, or feeding may be temporarily suspended. In contrast to carps, a not inconsiderable growth increase can also be achieved with trout in the winter.

In case of digestive disorders or excessive losses, feeding has to be stopped immediately for a week, or even for from 2 to 3 weeks. Variety in the food shows good results. Sudden changes in the diet are to be strictly avoided. If such changes become nece sary, the fish are to be accustomed to it gradually.

In a test, made at the hatcheries at Eberswalde, increase in weight and growth came to a sudden stop by changing abruptly from a spleen diet to a diet of liver. The growth curve of this brood was at a standstill for 5 days, while the control fishes kept on spleen showed a curve which increased steadily.

It is a fundamental rule in trout feeding that the fish must be fed until their appetites are fully satiated. The faster they grow--at a certain temperature--the less food goes for strict sustenance and the more goes for increase, the more favorable is the food quotient.

"Forced fattening" in trout culture is the cheapest routine, after all, provided it does not interfere with a good general health. Inferior food and long continued sameness of diet may be injurious to good health. Well-fed trout, just like well-fed carp, are distinguished by a well rounded-out high back. This is.especially the case with rainbow trout. Naturally nourished fingerlings are as a rule, slimmer than strongly fed ones.

The brood can be given food by two different methods whether they are nursery fed in the brood house or fed in the pond. The food mash can be spread on the rough top surfaces of flower pots which are then placed inverted on sticks under water in the ponds or they can be hung on a wire in the brood troughs, or the food mash can be conveyed into the water by means of sieve boxes (see Fig. 42) briefly placed on the water surface. There it must.be at once taken up by the brood. The sieve box is a simple small box, the bottom of which is spanned by perforated metal or with wire screen (see Fig. 13). In the nursery feeding with spleen of brood capable of eating, a sieve with 1 millimeter mesh or perforations may be selected. The spleen which has been scraped from the membranes is forcibly rubbed through the sieve if necessary. The food thereby reaches the water finely divided and clouds it for a short time, which is very favorable for the intake of food.

In feeding with the help of flower pots, two sets of pots must be available, of which one set must alternately be cleaned and placed on the pond dams to dry, while the other set with the food is under the water. The fishes become easily accustomed to this method of feeding. When they are hungry it has often been observed that the flower pot has been emptied in a very few minutes. Many fish growers maintain, that the feeding out of flower pots expedites the development of strong size differences among the brood. The number of flower pots in a pond must therefore not be too small.

The first nursery feeding often causes several difficulties. It succeeds best if the food mash (spleen) is rubbed through a fine hair sieve into the water, especially in the inflow. The brood troughs in the brood house must, from this time on, be set to receive as much light as possible. They must no longer be covered. Food rests which have sunk to the bottom must be regularly removed from the brood box shortly after the feeding. Brook trout as a rule are at first particularly poor feeders, but once accustomed to artificial feeding, they later become remarkably lively.

Larger trout are simply fed with the aid of a food scoop (see Fig. 43). The trout learn very quickly to take up food and come swimming to the surface with lively motions when the feeder approaches (see Fig. 43). The food is taken in almost entirely on its way from the surface to the pond bottom. Entirely blind trout seek their food to a large extent from the bottom. It has been recommended frequently to have a few carp or tench in the pond to keep the bottom free of food residues. These fish, however, cause cloudiness in the water by wallowing on the bottom and make the fishing out more difficult. The planting of "side line" fishes has therefore recently become unpopular.

In any case in trout feeding the food should be very well distributed upon the pond surface or in the brood box so that the weaker trout are not crowded away from food by the stronger ones. It should be mentioned again that the brood ponds and more especially the "mast ponds" in intensive feeding management must not be too small and that the food utilization is good only in the correctly stocked pond. On the one hand, there must be enough fishes in the pond so that a certain competition over the food increases the food intake, and on the other hand, there must not be so many fishes on hand that the space factor complex and perhaps also the share of natural food becomes unfavorable for the individual fish.

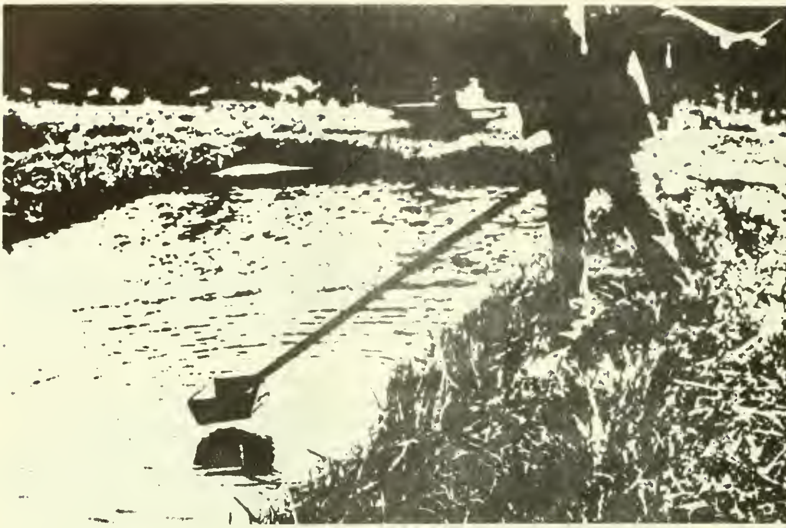

Fig. 42. Feeding of Trout Broodlings by means of a pole-handled box with a sieve bottom.

Fig. 43. Feeding of Trout Fingerlings.

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Chapter VIII

CARE OF PONDS

A. Objects and Methods of Pond Care.

Aside from the rationally planned stock regulation and the artificial feeding, the care of ponds is the most important means for the intensification of the pond industry, and is indeed predominantly for the increasing of natural growth in natural carp and trout ponds. In the main, the care of ponds has three tasks:

(1) Proper maintenance and improvement of the pond with regard to construction and spaciousness, that is, maintenance of dams, elimination and prevention of shallows, etc.

(2) Creation of non-objectionable environments from the viewpoint of hyginene, that is, improvement of the oxygen content, prophylactic and destructive measures against disease and disease carriers in the pond.

(3) Increasing of productivity by definitely aimed control in the metabolic cycle in the pond to gain more favorable conditions for the strongest possible development and utilization of fish food animals.

These three main objects are always closely interwoven and often react upon one another. A technical mode of action is often successful in two, three, or more directions. Liming, for instance, will not only destroy disease germs and food competitors, but will also bring about a most favorable alkaline reaction, which is important from the viewpoints of hygiene and production. Liming also introduces into the ponds certain necessary aliments, to wit: calcium and carbonic acid, which in turn stimulate the aquatic life of the ponds. A separation of the various methods of pond care, in the sense of their action, is not practical. Therefore in the following, the various methods of pond care are arranged in groups and discussed in succession and at the same time the varied activities of these methods, which are at once obvious on the basis of already discussed production-biological fundamentals, are pointed out.

The most important tasks in the proper care of ponds are:

Improvements in construction.
Improvement of the soil.
Clearing of the ponds from rushes and weeds.
Clearing of the banks.
Improvement of the oxygen content.
Liming and fertilizing.

B. Maintenance of Pond Arrangements.

It really remains to be pointed out, that pond arrangements must be continually kept in order. Immediately after the fishing out, the fish trenches in the pond are to be cleaned out, newly formed cavities are to be drained off or eliminated, floating islands are to be anchored down by pouring on sand, loam or similar material. For ditch cleaning, simple ditch scrapers (firm wooden boxes having one front wall removed) are often used. They are drawn through the slimy ditches by draught animals. Also the dams must be continually controlled and kept in order. Wherever the crown of the dam is too close to the water surface, the dam is to be subsequently raised. With too low a dam crown, leaping trout too easily land upon the crown and cannot get back in the pond. The same happens when plants on the dam crown are not mowed off regularly. Paths made by animals must at once be dug up and obliterated as they can easily cause dam breaks. Smaller fissures in dams may be plugged with sand bags and temporarily repaired. In case of water seepage on account of the presence of alluvial sand, etc., it may be attempted to tighten the dam by coating the inside with a sawdust sludge or worked up clay. Seepage at the sluice box must be eliminated with particular care.

The sluices themselves must be continually repaired. With sluices made of masonry or of concrete, any fissures occurring after draining must at once be carefully plastered so that they will not be split apart by penetrating and freezing water at these places. Inflow ditches and shunting ditches are of course to be cleaned regularly, the shut-off arrangements must be cleansed and maintained in condition.

All trees and shrubs whose settlement upon pond dams has not been prevented, must furthermore be kept away. The south side in particular must remain free of all shade giving trees. Every unnecessary shading of pond dams is bad, unless it is concerned with maintaining coolness in trout ponds by shading. With carp spawning and nursing ponds, trees are often necessary for protection against wind but they must not shade the ponds. It has been previously shown that light and heat form the foundation of all production and that these factors are not available in excessive strength in Central Europe.

C. Aeration of the Water for Oxygen Enrichment.

Oxygen enrichment in the water is necessary mainly in trout fisheries, where a high oxygen content in the water must be continually promoted and where water in an almost oxygen free state has just left the spring and must at once flow into the ponds. It is also an advantage to introduce an aeration device when the water is to flow through a series of several ponds. Where there is a high content of iron it can be precipitated out by aeration and in some cases by simultaneous liming. In accordance with natural conditions the oxygen enrichment should take place before the water enters the pond.

The aeration may be practically accomplished in three ways. The most natural way is to plant the water inlet with overwater plants, such as water cress, swamp cress, bitter cress, brooklime (Veronica beccabunga), water-speedwell (Veronica anagallis), water mints (Mentha aquatica), etc. The plants divide the streaming water and bring it into better contact with air and at the same time considerably enrich its oxygen content by their own production of oxygen. In deeper inlets it is very advisable to have an abundant growth of oxygen-producing under-water plants.

Secondly, an enlargement of the contact surface between air and water, which serves for better oxygen absorption from the air, may be produced by adding turns, or if possible, water falls (masoned steps, etc.) in the water inlet. Thirdly, water dispersing water wheels may be installed under the inflows in the pond itself. (These wheels may be gotten from Poetzschke, Pond Estate Bräke at Iserlohn in Westphalia.) Similar results are achieved by building in horizontal sieves or boards under the inflow. They likewise disperse the water and provide intimate agitation of water and air. These arrangements also prevent trout from leaping into the inlets.

Serving indirectly the oxygen enrichment in the carp pond, are all measures which decrease the amounts of putrefiable organic substance on the pond bottom or in the pond water (bottom-cultivation, liming), which provide better illumination (elimination of excessive plant growth and of trees, or which provide better growth of green submerged plants (fertilization). Several methods for the increasing of the oxygen content, which are concerned with hibernation only, are discussed in Chapter X.

D. Removal of Undersirable and Excessive Plant Growth in the Pond.

The removal of production-biologically injurious plant growth in the pond includes both submerged weeds and above surface plants. The latter group includes not only reeds but also the total above-water vegetation or "hardy flora".

The positive and negative significance of the water plants for the metabolic cycle in the pond, has been already discussed. The complete or partial removal of the plants has the purpose of permitting the least possible reaction of negative factors in favor of production biological positive values. The conquest of plants therefore represents interference in the result of the life processes in the pond. It will clear the way for the cycle of the substances which will lead to the highest possible production of fish animal-food. At the same time the removal of excessive plant growth wherever it is necessary makes the natural food production better available to the fishes. The maintenance of the pond and of the health of the pond fishes are not less important tasks of reed and weed removal. Experiments in Wielenbach in 1924 have shown that by the removal of above-water plants the yields of fertilized ponds were on the average about 56.4 kilograms per hectare higher than in un-mowed ponds, which had an average natural growth of 136.8 kilograms per hectare. Roessler announces, that in Crna Mlaka, the yields in fertilized mowed-out ponds in 1928 were about 79 percent, in 1930 about 56.8 percent higher than in fertilized comparison ponds which were not mowed out.

For the immediate removal of above-water plants they should be mowed regularly and closely above the pond bottom. This is undertaken in the period from the beginning of May or June to the beginning of August and at least three times a year if possible. Unfortunately there are no more exact investigations available upon the various reactions of cutting of the many kinds of water plants in consideration, upon the various actions of cutting above or just below the water surface or on the pond floor, and upon the variable action in individual months. These kinds of important investigations should actually form the foundation of all plant control methods in the pond. The question of plant control in the pond has all along been treated in a too strongly generalized way. I have observed from experiments that many plants in certain stages can least endure a cutting above water. Heyking announces that the most sensitive places are 25 centimeters below the water surface. Practical experiences finally have shown that cutting at the ground almost always works best. Besides it is repeatedly shown that reeds especially must be mowed three times if possible (the first time in the beginning of May) for lasting shortness and for the most complete destruction. Reeds suffer greatly even from one mowing in the beginning of August. Sedges, if the cutting is to be successful, must be mowed as early as the beginning of June. With most above-water plants another cutting after mid-July should not be omitted, because cutting immediately before blooming is frequently most effective. With earlier cutting the plants always grow again. Of course, the second cutting is thereby made easier. Besides this, the earlier cutting should not be spared, because otherwise the damage from the above-water plants lasts too long. From August onward, if the reed was not mowed previously, it becomes very woody; late mowing becomes expensive. Unfortunately, where agriculture and pond culture are interwoven, the harvesting work often hinders a July cutting. Furthermore, the destruction of above-water plants is in part also the task of ground cultivation. The regular cutting, however, is by far the cheapest manner of attack. The restoration of strongly reeded and deposited ponds is expensive and most unprofitable as the war period has shown. Regarding the influence of pond depth upon reed formation, compare Chapter 1, E, 4.

The mowed above-water plants may be left lying in the pond, provided they are not too rich in cellulose and that there is no danger of gill rot disease or oxygen impoverishment. The layering of the mowed material upon the reed stubble favors its further destruction and delays the after growth of the reeds. Kisker announces that experiments by Alm have shown that a thirty day shading in June and July causes reeds, water plantains (Alisma), and green algae to perish completely. If the mowed off above-water plants are to be taken out, which naturally causes expense, it is best to carry them to a suitable location and then pile in heaps on the bank or, better still, right in the pond. The heaps, which can still be formed in the autumn, may be layered throughout with lime as is customary with compost heaps.

In the removal of excessive amounts of under-water plants, which primarily serves to combat all too strong shade formation, it is obviously necessary to pull out the mowed weeds.

The implements and machines for cutting above-water and under-water plants will now be discussed in the following.

One of the simplest though most important of implements, is still the hand scythe. For reed cutting, it must be selected not too long and not too narrow, so it will tend from its own weight to lie well on the bottom. There should be a larger space between the neck and blade of the scythe to prevent repeated gathering and wedging of above-water plants from retarding the mowing. The plants are cut off mainly by short jerky movements toward the mower. The scythe is the cheapest and most endurable implement for smaller fisheries and besides it is best adaptable to special conditions of the bottom and shore. The mowers go into the water with water boots or rubber trousers. There are usually no difficulties because the over-water plants occur mostly in shallow parts of the ponds. When the mowers have waded with naked legs for longer periods in summer, there is frequently noticeable an itching eruption which is probably due to the action of hydrophyllous plants, expecially the blue-green algae.

The Roessing jointed scythe, according to my experience, has almost always given the best results, next to the simple hand scythe for reed cutting in ponds. It consists of individual scythe blades 50 to 80 centimeters long, which are similar to the usual scythe and may be used sharply ground or also sharpened by hammering and grinding. The blades are uniformly wide (9 to 12 cm.), rounded on the ends and each end is provided with a hole (see Fig. 44). They can be fastened together in any number desired (mostly 5 to 10 blades), by means of screw bolts or rivets, and in any desired degree of mobility. Chains or ropes are attached to the ends (sometimes to riveted-on draught hooks or rings) and connect the scythe to a transverse wooden grip. Single parts of every form, size and weight may be had from the above mentioned firms. The Cronenberg firm furnishes a finished Roessing Jointed Scythe with draught chains and weighting spheres, under the name of "Sophienhammer's Universal Reed-Scythe". The weighting spheres are superfluous and even hindering if the individual blades are worked sufficiently heavy.

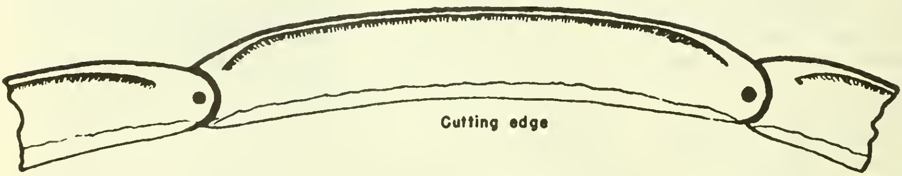

Fig. 44. Single blade of a Roessing jointed scythe. Length about 50-80 cm.; 5 to 10 blades may be joined together according to requirement.
"Rucken" = back. "Schneide" = cutting edge.

Fig. 45. Mowing of Over-Water Plants with the Roessing jointed scythe from two boats. The raised mounting of the connecting pole toward the front facilitates the penetration into the stands of over-water plants.

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The jointed Scythe is operated by two people, in water boots or rubber trousers, standing in the water, who pull the scythe from side to side and forward. Its great advantage is its firmness and its automatic maintenance of position on the ground provided the links are correctly, that is, sufficiently heavily and broadly worked. The Roessing scythe chain therefore always cut the plants closely above the roots, which is generally regarded as very essential, and which cannot be done by any other appliance, excepting perhaps the hand scythe, in so safe a manner.

Where the water is too deep or too cold, the cutting can be done from two boats firmly bound to each other, but this requires two more men for poling the boats. The work is therefore more quickly accomplished. In order to facilitate the difficult pole work into the reeds, it is recommended to combine and use the boats as shown in Fig. 45. In Poland it is customary to couple three boats in a similar way, and have them drawn by oxen and using six men with three Roessing scythes for the cutting. Blohm and von Rochow (according to Walter, 1922) have constructed contrivances for the reeling forward of two firmly bound boats.

Ever increasing efforts to operate Roessing chain scythes by hand or motor drive apparatus proves the great value of these scythes. A simple apparatus of this kind is that of Rochow. A 3.5 to 4 meter long cross beam rests on the tip of a 4 meter length boat. The mid-point of the crossbeam is attached to a pin fastened to a plank, so the beam is turnable. On the ends of the cross beam hang the draught lines of the Roessing chain scythe which trails behind the boat. In the center of the cross beam there is firmly fastened a longitudinal beam of 2 to 2.5 meter length which extends into the boat, so that a T-shaped lever apparatus is formed. The jointed scythe is operated by the sidewise back and forth movement of this longitudinal beam. The man who carries out this motion, sits on a bench in the center of the boat. A second man standing in the rear of the boat poles the boat with cross beam in front into the eeds. The apparatus is suitable only for cutting loose stands of over-water plants, since the boat must unfortunately ride over plants which have not yet been cut. Besides this the back and forth motion of the lever is quite strenuous. A further disadvantage is that stumps, reed residues, and other obstacles on the bottom retard the cutting. According to von Rochow the performance amounts to 2 to 2.5 hectares (5 to 6 acres) of pond surface in one day. A fundamentally similar machine was the "Harald", which also cut with the Roessing scythe, but it has not been further introduced.

The advantages of the Roessing scythe, and also many disadvantages of the Rochow apparatus are combined in the Oco Motor-Reedcutting Machine (obtainable from the Nickel Co., in Niesky, Lower Lusatia). In spite of this, it has become well established in pond culture. The forward motion is produced by two paddle wheels on the sides of the boat. They are driven by a strongly vibrating 10 horse-power benzol motor, and are so constructed that they bring the boat over still unmowed reeds, without danger of tangling the wheels. Oblique backward directed poles on each side of the boat, both of which are alternately moved forward and backward by the same motor, operate the Roessing jointed scythe which trails in the rear and under the boat. The paddle wheels can be rotated independently of each other, whereby an easy steering is made possible. Denser stands of reeds, in spite of this, can hardly be cut close to the bank, because one paddle wheel becomes very much retarded compared to the other, thus preventing steering. According to von Davier, who recently added improvements on the machine, the "Oco" can be operated by one man and mows 4.5 to 5 hectares (11 to 12-1/3 acres) in eight working hours. Von Davier, 1929, figured the total costs of the mowing at 8.40 marks per hectare (81 cents per acre). The machine is built in two sizes and is quite lightly constructed. Its weight amounts to 800 to 1400 kilograms (1,760 to 3,080 pounds). The depth drautht is very small; the machine operated unrestrictedly in a water depth of 30 to 35 centimeters (11.4 to 13.77 inches).

The Dreilich reed scythe consists of two ordinary scythe blades welded together into a half moon and attached at the welded joint to the end of a lever which dips into the water. Mostly two levers are placed on two boats as may be seen in Fig. 46. Both people must mow in unison and must change off with the polers who have a more arduous task. A combination of three boats with two pole men and three mowers, as Mehring states, is therefore also suitable only if cutting is done regularly and if the not too strongly developed above-water plants do not too greatly impede the poling. According to von

Davier, apparatuses with two scythes mow from two to three hectares (5 to 7.4 acres) per day, according to the density of the vegetation stand.

Fig. 46. The Mowing of water plants with the Drailich reed scythe. The lever arms, on whose ends are the half-moon shaped scythe blades, are moved from side to side in unison.

The Ziemson angle scythe consists of two long blades, firmly united in V-formation, whose outer edges cut the reeds. For pulling them a boat hitched to a horse or to oxen, or a boat with paddle wheels, etc., may be used. The angle blade is especially suitable for the cutting of paths and for cutting in ditches, since the working width is not all too great. Resistances may cause bending.

The Ziemsen weed saw is in fact essentially a weed saw, for the reason that in the cutting of firmer plants it easily tears through. It consists of a steel band, about 0.75 millimeters thick and provided with saw teeth on both edges, which can be weighted by spindle-shaped weights. With a length of 30 to 40 meters (98 to 131 feet) the weed saw will lie well on the bottom also without weights. The saw band is easily distorted in itself. It must be at least 10 meters (32.8 feet) long, but on the other hand, it must not be selected too long since drawing it back and forth under water causes too great a power strain.

Reed mowing machines with comb cutters, which like grain mowers are provided with shear-like taloned cutting beams, have in recent years been constructed in many forms. Probably all the systems cut in front; with the exception of the Ifland Motor reed mowing machine which, according to Lietmann, cuts on the left side.

The Three Star of the firm Paulsen and Co. in Vetschau is probably the oldest German manufacture. It was originally provided for hand operation. The newest model, which is furnished in two sizes, has an 8 horsepower motor, which drives not only the cutting arrangement, but also the paddle wheels (individually) which are now placed in the rear. Therewith, the theoretically correct principle: Front cutting arrangement, rear drive, has been carried out for the first time (Fig. 47). Naturally the machine is relatively heavy and suitable only for larger fisheries. The width of the cutting comb is 2.5 meters (8 feet, 2 inches). A disadvantage of all machines with the comb system is still, that the cutting arrangement, which in the Three Star can be sunk up to 1 meter (3 feet) below the water surface, must be continually readjusted as it does not automatically adjust itself to correspond to the momentary pond depth. A fault of the Three Star and other machines is the attachment of the comb on two side beams in whose angles the reeds very easily become firmly lodged. Generally the reeds very easily pile up in front. In spite of a recently added protection basket, the Three Star requires a man to continually remove reeds. Thus the machine requires the services of three men.

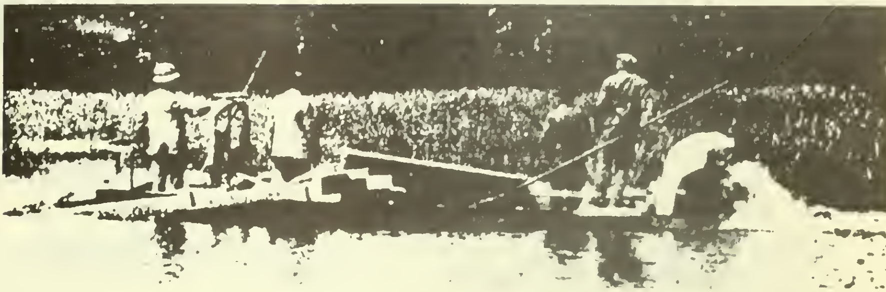

Fig. 47. Three Star reed mowing machine (Model of 1930). To the left at the front end are the movable oblique beams, between which and under water the mowing comb is located. In the center, the motor, right at rear end the paddle wheels and rudder.

The fastening of the cutting beam to a central lever and the attachment of a vertical cutting arrangement as is to be found on almost all French machines, according to Roehler, is perhaps a forward step for the future. These vertical finger beams which are attached both in front and behind, cut all cross laid already cut reed stalks in two.

Similar to the Three Star, but more easily transportable and dipping somewhat less, that is, only about 15 centimeters (about 6 inches), is the motored reed mower machine "Master". The Master according to its size is provided with a 12 or 6 horsepower D.K.W. gasoline motor or with a crude oil motor. According to statements of the manufacturer it cuts about 4 hectares (about 10 acres) a day, the total costs per hectare mowing work amounting to 1.2 marks (11 1/2 cents per acre).

The French machines are furnished with two wheeled carts which can be run into the water and under the machines. Such an arrangement is extremely valuable, as the apparatus can be quickly transported from one pond to another.

To be finally mentioned are the Dr. Engel reed cutting machines which have not been introduced to a larger extent, and which (according to Nanz) have a lateral back and forth moving knife, and the Frank reed roller which, according to Blohm, serves to break the reed stalks.

The driving in of cattle is likewise a good way to eliminate over-water plants, since the animals trample the roots and eat the stalks. In larger fisheries the application of that sort of remedy is mostly unimportant.

An elimination of filamentous algae, which can be of importance in trout ponds, is only practicable by pulling them out by using rakes, linen weighted with stones, or nets, etc. Unfortunately the effect lasts only for eight to fourteen days. The combating of algae with copper sulphate, should have a concentration varying from 1:10,000 to 1:5,000,000, according to the species of algae. Ebeling (according to Czensny) however, found that a dilution of 1:2,000,000 (0.5 milligrams of copper sulphate per liter) reacts fatally on rainbow trout. The solutions must at least not be left in the pond unchanged for any length of time. Injuries to the trout would be unavoidable. Carps are far more resistant.

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Also all other control methods suggested up to now, such as fertilizing with liquid manure, shading by boards or ash (trees), liming with 10 to 20 percent milk of lime shortly before water covering have their great faults and often even contrary action. It may, however, be said that clear water, especially spring water, and prolonged water coverage favor the development of the filamentous algae. As in every combat against water plants, it must not be forgotten with the filamentous algae, that only an excess is injurious and to be removed. In every plant development in the pond, the measure of occurrence primarily determines the usefulness or injury.

E. Drainage and Cultivation of the Pond Bottom.

Rational care of the pond bottom aims to ameliorate its biological processes and to "interfere" in the metabolic cycle of the pond from the viewpoint of better productivity, that is, a possible and desired increase in profits. Bottom culture chiefly aims:

(1) To create a fertile, fine-colloidal and absorptive organic mud, leading to a gradual reduction, that is, mineralization of all excess mud, especially of the indigestible cellulose mud.

(2) To destroy the web of roots of surface plants, which cover the bottom and which form a blind alley to the normal course of the metabolic cycle.

The conditions named in (1) can easily be achieved through drainage of the pond and exposure to winter frost. This will lead to a gradual mineralization of the accumulated layers of mud and an amelioration of same along the lines, mentioned previously and following.

Spading and ploughing of the top layers of the bottom will aid the process still further.

Unfortunately the aims in (1) and (2) may not always be achieved by one and the same method of soil cultivation. The destruction of surface plants, for instance, requires deep ploughing which will of course bring about the ploughing under of the fertile, upper layers of the mud, while the sterile, inert mud of greater depth will be brought to the surface. The achievement of the first aim meanwhile permits only the cultivation of the uppermost active pond-bottom layers which are often extraordinarily thin. Otherwise the soil cultivation as such could not be worked out valuably in a production-biological sense.

Finally, the care of the pond bottom also has a third aim: the providing of good hygienic conditions. By means of the draining, disease germs and infected intermediate hosts of disease instigators resting upon the bottom should be destroyed. The reduction of gradually accumulating masses of mud in fertile or reed infested ponds decreases the possibilities for the occurrence of diseases. In the trout-feeding pond their viewpoints even step exclusively into the foreground.

The draining of the pond bottom, which is comparable to fallowness, takes place today only in the winter until March or April or with brood ponds even up to July. This is spoken of as "wintering". The draining during the summer also called "summering", is customary in only very few fish industries. There are, however, individual, often large industries, which every year alternately "summer" approximately 50 percent of their ponds. Or a pond in the first year is covered in spring, planted in the second year with lupine which is turned under in blossom in July as the pond is then to be used as a "brood nursery pond". In the third year potatoes or oats are planted and harvested, that is, the "summering" is done throughout the summer. With this crop rotation, the total yields according to experience are often higher than by flooding over every year. By means of the agricultural utilization, the suppression of weeds is of especial advantage. In a Holland pond industry, the ponds after a utilization of seven years, are then planted in one year with oats, and in the next with clover, whereby very good yields of oats and clover are obtained, and the ponds are simultaneously considerably improved. After the "summering" the ponds are first used for brood nursery ponds. In the regular wintering of the ponds also, especially of nursery and brood growing ponds, it is to be recommended to cultivate the pond bottom and plant it with mixtures of oats, also rye and barley, etc. The plants, especially the deep rooted ones, contribute to better drying out of the soil and promote the course of bacterial decomposition processes in the soil. A crop or a soil fertilization can be achieved at the same time. The yields by soil fertilization alone--immaterial whether the plants are left standing or turned under--are considerably increased. Thereby there are conditions similar to those of new water coverage. The experiments in Sachsenhausen according to Czensny and Wundsch, have shown, however, that the total special growth was about 43.2 percent better in the first time covered ponds than in the twice covered ponds if no fertilizing was done and about 88.1 percent better with full fertilization. It must, however, be pointed out that Schiemenz and Zuntz have taken up the opinion, which was later again adopted by Nordquist, that it is not advisable to regularly drain the ponds over the winter, because great numbers of nutrition-animals are caused to perish.

Regarding the prospective success and usefulness of a soil cultimation, it is shown from what has been said, that soil cultivation must be profitable in the first place with very strongly reeded soils, and in the second place with "thickly humus-layered" soils, and therefore with fertile ponds. With poorer and average ponds, soil cultivation even if it is merely tearing up the soil, can be even injurious, which Demoll very correctly emphasizes. If the soil cultivation combines tillage and a relatively prolonged drainage, it is naturally profitable on poorer soils. In the operation of carp pond industries in full activity, it should be seen too, that the soil cultivation, aside from reed control purposes, should be regularly applied above all to ponds which are to be used for growing of brood to one-summer fingerlings. Only after this do other ponds come in line for consideration, and first of course, those with the most fertile soils.

The soil cultivation may be started as soon as the pond bottom is sufficiently dried out and firm. This is unfortunately often not the case until spring. I shall name the plow as the first implement for soil cultivation. Multiple plows, moor plows, special motor attachment plows, and others are in use. For pulling wheel tractors, caterpillar tractors (chain tractors), also oxen and horses, may be used (see Fig. 48 and 49). Moor tilting-plows, which are drawn back and forth by tractors with rope winches, are very usable, according to Gennerich (1932).

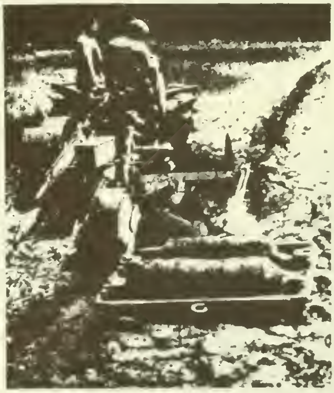

Fig. 48. Standard plowing up of a carp-brood nursery pond with a single shared motor tractor plow. A wheel tractor serves for pulling. The clods are turned about 180° and pressed down by an attached annular roller.

Fig. 49. Poor plowing up of a pond bottom. The clods, consisting of the root systems of above-water plants, are turned only about 90°. They grow out again later. An after-treatment with the cutter is therefore desirable. The plow is here drawn by a caterpillar tractor.

Plows are especially suitable for the destruction of the above-water plants when a not exactly very fertile subsoil is available. It is desirable here that the clods are **cleanly** turned over about 180° and then somewhat pressed down if necessary by an attached annulated roller (see Fig. 48). Only then will the regrowth of the roots be thoroughly prevented for about two years. Clods (see Fig. 49) raised only 90° which in strongly reeded ponds consist entirely of reeded root systems, readily sprout forth again. Their unevenness also retards the reed mowing which should shortly follow the soil cultivation. A lodgement of mud layers plays no part in ponds with root systems of reeds, since mud occurring between above-water plants is hardly usable, and finally a clean sandy bottom is always more favorable than a hopelessly reeded pond. Therefore in reed control work, the ploughing may be done deeper (to 25 cm. = 10 inches) with confidence, even though deep plowing in general is to be anxiously avoided.

Where the soil is not covered by a firm continuous layer of root systems of above-water plants, grubbers, harrows with spring tines or comma tines, and disk harrows are of much greater advantage than the plow. Also the tearing and cutting of thinner plant covers, loosening and breaking up the soil and mixing the ingredients should be done without carrying the valuable top layer of soil into the depths.

In the regular care of well cultivated ponds such as carp brood-nursing ponds, brood growing ponds, winter ponds, and natural trout ponds the use of the disk harrow is in order. Unfortunately the working breadth of many valuable implements such as the disk harrow is not very large. It can be broadened by coupling several implements.

The rotary cultivator is the soil cultivating implement which also belongs with the future in pond industry. It crumbles the soil very finely, loosens it uniformly and well, breaks up the root covering into the smallest pieces, mixes everything carefully and thoroughly and with the subsoil, and leaves behind it a completely smooth soil, without carrying fertile top layer into the depths or sterile soil to the top. In cases of soft soils, "marsh extensions" on the wheel rims give good services. Lime can be mixed in with the soil during the same work run. In many pond industries, the machine is not well liked, because the hooks and knife claws too frequently break. It should also be mentioned that attempts made in Wielenbach, 1928, to more completely destroy the chopped roots of water plants by strewing on potash, were complete failures.

The Lanz Agricultural Motor with its strong cutters, was shown to be excellently suited to reed destruction. I can abundantly confirm the experiences of Mehring, that pond stretches which were worked by this implement were free of reeds in the next year and were in sharp contrast to unworked parts.

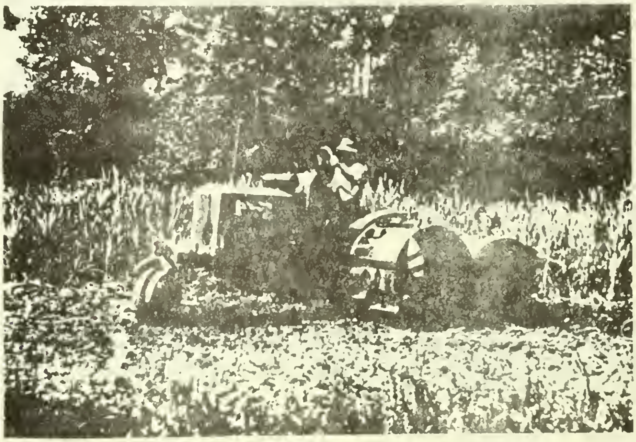

Fig. 50. Siemen large pulverizer in the cultivation of a strongly reeded pond. In the foreground, the finished cultivated, finely chopped, loosened, well mixed and even soil. In the background, still uncultivated strongly reeded pond bottom.

Fig. 51. Siemens small pulverizer in the cultivation of a weakly reeded brood pond. Front, the well pulverized and thoroughly mixed pond bottom in one work round.

The Siemens large and small pulverizers which are provided with claws can destroy the densest plant covers in two working operations (see Fig. 50 and 51). The large pulverizer, whose wheel rims can be provided with "marsh extensions" for soft soiled ponds, and which has a working breadth of 160 centimeters (64 inches), receives first consideration for large industries. The total costs of the pulverization work are said to be about 60.00 marks per hectare (or $5.75 per acre). The Siemens small pulverizer, which is also suited for small industries, has a working breadth of 70 centimeters (28 inches) and a working depth up to 30 centimeters (12 inches) according to selection and the soil character. The surface yield amounts to from 50 to 60 ares (1.23 to 1.48 acres) per hour. I shall finally remark in general that cultivation of the soil and plowing up to a depth of 15-25 centimeters (6 to 10 inches) is mostly correct. On the drained pond bottom, any projecting columnar clumps of above-water plants (see Fig. 20) may be lifted out with a Sacks No. 14 one-shared plow which is drawn by horses. For sawing them at the ground, a Maurer or clump saw, which is operated by four men, is used. It consists of a horizontal lying saw blade with a tension frame about 150 centimeters (5 feet) high, similar to a joiner's buck-saw. Two people guide the frame, two pull back and forth on ropes attached to the base of the frame. In large industries motor saws, very suitable for this purpose, may be used.

F. Liming.

Liming is a means of pond care, which has to serve particularly many different purposes. On the one side it protects the health of fishes in various ways, and on the other side, it increases production by producing favorable production biological conditions, which react to increase the yield.

These various actions are obtained in the following way:

(1) A suitably applied liming kills, by caustic action or by toxic and caustic action, the bottom dwelling, freely swimming stages, resistant stages, eggs, and intermediate stages of parasites living in intermediate hosts (snails), parasite carrying fishes, and also for a brief time algae and water plants without deep roots. In a short time the lime is chemically transformed and becomes harmless to fishes.

(2) The low pH value of acid waters will be raised, through liming to the normal value of slightly alkaline waters. Dissolved and noxious iron will eventually become neutralized and precipitated. The slightly alkaline reaction of pond water (pH value 7 to 8) is:

a. Most favorable to the health of fish.

b. Is absolutely necessary for favorable conditions of the metabolic cycle and of all other measures for an intensified culture.

(3) Liming will raise the acid combining value, A.C.V. This in turn--as long as the A.C. value is greater than 0.5 to 1--will:

a. Prevent extreme changes in the pH value, either upward or downward.

b. Will create a carbonic acid reserve making a carbonic acid minimum impossible; (as accepted by Zuntz 1913 and later by Czensny).

c. Will preserve sufficient Ca as necessary nutrients for plants and aquatics; and for building animal shells, carapaces and other substances.

d. By the presence of enough calcium, any soluble magnesium, sodium and potassium compounds are "detoxicated". Solutions of any one of these salts alone cause distinctly toxic reactions, according to Schumann.

(4) The bottom of the pond is greatly improved through liming. It will lead to speedier decomposition of minerals, to base exchanges and liberation of potash; it will bring about a neutral reaction of the soil and will speed up the decomposition of the soil. Hand in hand with all this goes a greater resistance of the soil against disease promoting bacterial colonies and parasites through lowering the amount of organic substances, necessary for the existence of these pests. Furthermore, the often dangerous amount of oxygen consumption will be greatly lowered through mud elimination.

(5) By liming the water, strong excesses of putrescible organic substances are precipitated and eliminated, as proved by Ebeling's experiments. By this means in times of danger the conditions for the existence of many disease instigators (gill rot instigators) are eliminated. The oxygen content, which is extremely important for the existence of the fishes and also for the fertility, is indirectly increased. The expectations of the practitioner in this respect are of course frequently exaggerated. Ebeling has shown that under conditions usually existing with gill rot, even a liming of 1,425 pounds of quick lime per acre in nine days exerts no appreciable influence on the oxygen content.

It follows from all this that liming is necessary in case of too low pH rate and a low A.C.V. It is also indicated and strongly recommended in cases of very muddy and neglected bottoms, in case of gill diseases during the summer months, when the rate of organic matter is always rather high, i.e. when the $K\ M_n\ O_4$ consumption of potassium permanganate rises over 150 milligrams per liter, and when therefore the oxygen content is low in the morning.

Finally, a thorough liming becomes necessary after the appearance of contagious diseases. Heavily stocked trout ponds are--for hygienic reasons--to be limed regularly after the fishing out, and in such a manner as if disease had been present.

From the fact, that for instance in the pond fishery territory of the Lusatian and Lueneberg districts, the area comprises about 32 percent of the total German pond industry, and from the frequent occurrence of naturally acid water, it is evident how important liming is in regard to the pond industry. All other precautionary measures of fertilization and pond care in such cases are completely useless if liming has not been done first. Induced by the experiences of the author, Reinecker has gathered extensive material in upper Lusatia upon the question -- what significance has liming in the pond industries upon heath and moor soils according to their extent. Among 60 investigated ponds altogether, only two had an A.C.V. of over 2, only three an A.C.V. of over 1, and only eleven ponds an A.C.V. of more than 0.3. Only once was the pH value greater than 7. A yield increasing action of lime dosing cannot be expected in general even in a pond water with a high A.C.V., whose lime content has also not been gradually reduced again by an acid soil with pH values below 6. In such ponds the most that can be achieved by liming is a general soil improving action in heavy and in muddied bottoms, and a disinfecting action. Lime rich ponds with a non-mudded sand bottom therefore come least into consideration for lime fertilization.

Lime is used in the following forms:

(1) Powdered limestone and limestone marl. Powdered limestone contains only calcium carbonate, which as such is almost insoluble in water. The CO_2 of the water will dissolve it, though—within about a month—into $C_a(HCO_3)_2$. Carbonated lime can be used where only acid fixation and an increase of the A.C. value is desired and where fish life is jeopardized through the caustic action of quick lime. (As in winter ponds, especially with ice coverage, and trout ponds). Calcium carbonate is likewise specially used in bottom liming of light pond bottoms for fertilizer purposes. Powdered limestone contains about 90 to 95 percent of C_aCO_3, (100 parts of C_aCO_3 contain only 56 parts of quick lime (C_aO), that is, calcium carbonate will bring only slightly

over half the amount of lime into the water as CaO, than would an equal amount of quick lime.

The finer is the grinding the greater is the solubility. Limestone marl must have 80 percent of the granules under 0.75 mm., fine marl should have 80 percent under 0.3 mm.

(2) Quick lime, burned lime, calcium oxide, as long as it is fresh acts strongly caustic, and deadly when sufficiently concentrated. In the liming of pond water with an A.C.V. (acid combining value) of more than 2, the pH value often rises to 8.5, and temporarily also over 9, but soon sinks again. In the liming of lime poor waters with an A.C.V. of below 1, the pH value even with small additions rises quickly to 10 and more. But here also it sinks down in very few hours. In soil liming, a deadly pH value of over 10 can be reached only by intensive liming of the moist soil. By combining with carbonic acid, quick lime in water quickly changes, just like in the air, into calcium carbonate. This sinks to the bottom and during the course of one ot two months it is to some extent changed into dissolved calcium bicarbonate, $Ca\ (HCO_3)_2$. By withdrawing carbonic acid from the water, the quick lime can cause the precipitation of dissolved lime already in the water, and lead to lowering the A.C.V.

Even though caustic lime tends to bind acids and raise the pH rapidly, yet in its application lime enrichment in the water, the increase of amount of lime present, and of the A.C.V., proceeds more slowly than with calcium carbonate. An advantage of caustic lime over calcium carbonate is that for equal final results, only half the weight needs to be dispersed.

In the control of parasites, disease producers and brood foes in the drained pond and also in the liming of heavy or muddy pond bottoms, and for the precipitation of organic substances in the water, only caustic lime is to be used. The lump lime is more stable than the ground quick lime and therefore has a greater caustic action. But, it can be used only for preparing milk of lime for small ponds. The finely ground caustic lime must not have been long stored or stored in dampness, or else the absorption of carbon dioxide and water from the air, will make it useless for disinfectant purposes. Mixed limes from burned lime and calcium carbonate in various proportions are also in commerce, but offer no advantages in pond culture.

(3) Calcium Cyanamide. This contains 60 to 70 percent of quick lime and 18 to 22 percent of nitrogen. Is not only caustic but also deadly on account of the liberated cyanamide. (This will disappear though, through gradual decomposition into urea, ammonia and nitre.) Still, the effects of cyanamide persist much longer than the caustic effects of the quick lime, which are usually over after 2 or 3 weeks.

On the other hand, I have found that the effects of cyanamide are still noticeable months afterwards, especially in winter. This makes the product especially serviceable for the destruction of unusually resistant disease germs. Still greater care than when employing quick lime must be taken to prevent an outflow from a trout pond, thus treated, into other ponds, stocked with fish.

Liming is so conducted, that either the drained pond bottom is limed, or that pond water is limed from a boat, or the inflow water may be limed. In the control of gill rot and the precipitation of organic substances, naturally the water must be limed. Otherwise in parasite control, the bottom of the pond is to be sprinkled, and likewise for bottom inprovement. In some cases the lime is worked in with the soil pulverizer. In all other cases it is immaterial how the liming is done. In strewing on the bottom or from a boat the distribution must be very thorough. Only finely ground lime must be strewn. No lumps of quick lime must get into the pond. However, in small trout ponds, the bottom can be treated with milk of lime made from lump lime. Bottom liming should be done in autumn if possible. Strong liming with caustic lime immediately before stocking is very dangerous. In the liming of water, 177 pounds of burned lime per acre may be given daily on numerous successive days, without hesitation. Care is advised only with water very poor in lime and containing but little carbonic acid. It is best to control the pH value and keep it below 10.

The quantities of lime to be given in bottom liming against parasites should be at least 2,200 to 3,300 pounds per hectare (887 to 1,330 pounds per acre). These quantities are to be strewn on the wet congested flat bottom. With trout ponds, calcium cyanamide should be used in the proportion of about 4,400 pounds per hectare (1,774 pounds per acre). For regular yearly bottom limings for fertilization, 220 to 880 pounds per hectare (88.7 to 354.3 pounds per acre) of C_aO is sufficient, if we are not dealing with lime poor or acid soil. Larger quantities of lime generally do not harm in the pond. With acid ponds it is often well to provide a safety factor by having a reserve liming.

Figures for calcium poor ponds must be decided in each individual case. The amount of necessary lime in such cases depends quite obviously upon 2 factors: calcium content of the water and calcium content of the bottom, in other words upon the pH rate.

To increase the A.C.V. of the water to 1--desirable in most cases--a liming with 440 pounds per hectare (177 pounds per acre) is usually sufficient. Experience shows, on the other hand, that much larger quantities are necessary since the acids, present in the bottom, must also become neutralized. The pH rate of the upper layers of the bottom soil must be raised to about 6, even to 6.5 if the A.C.V. shall not fall off continuously. Only proper determination of the lime requirements of the bottom can lead to proper estimation of the necessary amounts of lime.

In agriculture, the calcium requirements of any kind of soil are approximately calculated through the pH value. The figures, so obtained may need corrections, according to regional conditions, but I will give some of these figures as evaluated by Trenel.

Table 23.

pH value, measured at the bottom.	Lime requirements (dz. of C_aO per hectare) (1 dz. eq. 220.46 lbs.)		
	heavy clay or loam	loamy sand	sand
more acid than 4	40	20	12.5
4 to 4.5	30	15	12.5
4.5 to 5	25	12.5	10
5 to 5.5	15	10	5
5.5 to 6	10	5	2.5
6 to 6.5	5	5	0

From this chart, the approximate amount of lime--necessary for the soil--can be calculated, provided the pH rate of the soil is known. This amount has then to be added to the amount, necessary for the water (approximately 2 dz, equal 440.92 lbs. per hectare).

Naturally the total lime requirements of a pond can also be determined simply by liming the pond--after shutting off the inflow--until the A.C.V. rate reaches 0.5 to 1 cubic centimeter of nHCl per liter. If especially good returns are desired and fertilization is intended, the A.C.V. should be raised to even 1 to 2 cubic centimeters nHCl per liter. In case of very calcium poor water and soil, the required amount of lime ranges between 10 to 15 dz (887 to 1,330 pounds per acre) of quick line per hectare during summer. (1 dz equal 220.46 pounds), according to Schaeperclaus and Reinecker.

Liming the water inlet saves scattering the lime and is therefore cheaper than scattering on the ground or in the water. The liming of the water inlet is almost indispensable, with acid influxes to winter ponds, trout ponds, etc. A very primitive poorly acting method is simply to throw lime into the inflow ditch. Far more effective on the other hand is the liming of a large pond, from which the improved water is then taken for the winter ponds. The simplest and cheapest in the long run is liming by machine, with the lime mill (see Fig. 52). This kind of lime distributor can be constructed easily in a blacksmith shop, from old bicycle chains, cogwheels, etc. They are now produced clean cut and suitable on the factory scale. The essential part of the lime mill is a funnel (Fig. 52), which has an adjustable slot below. Finely ground lime is filled in at the top. The lime is continually forwarded downward by a stirring device inside the funnel and a tapper device on the outer wall of the funnel both operated by a chain drive from the water wheel. The purchasable machine is furnished with a top or bottom placed wheel. The wheel is set in motion even by a water inflow of 1 liter per second. In one week 110 to 2,200 pounds of lime may be used up, according to the size of the slot and the inflow velocity of the water. The greater the water flow, the more plentiful the automatic liming. An acid combining value (A.C.V.) of 0.5 can easily be increased to a double or threefold value by lime marl as well as by burned lime.

This lime mill has worked very prosperously in exceedingly large numbers of winter ponds having acid inflows. Only with its help has it been possible to rescue wintering fish stock from perishing on account of too low pH values. The value of liming can hardly be correctly expressed in figures. In very many ponds, in fact, commercial operation is only possible after liming.

Fig. 52. Lime distributor for the mechanical liming of water inlets. An under-driven water wheel in the background. In the front, a lime hopper with an adjustable slot in the bottom, stirring arrangement within, and hammering arrangement on the left side. The factory-made liming machines are covered on all sides by sheet metal walls.

In many other cases the conditions are so peculiar that generalizations cannot be deduced from them. Nolte calculated on the basis of purely fertilizing experiments in five very different Prussian carp fisheries, in which 330 to 3,520 pounds of calcium oxide per hectare (133 to 1,425 pounds per acre) were given, that 1 dz (220 pounds) of calcium oxide caused a growth increase of 1.68 kilograms (3.7 pounds) of fish flesh.

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G. Fertilization with Commercial Phosphate, Potash and Nitrogenous Fertilizers.

The artificial fertilization with commercial mineral phosphate, potash and nitrogenous fertilizers has above all the purpose of increasing the utilizable quantities of minimum occurring primitive foodstuffs which in the final analysis control the level of production of fish flesh, as has been shown in Chapter 1. The introduction of fertilizers into the metabolic cycle of the pond increases the natural nutrition of the pond fishes, just like any other of the above-mentioned methods of pond care. At times this occurs by means of growth, at other times by the mass development of plant plankton visible by the clouding and green coloration of the entire water, and this again promotes the nutrition of the flora and bottom fauna. In this way fertilization is especially valuable for the pond industry, for as I repeatedly emphasize, the natural nutrition in the carp fishery is the basis for a profitable feeding. Natural nutrition can never be completely replaced by other foodstuffs. In trout culture the natural nutrition is indispensable for the production of usable spawning trout.

Experiments on the action of artificial fertilizers were principally and almost simultaneously started for this purpose in the experiment stations at Wielenbach and Sachsenhausen. Naturally in spite of this, a great many questions are still unclarified. This is mainly for the reason that further experiments in practical pond fisheries have mostly had to combat extraordinary difficulties.

The water in Wielenbach has an A.C.V. (acid combining value) of about 2.5 to 4 cubic centimeters of N hydrochloric acid per liter, a potash content (K_2O) of 1.5 to 2.2 milligrams per liter and a phosphoric acid (P_2O_5) content of 0.012 to 0.06 milligrams per liter. The soil consists mostly of top layer 20 cm. thick humus soil, under this a 30 to 40 cm. layer of whitish green marl, and then 40 cm. of loam. In Sachsenhausen, an A.C.V. of 2.0 to 2.8 cc of N hydrochloric acid per liter, a potash content of 1.4 to 3.0 milligrams per liter, and a relatively much higher phosphoric acid content, namely 0.25 to 0.8 milligrams per liter was determined in unfertilized pond water. The extremely permeable soil consisted, according to Zuntz, of sand with a thin layer of humus brown pond mud and in greater depths of moor. These special regional soil and water conditions have therefore been taken from the Sachsenhausen and Wielenbach experiments as a basis for conclusions.

The conclusions therefore cannot have a direct general validity from purely theoretical considerations. In the largest German pond fishery districts more or less different conditions are present. Scientific experiments by Jaernefeld have likewise shown that in different quality conditions, one and the same fertilizer combination gives various results. For these reasons the pond manager in considering his own soil and water conditions cannot avoid fertilization experiments if he wishes to determine which main nutritive substances will act favorably in his ponds and call forth a good revenue.

Pond fertilizing experiments must be extremely or critically conducted, even if they serve exclusively practical purposes in one's own fishery. Unfortunately, many experiments have been undertaken without a knowledge of the influence of unequal fish stock density. It is possible that many older experiments could not stand a critical consideration in this direction.

It is fundamentally required in pond fertilization experiments that completely isomorphic and equally fertile ponds which have been operated at least three years, be compared. Simultaneously fertilized and non-fertilized ponds must be available. No feeding must be done. The natural growth increase during several years, if possible, should be known for all experimental ponds. The experiments are to be conducted as simply as possible.

The results of fishing out would best reflect the true fertilization success if all the fishes had equal normal piece growth and equal fishing out weight, which is striven for in practice. If this condition could be fulfilled, a combination of fertilization experiments with feeding could be very instructive.

Such ideal conditions are, however, hardly attainable. For this it would be necessary to have a sure knowledge of the experimental results in advance. Only then could the stock be adequately formed. In order to eliminate every inequality between the experimental ponds and the results of unequal stock densities it must be a prerequisite for every fertilization experiment to have: --equal stock density in all ponds, equal inset piece weight, uniform species, equal hereditary factors of the experimental fishes. Experiments with different stages of stock are not usable. The success of fertilization experiments undertaken according to these rules, of course, does not entirely correspond to what will be obtained later in practice with equal fertilization and increased fish stock density, but in order to have scientific accuracy the lesser evil must be chosen. Demoll and Walter rightly advise that for experimental fishes, at least a part of them should be yearling carps (naturally an equal percentage in each pond) and not two-year carps exclusively. The yearling carps on account of their great growth capacity yield better utilization possibilities.

It is to be observed in fact that fertilization experiments under practical conditions and due in part to disregard of these rules show unsatisfactory results. Frequently there are further, especially secondary appearing factors, which are stronger than all fertilization actions. A descriptive example of this has of late been offered by experiments published by Goepfert, and by many other cases.

The great advantage of fertilization with mineral substances is because it has made possible larger scale fertilizations in the pond also, and from a metabolic physiological viewpoint, only those substances which occur in minimum are added to the metabolic cycle. Naturally, however, the yield cannot be arbitrarily increased by supplying a substance. On the contrary presently a second, third, fourth primitive foodstuff or even the light and heat factors go into minimum. The purpose of the fertilization experiments of the practical pond manager is to make determinations on local conditions in this regard.

Another method to determine the fertilization requirement of the water, is the beaker method of productivity appraisement, which I will mention at least briefly here. Fertilizers of different kinds and of different concentrations are added to various beakers which are filled with water samples inoculated preferably with growing algae. After about 10 to 20 days determinations are made as to the amount of algal growth (important to the metabolic cycle) which has developed on inset glass plates (compare Lundbeck). The glass with the strongest growth development shows the most favorable fertilizer addition. In the beaker appraisement it is to be noted further that, in accordance with Sachsenhausen experiences, potash above all promotes plankton plants. The effect of potash will perhaps be most evident by a general green coloration if there has been a simultaneous inoculation with suspended algae. The glass beaker appraisement is seldom used by the practician.

In the application of fertilizer in Sachsenhausen the most frequent possible fertilization was striven for, in order to continually fill up the foodstuff reserve and to counteract undesirable denitrification when nitrogenous fertilizers were distributed. After it was recognized that the fertilizer is absorbed by the soil (as also taught by agriculture), and from there is gradually given off at places where it is consumed, and that many fertilizers must simultaneously fulfill important functions in nitrogen fixation, in the improvement of bottom mud, and in the decomposition of nutritive substances, it was rightfully required that the fertilizer be given in one dose. This method is also cheaper. The finely divided fertilizer had best be strewn out on the dry pond floor shortly before it is covered with water, or if better distribution is desired it may be distributed from a boat into the water immediately after water coverage. Reeded ponds remain free of fertilizer.

Lining is, as I again emphasize, just like the regular elimination of over-water plants, the most important provisions for a good reaction of the mineral fertilizers dealt with in this chapter. The most profitable fertilization as already stated is always a fertilization with phosphates. This is particularly the case in lime rich ponds with good rotted mud. With clean sandy soil and water rich in combined phosphoric acid, phosphate fertilization reacts just as feebly as liming as an increaser of production. So far as we know today the approximately equivalent fertilizers in preponderant consideration are: Superphosphate containing about 16 to 20 percent water soluble, Rhenania phosphate containing about 25 percent citrate soluble, dicalcium phosphate with about 35 percent citrate soluble plus 2 percent citric acid soluble, and Thomas meal with about 13 to 20 percent citric acid soluble phosphoric acid. The phosphoric acid in Thomas meal is the most difficult soluble, however Thomas meal contains about 40 to 50 percent of calcium oxide. It is therefore especially suitable for acid and for light pond bottoms. Super-phosphate with the most easily soluble phosphoric acid is especially suitable for heavy bottoms. Dicalcium phosphate contains about 28 percent of active lime, Rhenania phosphate about 42 percent calcium oxide, both are intermediate in action between super-phosphate and Thomas meal.

Bone meal and other fertilizers are naturally suitable also. Bone meal of course, acted less favorably than other phosphoric acid fertilizers in Wielenbach. The local price of the fertilizers is frequently the most decisive for the choice of one or another fertilizer.

In Wielenbach, according to Walter, the best results are obtained with 25 to 30 kilograms of pure phosphoric acid per hectare (22 1/4 to 26.7 pounds per acre), in Crna Mlaka, according to Roessler, with 3 dozen per hectare (267 pounds per acre) of super-phosphate. In agriculture similar amounts are distributed and in pond culture practice, I have repeatedly been able to determine that favorable results were obtained with about 2 dozen per hectare (178 pounds per acre) of super-phosphate or Thomas meal. Also according to Nolte, about 30 kilograms P_2O_5 per hectare (26.7 pounds per acre) proved best in the most variable conditions.

With that sort of a fertilization increased yields were attained in Wielenbach of 30 to 100 kilograms per hectare (26.7 to 89 pounds per acre, about 50 to 100 percent, and in Crna Mlaka of 50 to 125 percent. In the last years the effects in Wielenbach were to a large extent weaker than formerly. According to Demoll, the spring weather is very decisive for the phosphate effect. Nolte calculated from 12 fertilization experiments (which however were clouded by many kinds of unfortunate accidents) performed in practical managements, an average increased growth of only 16.4 kilograms per hectare (14.6 pounds per acre). Even then phosphoric acid fertilization still has economical advantages, because 1 kilogram of P_2O_5 produced on the average 0.54 kilogram of fish flesh.

The after-effects of phosphorus fertilization in Wielenbach in the first year after the fertilization amounted to 7 to 100 percent, in the second year to 50 percent. In other localities after-effects up to 170 percent were achieved in the first year. In Sachsenhausen the results with phosphate are less clear, since other specially fundamental and important theoretical problems were worked out there, and the preliminary conditions for a full effect were also manifestly unfavorable.

The indicated amounts of phosphoric acid to be given are to be regarded as "normal" and in like measure as "LEAST-VALUES". With weaker fertilization, the results as a rule are non-relatively much poorer. Stronger doses (50 to 70 kilograms of P_2O_5 per hectare, 44.5 to 62.3 pounds per acre) can of course, still further increase the yields, but the increase is not in any economic ratio to the greater application of fertilizer.

Through-flowing trout ponds, according to experiments by Walter in the years 1924 and 1925, with phosphate fertilization, likewise give increased yields of 50 to 100 percent. With the use of easily soluble super-phosphate, the through current must remain shut off approximately five days until the fertilizer is absorbed by the soil.

Fertilization with potash in Wielenbach like in Sachsenhausen and in many other "average to good" ponds achieved no substantial yield increases. Jaernefeld determined that potash at first retards production, increases later with peat mud, but is not perceptibly effective with rotted mud. In ponds which are poor in potash there are certainly very different conditions on hand than there are in potash rich ponds, as these experiments of Jaernefeld also show. With a low A.C.V. (acid combining value), potash will react as a detoxicator in liming by counterpoising a one-sided introduction of calcium-ions. A good effect from potash is likewise to be expected in plant-poor hard-soil ponds. According to observations of Mehring, horsetail (Equisetum) is said to disappear after the application of potash and is replaced by soft under-water flora.

In fact Nolte was recently able to demonstrate that a potash fertilization is quite profitable in "poor" ponds in the high moor. In four-year experiments in Geaste an increased average growth of 29.4 kilograms per hectare (26.1 pounds per acre) was achieved. One kilogram of K_2O per hectare produced 0.23 to 1.47 kilogram of growth increase. The results, however, varied greatly. Also in regard to the kind of potash fertilizer, great variations were found. In 1930 potassium-magnesium sulphate produced the highest results, kainite by far the smallest, and in 1932 it was reversed. The question as to which kind of artificial fertilizer is to be applied for existing conditions, must be regarded as completely unsolved according to other experiences also. Walter surmises that perhaps the acid constituents could act as mobilizers on phosphoric acid and lime so long as there is a sufficient supply of these substances on hand.

The potash salts are most simply mixed with the phosphates and then distributed. In practice as a rule about 2 double hundred weight per hectare of kainite (178 pounds per acre) has been given, which corresponds to Walter's suggestion to give 30 kilograms of pure potash (K_2O) per hectare, 26.7 pounds per acre. In potash-poor ponds, in moor and heath ponds it is advisable to experiment with larger doses of about 60 kilograms per hectare (53.44 pounds per acre) of K_2O.

In brood ponds, a potash fertilization is also still profitable in some circumstances if the monetary net profit is not increased. In the brood pond, especially in the carp-brood nursery pond every increase of natural nutrition is of the greatest value for the health maintenance of the brood.

On the question, whether and under what conditions a profitable nitrogen fertilization in the pond is to be considered, it is unfortunate that at present it is still not possible to form a fully clear conception. Increased yields can doubtlessly be achieved as well by nitrogen fertilization alone and also by nitrogen doses with phosphate and potash fertilization. Yield increases were also obtained in this way in recent years in Wielenbach, in spite of earlier failures, and similarly even earlier in Sachsenhausen. On account of the relatively high expenditures the net yields mostly do not rise with the gross yields, the fertilization with mineral nitrogen is practically unprofitable. Still it should also not be forgotten that the increase of natural nutrition can indirectly make itself more than profitable by means of a better status of health of the obtained fishes, even when the monetary yield increase with the fishing out seems to be abolished again by the costs of the fertilization. According to the existing pond experiments, also according to experiments started by Naumann and Jaernefeld under completely comparable conditions in half vats, it seems moreover as though even a nitrogen-free fertilization then always suffices for high production, if organic substance is present. The assumption of Walter, that the organic substance is a continuous slow nitrogen purveyor, has not been verified thus far, since equally good results were achieved also with pure practically nitrogen-free cellulose. From all this it follows that the "nitrogen problem" in the pond has been and is of great interest and merits further experiments and researches.

Sodium nitrate, ammonium sulphate and urea in experiments hardly showed any difference in action on the average and when applied individually they caused yield increases of about 50 percent. Jaernefeld believed, of course, that he has had better successes with saltpeter than with ammonium compounds which in agriculture act slower but more persistently. In Sachsenhausen it was the reverse.

Noteworthy are the results which Walter achieved in 1929 and 1930 with only guano fertilization (about 300 kilograms per hectare, 267 pounds per acre), in which the phosphates contained in guano must naturally have worked strongly cooperative. A yield increase of 100 to 150 percent was obtained. It may be asked, however, whether an organic fertilization would not have given the same success more cheaply. It is to be noted also that in Wielenbach, results with nitrogen without phosphorus remained far behind those with phosphorus without nitrogen.

Attempts to inoculate the ponds with nitrogen gathering bacteria (Azotobacter) by the use of various preparations, have had no results up to now in Wielenbach. With the strong influence of the environmental conditions upon the metabolic cycle of the nitrogen, this result is almost to be expected.

I finally suggest for comprehensiveness, that the pond manager in the first tangible fertilization experiments to determine fertilizer action, should proceed as follows. In order to correspond to field fertilization experiments in agriculture, ponds as much alike as possible and with absolutely similar stock must be used. Therefore the following fertilization plan is taken as a basis:

Pond I. Unfertilized.

Pond II. 40 kg ha (35.6 pounds per acre) of P_2O_5 (pure phosphoric acid) as super-phosphate, Thomas meal, dicalcium phosphate or Rhenania phosphate.

Pond III. Fertilization as in II plus 50 kg ha (44.5 pounds per acre) of K_2O (pure potash) as No. 40 potash fertilizer salt, potassium-magnesium sulphate or Kainite.

Pond IV. Fertilization as in III plus 5 to 10 dz ha (445 to 890 pounds per acre) of CaO as burned lime, limestone flour or calcium carbonate marl. The liming should be done in the autumn.

All experimental ponds must be kept free from excessive over-water plant development.

Experiment IV obviously can only be started if liming in all ponds has not already become necessary on account of a very low A.C.V., and in accordance with the fundamental rules given in Chapter VIII. It can be replaced if necessary by an experiment using 50 kg per hectare (44.5 pounds per acre) of nitrogen. The foremost rule operating in the setting up of the fertilization plan as well as in all scientific experiments is the following: In every new experiment only one factor may be changed, otherwise no comparison of results will be possible. Although this fundamental law is quite obvious, it is repeatedly left out of consideration.

I have purposely chosen relatively high, the quantities of fertilizers given in this plan for reasons of safety and for psychological reasons because of the danger that in first time fertilization a certain reserve fertilization must be undertaken. Later experiments can then show to what extent these quantities can be lowered.

If it is first determined by the experiments that a natural growth increase of about 30 to 100 percent occurs as in other places, then in the practical evaluations in fertilized ponds are to be based on a correspondingly higher natural increase, of natural increase plus fertilizer increase. In other words, the number of fishes to be set in is to be so increased that their piece increase remains the same.

H. Organic Fertilization.

The organic fertilization carries into the pond almost all of the foodstuffs which are required in the metabolic cycle. The introduction of the organic mass can simultaneously act to improve the soil. Many fertilizers also increase the freely suspended detritus and the quantity of bacteria in the water. So long as the water is not overloaded with detritus, the nutrition for animal plankton (especially Daphnidae) is also directly increased thereby. Fertilization experiments of Naumann (according to Walter, 1922) and of Jsernefeld under completely comparable experimental conditions in half vats, have shown that nitrogen free pond fertilization with phosphates and potash, and indeed with completely nitrogen free cellulose, leads to a high production. The details of the further favorable action of the organic fertilization in the pond have not as yet been clarified.

The extremely advantageous effect of the organic fertilization upon the growth increase of fishes is shown by a fertilization experiment by Probst with perished submerged water flora (predominantly pond weeds). In ponds which were fertilized with 30 kg of P_2O_5 per hectare (26.7 pounds per acre) a yield increase of 50 percent, and by the addition of a double quantity of plants (the total amount was increased about four fold), an increase of 100 percent was obtained. In Wielenbach in 1927, 10 loads of manure per hectare

(2.47 acres) doubled the increase. But great success was also shown with every organic fertilization in practice. The high productiveness of the village pond with its liquid manure inflows is generally known.

The manner of conducting organic fertilization has already been discussed elsewhere. Since the amounts of organic fertilizers are insufficient they can only be applied in few ponds. Extension and brood nursery ponds, which especially permit repeated fertilization are to be preferred. These ponds act to the growing pond somewhat like the garden to the field and therefore justly merit this preference. The green fertilization which was already discussed, is likewise a form of organic fertilization. A very special procedure has been developed in the Lueneberg Heath for the fertilization of ponds which are naturally extremely poor in nutritive substance. The pig stalls are erected on poles in the pond. Feces, urine and all food residues flow into the ponds. The method has excellent results and reminds of Chinese customs. A good fertilization and "soil cultivation" can also be obtained by keeping pigs in drained fallow fenced-in nursery ponds.

Stable manure and compost are spread upon the pond bottom in the distribution of fertilizers. They retard at the same time a luxuriant plant growth. For the production of daphnidae, Naumann advises a first time application of manure in a concentration of 5:1000 (which would be about 20,000 to 30,000 kg per hectare, 17,813 to 26,720 pounds per acre), and then every week in a concentration of 1:1000 in flat ponds. Fish meal, which has been found especially valuable for the production of cladocerae, is simply strewn about. Liquid manure can be released into ponds only in small portions and only once or twice about every eight days. Slaughterhouse scraps and sewage fertilizers are to be given as frequently as possible and in small portions. They are simply left on the flat shore in the pond.

This distribution is necessary, because every organic fertilization aside from its extraordinarily good production increasing action, also harbors a great danger: The production of oxygen shortage. This naturally occurs especially in warm weather. For the same reason the organic fertilization does not come into question for trout ponds. The progressive pond manager should make frequent early morning tests of organically fertilized ponds as to their oxygen content, and should also make especially careful observations on the fishes. The occurrence of gill rot is undoubtedly favored by organic fertilization.

The successes of organic fertilization have rightfully suggested the use of household and kitchen sewage and especially sewage of municipal canal systems in so-called sewage fish-ponds for fertilization purposes. The cleansing of sewage water in the best industrial manner is naturally in the foreground with such establishments.

The sewage fish-pond procedure is nothing else than one of the many biological sewage cleansing procedures and will be judged in the future according to this economy. Kisker showed that in the consideration of purely operating costs, sewage fish-pond arrangements can shut off with an excess and consequently are superior to all other cleansing procedures. However, in consideration of the total building costs and of the operating costs, the sewage cleansing is more advantageously achieved by an "activated sludge" equipment.

The construction of sewage fish-ponds must not cause large expenses. In other words, if sewage fish-pond equipments are to be profitable, the soil conditions must be favorable. Large soil movements make the construction too expensive. The letting in of fresh water with which the mechanically pre-clarified sewage must previously have been diluted at least four-fold in mixed canalization, must also not cause any substantial expenses in operation and in the construction. Reserves of fresh water must always be available in optional quantities. It is best if the sewage can be distributed over the entire pond surface. Where all these prescribed conditions are given, the sewage fish-pond construction must be absolutely recommended, inasmuch as values are hereby created upon the native soil.

2,000 inhabitants require about 1 hectare (2.46 acres) of pond surface. The natural yield in sewage ponds amounts to approximately 500 kg per hectare (445 pounds per acre), the losses are hardly higher than in usual carp ponds.

Chapter IX

FISHING OUT, SORTING AND STORAGE.

Two basically different kinds of fish catching are customary in the pond fishery: Catching without draining the ponds and catching by draining the ponds. Fish catching by draining is the more frequent essentially straight-forward procedure for the pond fishery. A systematic stock regulation is guaranteed only by draining the ponds.

Only the fishing out of newly hatched carp broodlings, the fishing out of non-drainable growth ponds, the catching of the daily requirement of table trout in trout fisheries and sample catches of every kind must be undertaken without the draining of ponds.

The carp brood is caught with flat nets of gauze, silk gauze, muslin or coarse mesh material. A sunny day is selected, when the brood is at the surface. The young carp brood can be kept in swimming hair sieves with wooden rims or in troughs painted white inside. Freshly zinc-covered or "galvanized" troughs are to be avoided. Naturally a sorting or even a weighing out is undertaken even less than with trout brood able to eat. On the other hand it has been stated in Chapter IV that the most exact possible count of the brood is desirable.

For this purpose broodlings are poured out of one little capsule into a second enamel capsule and counted as they pour over the rim. 1000 broodlings are left in the capsule. In the other equal sized capsule, brood from the reserve stock is scooped out and the amount is estimated by comparison. The counting is more exact if a definite quantity of water is scooped out of the trough with the stored brood and the number of brood found in it is counted. The contents of the trough is thoroughly stirred previously. It can be determined by calculation how much brood is contained in 1 liter or 2 liters of water from the trough.

Maranes (Coregonus) brood, and feeding trout brood is most protectively gotten out of brood troughs and brood containers by siphoning over with a rubber hose. The brood is only counted in an emergency, because the counting in the egg stage is much easier and more protective. If the quantity estimation cannot be circumvented, then marane brood should be counted like carp brood, and trout brood as given for trout eggs in 3, Chapter V, B, 5. Similar procedure is used with brood of pike, salmon, and graylings.

By means of cylindrical weir baskets, several fishes and even carps can be taken out of the ponds at any time. The fishing of spawn trout in brooks is best undertaken with drag nets. A thorough fishing out of non-drainable ponds (with even, obstacle-free bottoms), and a quick mass catch of table trout is only possible with drag nets. Sackless pond linen, also called net cloths are the most convenient. The mesh should not be greater than 20 millimeters, so that the skin of the fishes is not injured by over-sized meshes.

To get the fishes out of drag nets, storage containers and pond ditches, hoop nets (Fig. 58) are required. In the trout pond fishery the net bag must not be selected too deep, so that the sensitive trout will not be too strongly squeezed. The width of mesh and diameter of the loop must be regulated to the size of the fishes. Semi-circular nets with a straight front rim are the best for use in the holding boxes. The net loops must always be smooth rimmed, nails and wire ends must not be present either on the loop stem or on the loop because that would injure the skin of the fishes. It should also be reminded that the fingernails of persons handling fishes should be cut short to avoid injury to the fish in grasping.

In order to lengthen the durability of nets and net bags, care must be taken to wash fish slime and dirt thoroughly out of all net cloth. After washing, the nets are to be dried in the shade and then hung up in the net room. They must never be left in a pile for any length of time.

Since, according to Meseck, impregnated nets are from 30 to 100 percent heavier than non-impregnated nets, the nets which are mostly impregnated and purchased according to weight are mostly too expensive. It is very simple to impregnate the nets one's self. Tar, which makes the nets stiff and Carbolineum which contains poisonous and ill-tasting phenols, cannot be used in pond fisheries. Meseck recommends the plant extracts catechu, quebracho, mangrove bark extract and gambier. For impregnation, the nets are cooked for hours in a kettle having an inset to prevent burning. Even better is an impregnation at about 60° C (in a kind of cooking box) for 24 to 48 hours. According to Meseck, 1 kilogram of plant extract in about 40 liters of impregnation fluid is required for 10 kilograms of net (10 pounds of net require 1 pound of extract in 4.8 gal. of fluid). The cost of impregnation for 10 kilograms of net amounted to 1 to 2 marks (24 to 48 cents) in 1928. Starfish impregnation, which in later experiments of Meseck showed by far the least decrease of strength, is only done by the Worsted Yarn Spinning Mill in Delmenhorst on the factory scale.

Lengthy ice coverage with beginning suffocation offers a welcome opportunity for the thorough fishing out of non-drainable ponds. If holes are knocked into the ice, the fish gasping for air, come swimming to the openings and can be easily caught. Electricity has become a valuable aid for fishing out of difficult fishable and non-drainable, locked waters, thanks to a large series of experiments. The experiments have shown that fish catching by electricity is thoroughly profitable, and injuries to the waters as well as to the fishes do not occur. Alternating current of 40 amperes and 220 volts or 70 amperes and 130 volts which can be taken from overland power lines, has an active range of about 2 meters ($6\frac{1}{2}$ ft.) in water. The fishes, both large and small in the same manner, when they get in this range, carry out circular movements or lie rigid at the surface with stilted slightly trembling fins. The skin at the same time becomes very pale. Even large carps which seem to be almost dead, revive completely in five to ten minutes. A disadvantage is that the stunned fishes often rapidly sink again into the depths and therefore must be rapidly caught by nets from the boat. For the catching apparatus a 4 millimeter thick copper wire which is fastened to floats so that it is suspended 10 centimeters below the water surface. The ends are provided with porcelain insulators to which cords are attached for pulling the apparatus through the pond. The wire itself is connected with the electric circuit. Great care is always necessary. Details are contained in the fundamental thesis of F. Schiemenz and Schoenfelder, and in the theses of Schumann and of F. Schiemenz (1932) who reports the theses of Holzer. Explosions are unsuitable for the fishing out of non-drainable ponds, even when these are very small (Potonie and Wundsch).

The point of time for the fishing out of ponds by draining, falls in October and November in carp growing and maturing ponds, with early fishing already in September, and with winter ponds in March, April and May. The necessity of fishing out the large carp ponds only once in autumn, stamps the carp trade, even today, as a seasonal business. The sale of trout, since it does not have this peculiarity, is distributed over the entire year. With trout ponds the time point of fishing out is very variable. Fish catches must always be made in cool weather, and early in the morning in summer, and must never be done during frosty weather. Freezing of the skin causes severe injuries and leads after a short time to the death of the fishes.

Every fishing out must be most carefully prepared for in advance. The sheltering of the fishes during and after the fishing out must be exactly regulated. Everyone who helps with the fishing out must know in advance, exactly what he has to do: sorting, weighing, loading or something else. The draining of the ponds takes place very gradually so that all fishes go along with the drawn off water (see Fig. 19). With small ponds it lasts several hours, with large ponds it lasts for days, even weeks. Before a sluice board is pulled out, the water must first be confined by setting up sluice boards in the diverted sluice channel in the pond. Then a sluice board can be removed from the other channel and a restraining grid frame or the sieve box can put in place (Fig. 10). It is still better to place the grid way down in the channel turned toward the pond, and set up sluice boards on it to extend above the water surface, and to pull one board after another from the diverted channel to regulate the outflow. Clogging of the sieve is thereby avoided and the pulling of another sluice board is made considerably easier. Shortly before running empty, the sieve frame should be continuously wiped clean with brushwood, or, after previously closing the pond, a second sieve is alternated, cleaned, etc.

During night hours, a watch must be kept for regulating the outflow and to guard against fish thefts. There are two possibilities in the actual taking out of fishes from the drained pond: "Transmission" of the fishes through the sluice into a catching box outside of the pond, or taking them out of the pond in front of the sluice.

Fig. 53. Sieve box for fishing out smaller and more sensitive fishes. Fastening to the outflow pipe of the sluice with the help of a sack hose.

The former method should be absolutely applied with all smaller fishes and with sensitive fish species swimming freely about and which would become hopelessly choked in the mud accumulations in front of the sluice. At the outlet of the sluice outside of the pond (Fig. 53) a sieve box is attached by means of a sack hose 2 meters ($6\frac{1}{2}$ ft.) long (made from sugar sacks, Eckstein, 1929). The sack hose must hand loose so that the fishes and also partly the mud toward the end of the fishing out, can remain behind in it. The bottom and sides of the hose are fastened tightly about the sluice outlet. On the sides it is nailed to strips and on top it is gathered together and is to be fastened by a large nail. All nails are only partly hammered in, so that they can be quickly removed. At the fish-out box, the sack hose is securely nailed. The sieve box itself is so placed in the outflow ditch outside of the pond, that when the water current is shut off, all water can flow off. The fishes at first come with the freely released water and without all the mud into the sieve box. The water flows only gradually from the sieve box so that the fishes are not injured; also many remain behind in the hose and are driven out from time to time by lifting the hose. All fishes are to be removed immediately from the box. Mostly toward the end of the fishing out, some mud comes into the box. It is then continually removed by hand.

All trout, especially also larger carp brood grown in carp nursery and extension ponds (Fig. 19), yearling carps, stock tenches of every size, perch-pike and marane fingerlings can in this way be conveniently and cleanly let into the Eckstein fish-out sieve box with the outflowing water through the sluice. If too many fishes come at the same time or if the box has to be cleansed of foliage, mud, etc., the outflow is interrupted for a moment until the box is again free. With large ponds it pays to build in firm fish-out boxes.

Frequently the box is replaced by nets which are suspended horizontally between two poles and under the (highly placed) outflow pipe. This method is especially recommended for catching larger carps and trout. For tench, a fishing out at night is always recommended, however this advice is practically seldom followed on account of many other disadvantages.

The second method of taking out the fishes in front of the sluice is only to be recommended for fishing out larger carps and tenches which can endure a brief sojourn in water which becomes thoroughly muddy from swimming movements and the catching procedure. The catching must not be begun until all the fishes have arrived close to the sluice. Fishes remaining back in the upper part of the fish ditch in large ponds are driven down with nets, reed rolls or with movable fences of bound wooden laths. With small ponds, nets are used to get the fishes out of the fish ditches. With extended ponds, the largest volumes of fishes drawn together in spread out fish ditches at the sluice are to be first taken out with meshed scoop nets. Unnecessary stirring of mud is to be avoided in the final taking out of fishes. The fortification of the ditch borders gives good services in this respect.

If extended carp brood or even trout brood are fished within the pond, it can be lured to the inflow by addition of fresh water and taken out there.

The caught fish, if soiled, should first be placed in a container or tub to be "rinsed", and then upon the sorting table, where they are sorted out according to customary commercial sizes. Smaller quantities of carps can, trout must be sorted by hand without the use of a sorting table. The sorting tables are to be covered smoothly with sheet zinc (see Fig. 54) for the protection of fishes against injury. Smoothly filed holes on the bottom allow the water to flow off. A sloping of the bottom on the one narrow side and a rounded hollow in the transverse wall facilitate the dumping of fishes out of the nets. A cutout on the opposite small side serves for shoving out residues of the sorted fishes (Fig. 54). The smallest numbers of fishes present (and all sick fishes) are separated out. The fishes are thrown into specially designated vats filled with water, which are grouped about the sorting table. The vats can temporarily be so strongly stocked that there are only about 3 liters of water per kilogram (2.74 pints per pound) of fish on hand. For a short time an even stronger stocking of the vats is admissible if some artificial oxygen is introduced. The sorted fishes are then counted, and weighed and then placed in fish boxes, earth containers, hibernating ponds, in other ponds, etc. In regard to the sorting of carp brood see Chapter IV, B, 2.

Fig. 54. The sorting of carps on the sorting table.

If it is possible, the sorting of carps and tenches is done right at the pond. In trout fisheries, the erection of a lasting, firm standing and strongly flowing sorting arrangement (in the brood house or at a sluice) to which the fished out trout are brought, is advantageous. It is simplest to use through current holding boxes, similar to long-stream apparatus, which can be separated into many compartments by sieves, for separating the size classes. The sorting itself can be done not only by hand, but also by pouring the trout through stacked boxes, whose bottoms are made of iron rod grates of various widths (see Fig. 55), and which are set in the water. By gentle lifting the fishes which are too small, slide through the grate. Bachmayer's fish-sorting apparatus consists of a similar box, which has aluminum rods on the bottom, and the spacing can be altered. By means of a simple mechanism the spacing can be varied from 5 to 22 millimeters (1/5 to 7/8 inch).

Furthermore, in similar fashion, exchangeable grates have been set into carp sorting tables. Fishes below a certain thickness should fall through these grates and land in a tub placed beneath. But I cannot rightly imagine how that kind of an arrangement for sorting larger carps or various kinds of fishes would prove good.

Fig. 55. Sorting apparatus for the separation of fishes of various sizes. The spacing between the iron rods on the bottom is widest in the top box, and becomes increasingly narrower toward the bottom.

For the unloading and dumping out of fishes (carps, tench and trout) the extremely practical sheet metal slides, and sack hoses provided with a metal ring on the end also deserve to be recommended here. The galvanized iron slide is probably the more protective of the two. The sack hose is however more movable and permits the pouring out of barrels on the truck. In modern large scale operations, belt conveyors are used in loading the sorted and weighed carps into the transport wagons (Fig. 56). The filling of transportation appliances with water is best undertaken on the wagon, for which hand and motor pumps give good service. In filling the fishes into barrels, funnels or straw rings should be used in order to prevent every injury to the fishes.

The question of the temporary sheltering, of the holding of the pond fishes, is of the greatest importance from the moment the fishes have been caught. If in large scale fishing out, the sorting is to be done at the pond itself, then storing in the immediate vicinity of the pond is almost indispensable. Net cloths fulfill the service of reservoirs in the simplest way. They are suspended in a through-flowing ditch or also in a pond by means of poles, so that several sections are formed. In several progressive pond fisheries (see Fig. 57), every large carp pond is provided if possible with a sort of adjacent pond at the sluice. The adjacent pond receives its inflow from circulation ditches. Pole structures for the suspending of nets, are firmly built in, in these adjacent ponds (see Fig. 57). In every place where a continuously running circulation ditch leads around the pond, it should, at least in the vicinity of the sluice, be so widely constructed that it can be used for the suspending or placing of storage-containers.

Fig. 56. The loading of carps by the aid of a belt conveyer in a Silesian large pond fishery. The transport wagons provided with water are standing above on the pond dam.

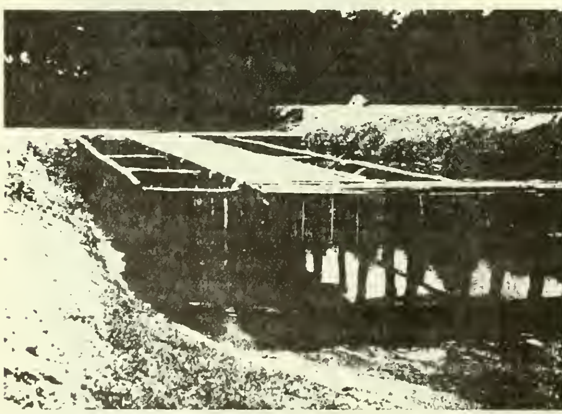

Fig. 57. Reservoir pond with a pole structure for the suspension of nets, next to the sluice of a 5 hectare (12.35 acre) carp pond (to the right behind the dam). The nets are suspended on the wooden prongs in the horizontal beams, so that a division for each fish sorting is formed. The pond is filled to the desired height from the water inlet entering from the foreground.

Swimming storage-boxes are extraordinarily well suited for small fisheries. These boxes are constructed as follows: strong wooden frames are covered outside with wire screen. The inside walls and bottom receive a lining of thin vertical standing laths. A cover prevents the disappearance of the fishes, two carrying arms on each side permit a convenient transportation, and setting on poles (Fig. 58). If the storage-boxes are covered with fine mesh screen or with perforated sheet metal, then they can also be used for storing sorted brood. These storage boxes can be put everywhere in the water, suspended, standing or swimming. In ponds it is best to anchor them in the water current in front of the sluice.

Fig. 58. Swimable storage boxes, which can be used in any desirable location for the temporary storage of fishes.

Not only with the fishing out but also later, the storage containers are indispensable for the pond fishery, if the yields right at the pond are not to be deposited at every price. In the carp pond fishery where the main seasonal business is done around Christmas and New New Year, and the fishing out must be done in October and November, a storage establishment for larger fisheries is most indispensable. For the temporary storage of sensitive stock fishes and for prolonged storage of table fishes, "earth reservoirs", which are nothing else than small ponds (Fig. 59), are still always the most suitable.

If they are also to be used for fishing out in winter during ice conditions it is recommended to build a pole structure (see Fig. 60). Reservoirs, in the narrower sense, are formed by lining the bottoms and walls of more strongly flowing "ponds" of only a few square meters area, with wood, stones or smooth cement. Or else trenches, which can be suitably supplied with water and flow through the entire extent, are lined on the bottom and sides. The linings must always be completely smooth, and cement is suitable only when it has been completely smoothed by coating it with "inertolan" or other agents. Obviously, such reservoirs can also be erected partly or entirely above the ground (see Fig. 59). The outflow of the reservoirs, like with the pond, is best regulated by means of sluice boards (see Chapter II), which are placed in a cut of the one narrow wall opposite the inflow. With smaller reservoirs the outflow can also take place by means of a horizontal lying pipe on the bottom. On this pipe and in the reservoir itself, is attached a turned up rectangular-bent zinc pipe which regulates the water level by turning it up or down. Frequently storage trenches are not only lined with wood, but they are also provided with covers, roofs and fence enclosures and are divided by partitions into many sections for separating the sizes and kinds (Fig. 59). All fixed and permanent reservoirs must naturally be erected where they can be protected, by continuous convenient supervision, against robbery by fish thieves.

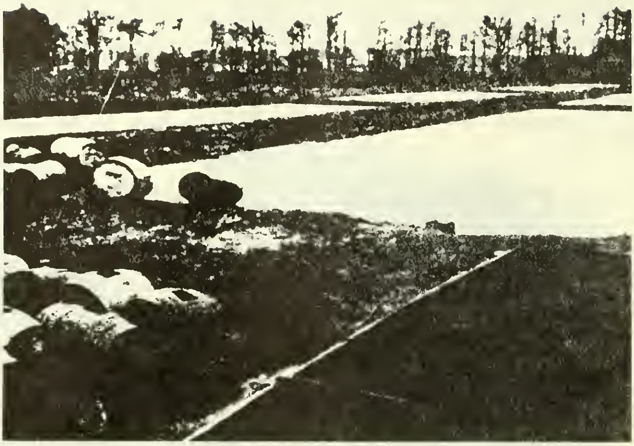

Fig. 59. Storage equipment of the stock-fish-growing fishery (see Fig. 15). Earthen reservoirs in rear; wooden reservoirs in front; left, oval fish transport casks for live shipment.

In the small fishery and for the carp dealer the fish boxes, with perforated or sieve walls are the most suitable. They are made more durable than the above-described storage boxes, and like the fish boxes, are hung in brooks, streams or lakes. It is best to hang every box to four beams, which extend out above the water surface and by which it can be drawn up with a winch. Fish boxes can easily be built in on the bottoms or shores of brooks so that they receive weak continuous water currents. Recently playing an ever increasing role especially for trout breeders, are also the smallest containers which are built like lid-covered aquariums as so-called unit fish-holders. They are provided with air sprays, in which a mixture of conduit water and air is introduced in the basin. This guarantees the best storage, with sparing use of water.

The air sprays consist of a pipe which leads from a water tap to the bottom of the basin. Here the water streams out of a nozzle and at the same time sucks air out of a second pipe which extends over the water surface. This can be purchased from Kraiss and Friz, in Stuttgart, Neckar Street 182. The unit fish containers (may be purchased from Albert Frank, Speyer or G. Zimmermann, Stuttgart, Post Compartment 348) are set up in restaurants where they give visitors the visual impression: live fishes = fresh fishes. If possible, every fish breeder should have his own larger aquarium where he can observe sick fishes in water.

With every storage, three kinds of things must be watched: The fishes should remain healthy, their flavor which may have suffered by detention in mud, that is by the fishing out or on account of strong artificial feeding should improve, their weight loss should be as small as possible. The first two conditions can only be fulfilled if the in-streaming water is rich in oxygen (by use of "air spraying" with water supply connection), sufficient, and free of detrimental flavor producing impurities, which otherwise retard beginning taste improvement in a very few days. The last of the three conditions makes it necessary to keep the basal metabolism of the fishes as low as possible. According to what has been said in Chapter I, B, this requires cool water (however not under 4°C) and the avoidance of strong fish motions. The through current accordingly must not be stronger than necessary, so that the fishes do not have to exert continuous swimming motions. No feeding is done in the storage container. This could too easily cause sickness, suffocations on account of strong oxygen consumption, and deteriorations of flavor.

Chapter X

HIBERNATION

"Hibernation", that is, the collecting of all stock fishes in small specially prepared hibernating (winter) ponds, has a double purpose in carp culture:

(1) To make possible the draining of the extension and brood extending ponds in the winter (on the significance - see Chapter I, last paragraph and Chapter VIII, E, 4th paragraph).

(2) To protect the fishes against dangers which threaten them in shallow ponds in winter.

The winter dangers for the fishes, are that the ponds sometimes freeze deeply, that the fishes can be frozen in the ice, and above all the danger of oxygen shortage occurring after prolonged ice coverage. In many regions injuries by acid water occur particularly in the winter. All these dangers are naturally most easily banished if the fishes are gathered in one or in a few relatively smaller ponds. The continuous supervision and the elimination of injuries is easiest there.

However, it would be obviously false to combat the dangers mentioned and at the same time permit new dangers to the state of health to enter from the other side. Endangering of the condition of health will absolutely set in if the fishes are too densely crowded, suffer long starvation, become disquieted, and if the ponds do not show faultless, completely unobjectionable hygienic conditions.

I must for this reason designate the ever more frequently appearing custom of using the hibernation ponds in the summer for extension and maturing ponds, as being a most dangerous bad habit, which must lead in increasing measure to the infection of fish stocks. In the silting up and neglect of the hibernation ponds I see one of the main reasons for the spread of the contagious ascites disease (see Chapter XV) and many other epidemics and diseases in the pond industries.

The most important requirement for good hibernation is therefore: Complete draining of the hibernation ponds during the entire summer, cultivation of the bottom surface if necessary, thorough liming of the pond bottom in the spring after the fishing out, particularly of the muddy places. The bottom must in no case show mud in larger amounts. The firmer and more loamy the soil is, the better is the hibernation of the fishes. The bottom should not be strongly sloping on the entire surface, but as horizontal as possible, in order to permit the fishes to rest upon a large area of the bottom.

Ponds which are perhaps somewhat small but well cared for, are better than large muddy and reeded hibernating ponds. The hibernation of yearling carps was already discussed. I have emphasized there that a "letting stand" of the brood nursing ponds makes possible the best hibernation for yearling carps. Where it cannot be carried out, the yearling carps must at least be hibernated separately from the two year old carps and the other fishes. It is likewise advisable to separate carps and tenches, in short a standard fishery requires numerous hibernation ponds, at best a special pond for every kind of fish and for every size class.

In order to protect the hibernation ponds from complete freezing close down to the ground, a water depth of 1.5 to 2.5 meters (5 to 8 ft.), and in the East a depth of 3 meters (9 ft. 10 in.) is necessary. In the East where the after winters almost every year are very long, the hibernation of carps is particularly difficult. In East Prussia, the beam structures erected according to the suggestions of Lietmann have given good results (see Fig. 60).

In every square of horizontal beams is placed another cross of wire, so that 4 smaller squares of about 1 square meter each, are formed.

The horizontal beams of this pile foundation must be so fitted, that the ice freezes above the carrying frame. In order that the ice does not melt away too rapidly about the beams, the beams are to be pared and painted white. By stretching barbed wire between the horizontal beams, the breaking off of ice can be more surely retarded.

The pile foundation structure permits the lowering of the water surface after an ice layer of at least 20 centimeters (7-7/8 inches) thickness has been formed. After the releasing of water a layer of air forms between water and ice. The air layer guarantees a continuous oxygen absorption by the water and hinders further freezing up. In mild weather, the ice-holding structure even makes fishing out possible (outside of the pond with catching boxes). The arrangement is also very suitable for reservoir ponds out of which, for example, table fishes are to be taken out for the Christmas and New Year holidays. A disadvantage of the pile foundation structure is its high cost. It is evident from Figure 60, that a great amount of wood is necessary for the construction.

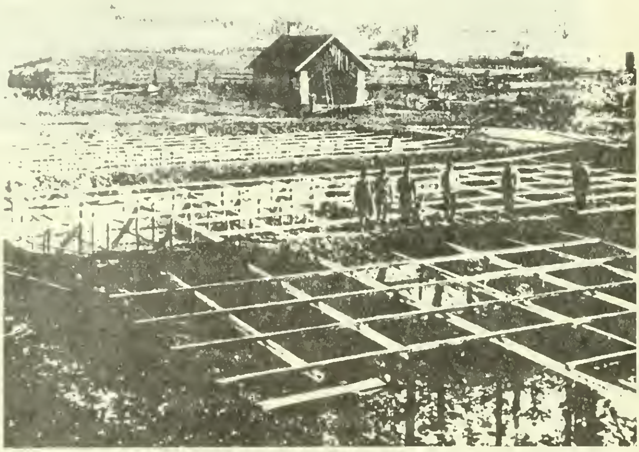

Fig. 60. Ice-holding structures for Hibernation Ponds and Reservoirs in an East Prussian Pond Fishery.

In most of the hibernation ponds there would not be sufficient oxygen available for the respiration of the fishes, if it were not for a continuous weak through-current of clear, oxygen-rich water (about 0.5 liters per second per hectare, 6 fluid ounces per second per acre) running through the pond. The oxygen content must continually amount to at least 4 to 5 milligrams per liter.

The through current must also otherwise be continually supervised. It must be uniform and must never become too strong, otherwise the fishes must carry out continuous swimming movements and will become emaciated. Furthermore the through current must never be colder than 4 to 5°C (avoid melted snow water) other wise the fish will "get up" and become sick (see cold injuries, Chapter XV, C). Water which is too warm unnecessarily increases the basal metabolism and likewise leads to emaciation. Finally acid water must never be supplied (in regions poor in lime avoid melted water and rain water), otherwise the fishes become unavoidably sick (see pH value, Chapter I, E, 4). Where there is acid water, a lime mill supplied with calcium carbonate is to be built into the water inlet (see Chapter VIII, F). In order that the through current traverses the entire pond, the grid is placed in the sluice on the bottom of the inner groove so that the water rises high between the two rows of sluice boards and drops off over the outer sluice-board wall, which serves the regulation of the water level.

As just mentioned, the oxygen content must not sink below 4 to 5 milligrams per liter. This cannot be achieved by knocking out holes. The area of these quickly freezing holes--however numerous they may be is much too small to permit sufficient penetration of oxygen into the water, if there is not a simultaneous intermixing (Neuhaus). On the contrary, the fishes are aroused from their hibernation by the strokes, swim about actively and require especially large quantities of oxygen, and come to the ice where they are frozen fast. Ice holes should at least be sawed. I frequently observed, that fishes perished in ponds in which holes had been hammered through the ice, and remained alive in similar neighboring ponds in which no holes had been hammered. For the same reasons, ice skating and the obtaining of ice on hibernation ponds must be absolutely forbidden. It is very significant, that especially at the beginning of spring, when the first sun rays stir the carps and tenches out of hibernation, fish mortality still occurs. At this time the oxygen content tends to be at the lowest, due to oxygen-consuming processes of decay and because the prolonged ice coverage has excluded the air from the water.

An often very effective means for enriching the water with oxygen is, in contrast to knocking out holes, the sweeping away of snow from the ice surface. The light then penetrates better into the water and the algae and plants, present in small amounts even in winter, can produce oxygen. In the greatest emergency, artificial oxygen can be carefully introduced in the deepest places in the pond. It has also been tried, to pump water from beneath the ice, aerate it in a channel, and again let it flow into the pond. The success herewith is largely dependent on the degree of mixture of the in-running pump water with the pond water. The setting up of strongly rumbling pumps upon the ice should be well considered, because the fishes become disquieted thereby. A pond fishery in Saxony, whose feeder is the Spree River which becomes strongly polluted in the winter, pumps the water of the hibernation pond into higher placed purchased reservoirs, from which after thorough aeration it flows back into the pond through several open 100 meter (328 ft.) concrete channels. In this way only little water needs to be taken from the Spree.

It is probably self evident that fishes which are closely crowded in hibernation, must be completely healthy. Most illnesses of whole pond fish stocks may be caused in hibernation. Fishes which are suspected of disease must therefore be hibernated separately from healthy fishes. Also a few large parasites (fish-leeches, carp lice, see Chapter XV, E, 2) which do not produce injurious effects in the summer, can lead to emaciation and to secondary illness by continuously disquieting the hibernating fishes. Injuries caused by fishing out, make the fishes in hibernation very susceptible. They are also often the cause for later illness.

The nutritional condition of the hibernating fishes is therefore very important, because it likewise determines the degree of resistance power. All fishes must go into hibernation in a well nourished condition if they are to endure the winter well. To prevent emaciation the water must not be too warm nor the through current too strong during the hibernation, as has already been mentioned. In warm winters, according to experience, the weight loss in the hibernation pond is the greatest. Regarding the height of the weight loss, see Chapter I, C. Since small fishes emaciate particularly rapidly (see Chapter I, B), yearling carps, and yearling and two year tenches are to be fed until the beginning of frosty weather, inasmuch as they are not hibernated in large ponds. Willer in 1926, confirmed this experience by an experiment. In water temperatures of 4 to 8°C, yearling carps still devoured lupine groats very eagerly. At temperatures lower than 4°C, the desire to eat subsided somewhat, but stopped only close to the freezing point (see also Chapter I, B). The losses of these yearling carps weighing only 3 to 5 grams and fed in the hibernation pond amounted to only 10 percent at the end of the winter, while in other fisheries where no feeding was done, at least 20 percent of yearling carps were lost in the same winter. According to this experiment also, the feeding of yearling carps can be carried out in the hibernation pond, and is to be recommended.

Moreover the fishes also find some natural nutrition later in the hibernation pond. In the beginning of spring this natural nutrition and also the artificial feeding to the starting of frost are apparently of great significance in the prevention of the contagious ascites disease (see Chapter XV, D, 2), which starts with an intestinal inflammation and is one of the worst epidemics of pond fishes (Schaeperclaus, 1930).

From all of this it is repeatedly shown, that the hibernation ponds cannot arbitrarily be strongly stocked. It is therefore necessary to give approximate guiding figures for the stocking of hibernation ponds. The details given in Chapter I, E, 2 and in Chapter VI show that carps, even in a warm summer where the maintenance requirement is high, can completely maintain their weight if 1 two-year carp of 300 grams (10.58 oz.) for each 5 square meters (53.8 sq. ft.) of pond water surface is set in, or if 2 yearling carps or 2 two-year tenches per 1 square meter (10.76 sq. ft.) are reckoned. As the nutrition requirement of the fishes is much smaller in winter and the amount of natural food animals in the pond can be very considerable, 2 to 3 one-year carps or two-year tenches or 1 to 2 two-year carps for each square meter (10.76 sq. ft.) may be placed in the hibernation pond without hesitation. This stock surface is to be decreased or increased according to the nature of the hibernation pond.

I recommend that the hibernation ponds be covered with water as early as the beginning of October. In October there are still large swarms of midges flying about as matured insects, while in November their number rapidly decreases. With water coverage in October an abundant deposit of eggs can be expected, from which larger hibernating larvae develop in about two months.

The above details on hibernation are valid, as already mentioned, for carp and tench pond fisheries. In trout culture, all fishes, with the exception of the spawn trout, remain in the mast ponds or in the fingerling ponds and are arranged in size classes. Where conditions permit, larger quantities of fishes can naturally be drawn together in single ponds. Feeding is done in the trout pond fishery as long as food is taken up, because trout take food well even with few degrees of warmth, and even at 3°C a considerable increase in growth may be achieved.

All hibernation ponds--especially true for the carp pond fishery, for trout culture it would not need to be mentioned again--must be situated in the vicinity of a warder's dwelling so they are protected against theft and can be continually observed. A protected location is also very desirable.

The above details which show the great difficulties of hibernation, give the small pond manager the serious reminder always to manage in such a way that he does not have to hibernate any fishes, and that his ponds become empty in the autumn. Usually, the small pond manager must grow table fishes in one summer. Purchased two-year carps or large two-year tenches and one-year rainbow trout must accordingly be set in, in the spring (see Chapter XIII).

Chapter XI

FISH TRANSPORTATION

The possibility of the live shipment of fishes to further distances cannot be valued highly enough: upon this depends the upswing of the modern pond fishery.

As transport utensils for live shipment, the most varied forms of fish cans are used for few small fishes, for fish brood and for individual fishes (Fig. 61). White metal (pure tin) cans may be used without painting, but they must if they contain over 20 liters (5.28 gal.) be packed in baskets with straw so that they do not become dented and leaky. Zinc plated cans and barrels are to be coated inside with protective paint (see Chapter IX), as zinc poisoning starts very easily. The sensitive little vitellin-sac brood of maranes (Coregonus) perishes in a few hours even in scoured and washed zinc coated cans. For protection against impact and sudden temperature changes, all cans are to be covered with paper and sewed into sack linen. Cans with 15 to 20 liters (4 to 5.28 gal.) capacity may also be carried by a man; but for brood transportation cans of up to 40 liters (10.56 gal.) are still often used. In the transportation of smaller brood a fine gauze should be stretched under the cover.

The most used transport utensils for averagely large quantities of fingerlings and table fishes are the lying, oval fish barrels and the standing fish barrels, and the tubs (Fig. 61). They are made of wood, particularly larch wood, or of "galvanized iron".

Aluminum was used for a while for tubs but did not prove good. The lying barrels, also called "shaking barrels" are still the most usable shipping utensils. The standing barrels serve almost exclusively for transportation with artificial oxygen. Fish barrels must always be stored in such a way that they will not rot, but they must also not dry out too much. The grips, which should be quite wide, and the bands should be protected against rust by painting. Twenty four hours before the shipment, the wooden barrels are soaked and larger cracks are stuffed with jute.

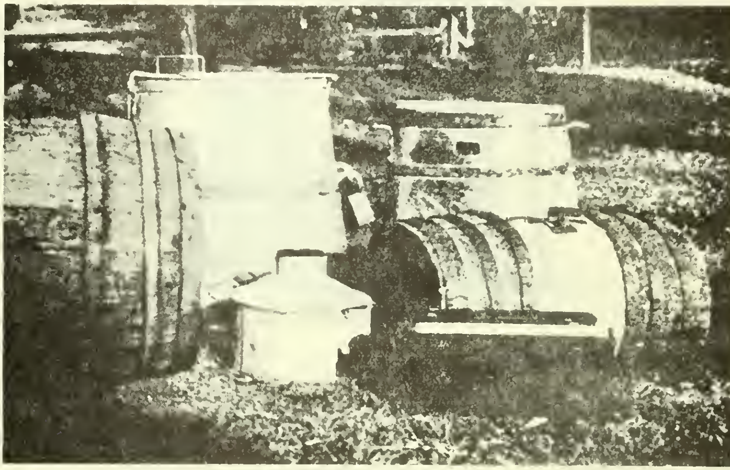

Fig. 61. Fish shipping utensils in the most customary shapes and sizes. Two horizontal lying, oval wooden casks with standard capacities of 350 liters (92.46 gal.) and 150 liters (39.63 gal.) and provided with cross-rod grips; a wooden tub of 80 liters (21.13 gal.), a metal tub of 150 liters (39.63 gal.) standard capacity. A round can for fish brood of 29 liters (7.66 gal.), an elongated can of 20 liters (5.28 gal.) for the individual transportation of larger fishes. (According to Kirschstein)

With short mass transportations overland, box wagons with a suspended lining of waterproof canvas or wagons with special boxes are usually used. Within the pond fishery, small box carts are also frequently used, and special power-wagons are used in large and long transportations. Obviously, with large scale transportation by railroad or water, special cars and special ships are used almost exclusively at present. In the small fishery and in fishing out, carps can be transported for short distances also in wetted sacks, in vehicles lined with sack linen, in transport baskets, etc.

For the oxygen provision of the fishes in transportation, the pond manager employs a number of very different methods. The cooling of the transportation water to 4 to 8°C (but not under 4°C, see "cold injuries" Chapter XV, C) provides first a lowering of metabolism intensity, and also of the oxygen consumption of the fishes and secondly an increase of the oxygen saturation value (see Chapter I, B, and E, 4). The cooling is to be done slowly, at best in the course of 12 to 24 hours. With stock fishes it must be undertaken only in narrow limits. Continuous shaking of the oval barrels (which in some cases must be done by an attendant during stops at stations) serves the more active oxygen absorption from the air by the transportation water. The horizontal elongated round form of the barrels also contributes to a surface increase of the water. For similar reasons the shaking barrels after flushing them, must be filled only to 15 centimeters (6 inches) below the rim.

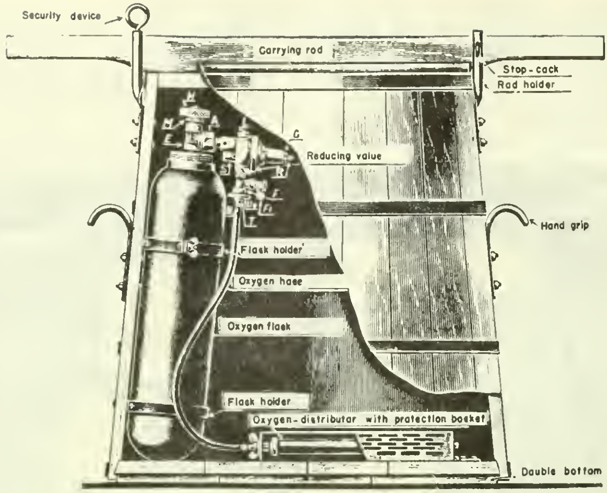

Fig. 62. Wooden Tank with oxygen apparatus of the firm of Kraiss & Friz.

The oxygen-needy trout are nowadays shipped only with a supply of artificial oxygen. Steel oxygen flasks of about 3 to 7 liters (0.8 to 1.85 gal.) capacity, which are mostly filled with 100 to 150 atmospheres of oxygen are fastened, by means of iron holders, in the standing barrels and tanks (mostly of capacities of 50 to 150 liters, 13.2 to 39.6 gallons), see Fig. 62. Complete oxygen barrels may be gotten from Draegerwerk, in Luebeck; Kraiss & Friz, in Stuttgart, Neckar St. 182; Pass & Co., Weidenau, Sieg. Special cars which are suitably provided with four containers 250 x 90 x 100 centimeters (98 x 35 x 39 inches), but whose use only pays with the transportation of at least 1,200 kilograms (2640 pounds) of trout, are obviously today provided with oxygen equipments. The oxygen, after the pressure has been reduced by a pressure reducing valve, flows out through a diffuser, of charcoal or other patent composition (to give the greatest possible porosity or surface), which is protected by an iron protection basket against obstruction by mucus. It enters the water in a misty state of subdivision on the floor of the barrel. In rising up to the surface, the oxygen streams through a relatively large layer of water, in which it is for the most part dissolved.

At the beginning of transportation the oxygen flask is turned on sufficiently so that the oxygen flows out about 20 liters (3.28 gal.) per hour . Until sufficient experience has been accumulated, this amount can be determined by determining the oxygen pressure reduction in the flask. The amount of oxygen in the flask is equal to the volume of the flask, multiplied by the oxygen pressure read off on the manometer. Screw threads must not come in contact with fat or fire. In a 120 liter (31.7 gal.) barrel with a transportation duration up to 15 hours at 5 to 6°C, about 25 kilograms (55 pounds) of table trout or 3,000 trout fingerlings or 50 kilograms (110 pounds) of carps, and at 10°C 20 kilograms (44 pounds) of table trout or 2,000 to 2,500 trout fingerlings or 40 kilograms (88 pounds) of carps can be shipped. Too much oxygen must not be given in any case, since the resistance power and storage power of the fishes suffer thereby. Trout brood and stock fishes must be shipped with oxygen under very special precautionary measures, otherwise gas-bubble disease, strong sliming of the skin, etc., occur.

The shipment with artificial oxygen production from hydrogen peroxide with the patented oxygen producer "Kralena" of the Oxysana Company in Nowawes near Potsdam (Wundsch, Czensny, Lehmann), perhaps has a future in many cases. Meanwhile numerous experiences with this apparatus must first be gathered before it can be recommended generally for practical use. A heavy egg-shaped bottle filled with highly concentrated hydrogen peroxide is laid on the bottom of the shipping container. Its neck, on which there is a stopper with a fine opening, is automatically turned downward. Before laying the bottle in, a catalyser perle is dropped into it, oxygen is produced and forces the hydrogen peroxide through the nozzle into the transport water. A fluid organic catalyser is poured into the transport water which should immediately decompose the emerging hydrogen peroxide. The fishes will be seriously injured if errors occur in this respect, because according to Czensny, white fishes (Coregonus) can endure only about 20 milligrams per liter of hydrogen peroxide.

In the transportation without a supply of artificial oxygen, the stock strength of the shipping containers depends on extraordinarily many factors, especially naturally on the kind and size of fish (see Chapter I, B), the transportation duration, the delays on the trip, and the temperature. All statements for the stock strength of shipping containers can therefore be only guide figures. The figures in Table 24, which I have compiled from the statements of Meltzer (according to Bugow) in the Handbook for Fishermen and Pond Managers 1932 and from my own experiences, must also be considered in this sense. The lower figures for the water requirement are standard for relatively low temperatures and shorter transportations, the upper figures for opposite conditions. With shaking barrels, a water filling up to about 80 to 90 percent is to be calculated.

Table 24.

Guide figures for the stock strength of various containers for live shipment of fishes without a supply of artificial oxygen for about 6 to 10 hour transportation duration.

SHIPPING CONTAINER	KIND OF FISH	WATER REQUIREMENT OF THE FISHES 1 liter = 1 kg	RATIO OF FISH WEIGHT TO WATER WEIGHT
Can	1000 Whitefish Broodlings	1-2 L	
Can or Barrel	1000 B_0 or R_0	7-20 L	1:70-200
	1000 B_1 or R_1 (5-7 cm)	200-400 L	1:50-100
	1000 B_1 or R_1 (10-13 cm)	900-1800 L	1:45-90
Can	1000 C_0	5-10 L	
Can or Barrel	1000 C_n (5 cm)	150-300 L	1:38-75
Barrel	1000 C_1 (9-12 cm)	250-450 L	1:13-23
	1000 C_1 (15-18 cm)	700-1000 L	1:9-13
	100 C_2 (250 g)	180-300 L	1:7-12
	100 C_3 (750 g)	375-750 L	1:5-10
	100 C_3 (1500 g)	700-1100 L	1:5-7
	1 C_2 (3000-5000 g)	40-75 L	1:8-25
Can or Barrel	1000 T_1 (7 cm)	80-150 L	1:16-30
Barrel	1000 T_2 (10-15 cm)	350-600 L	1:12-20
	1000 T_2 (15-20 cm)	600-900 L	1:8-11
	100 T (250 g)	150-200 L	1:6-8
	100 T (500 g, spawners)	450-750 L	1:9-15
Transport Wagons	100 kg Table Trout	1000-1500 L	1:10-15
	100 kg Table Carps	100-300 L	1:1-3
	100 kg Table Tenches	100-300 L	1:1-3

C_0 = Carp-vitellin-sac brood.
C_n = Carp-extended nursery brood.
C_1 = Carp-one summer.
C_2 = Carp-two summer.
C_3 = Carp-three summer.
R = Rainbow trout.
B = Brook trout.
T = Tench.

In carrying out live shipment, the following rules must be observed, in addition to the details already discussed.

(1) Become informed at the right time in regard to railroad, tariff and shipping rules, determine the route, in order to guarantee large reductions in the live shipment of fishes, and notify the receiver.

(2) Select night trains if possible, provide for continuous motion of the barrels at junction stations by notification. Have valuable shipments accompanied.

(3) Only standardized, not unhandy barrels up to the permitted sizes should be used.

(4) Before shipment, fishes should be allowed to recuperate and cleanse themselves in reservoirs. Ship only fishes with empty intestines.

(5) Barrels should be loaded before they are filled with water and fishes. When filling through narrow openings, funnels or straw rings are to be used.

(6) Ice should be added in large pieces for slow cooling.

(7) Shipments should be called for immediately upon arrival.

(8) When unloading use slides made of sheet metal or sack hoses (see Chapter IX).

The shipment of killed "living fresh", "living firm" fishes occurs ever more frequently for small scale sales in closer environment and also in pond fisheries. Value in this regard should always be placed on good sorting and on the uniformity of packing. The fishes should be packed firmly with ice, but the ice must not come into direct contact with them. In the trout pond fishery, the killed and taken out trout are frequently "ringed" together head to tail and arranged in rows in tightly closed slender cylindrical tin cans filled with ice (called "Schnede packing" after the large fishery at Schnede in Hannover). Very valuable suggestions on the methods of shipping of killed fishes in showing baskets, crates and boxes are given by the observation leaflets No's 2, 4, and 5 of the Prussian General Chamber of Agriculture, Berlin S W 11. Naturally in every industry there must be repeated and renewed consideration as to which kind of shipment is most profitable. The price conditions for living and killed fishes often give various answers to this question according to the time and locality.

Chapter XII

POND FISHERY BOOKKEEPING

Bookkeeping in the pond fishery also, like in the rest of agriculture, has the important general task of providing regulation, of verifying yield and income and of expediting the industrial organization and management. Pond fishery bookkeeping should therefore be copied basically from agricultural bookkeeping. It will be sufficient at this place to point out the peculiarities of bookkeeping for pond industries.

For the annual determination of the net yield, the gross yield and the expenses must be known. Records must therefore be available showing money received or covering the cash value of items used in one's own production, and the natural gross yields given in kind or as gifts converted to a monetary basis. According to the procedures of Bruening, they can be separated into main and secondary productions and other remaining receipts. The expenditures are composed of: Purchase of stock, food, natural and artificial fertilizers, salaries, wages, costs of water coverage and fish stocking of ponds, maintenance, insurance of the equipment (machines, sluice boxes, dams, etc.), interest on the dead inventory, building rental, expenses for special soil improvements, and other expenditures.

The net yield is calculated from the gross yield by the subtraction of all expenses, of the initial costs, including the wage requirements of the contractor. It is subdivided into a revenue portion, an interest portion, and a third portion which is the "rental from the land". It is the monetary expression of the economic success of a management considered free of debt, and can at all times be used for the defense of one's rights against outsiders. The calculation of the net yield per hectare (2.47 acres) enables one to judge whether a certain tract of land had best be used for pond culture or for agriculture. It is furthermore possible for the pond manager to determine from the figures, the production costs for 50 kilograms (110 pounds) and so decide for himself as to the lowest selling price he can set without additions, a determination which is often very important.

According to Bruening it is quite impossible to give a generally valid grasp of working costs, the local conditions are too greatly variable: the bookkeeping must give the information. The rule is probably generally true, that the working costs are lower in intensively conducted carp pond industries in which for 1930 the working costs for 30 kilograms (110 pounds) of carp growth increase were reported to be about 40 to 60 marks ($9.52 to $14.28), than they are in extensively conducted operations where the property values are placed too high. In one case in 1931, von Debschitz announced an actual production cost for 50 kilograms (110 pounds) of carps of 60 marks ($14.28) by utilization of all intensifying possibilities, of 57 marks ($13.57) with fertilization without feeding, and of 77 marks ($18.33) with natural operation.

The annual balancing of accounts makes it possible, furthermore, to decide whether the development is going upward or downward. It may at the same time be determined if the reason for a change of the natural gross yield is to be sought in unusual weather conditions, or in the market conditions for table fishes, stock fishes, foodstuffs, and fertilizers. Bookkeeping assists the memory of the pond manager.

It is also of very special value in the consideration of economical precautions. The success of various methods of stocking (see Chapter VI), feedings, and fertilizations can be judged by the achieved growth increase. It is therefore best to provide for each pond a book of receipts and expenditures and also tabulations with the following columns:

(1) Stocked on, number, kind, weight (with small stock fishes, the lengths), place of origin.

(2) Fished out on, number, kind, and weight of fishes, shipped to.

(3) Food, fertilizers, reed clearing, soil cultivation, pond treatment.

To make comparisons possible, the yearly accumulated figures must naturally be converted to a unit common denominator. For carp and tench ponds, therefore, a further tabulation must be calculated:

> The piece loss per pond and in percent, the fish growth increase per pond and per hectare, separated into natural increase, food increase, and fertilizer increase and with feeding, the food quotient.

I am acquainted with pond managers who prepare these figures graphically year after year and thereby draw valuable conclusions in regard to the profitability of feeding, soil cultivation and reed clearing. At the top of each pond tabulation, statements are made on the size and depth of the pond, filling and running out time, and about the conversion factor for calculating the yield per hectare from the yields for the pond.

Naturally these many calculations require much effort and time, but they are extremely important for a well planned management. In smaller managements they can often be regarded as unnecessary. There the bookkeeping must be as simple as possible for a quick convenient survey. The greater the management is, the more detailed must the bookkeeping be constructed.

Under some circumstances and especially also with the cash books, special calculation must be opened for the individual branches of operation, such as carp, tench and trout culture, stock fish and table fish culture. Special annual brief summaries for all ponds show a general view regarding the fishes available for stocking or for sale. Every bookkeeping can naturally benefit only the capable pond manager, who understands how to make the records useful for the improvement of the industry.

Chapter XIII

SMALL POND MANAGEMENT

The small pond management is understood to be the management of a single small pond or of a few small-sized ponds, that is of "Small Managements". It is always only a secondary operation. It has been frequently emphasized that it can be only secondary. For raising fishes from the egg to table-sized and spawn fishes, the necessary pond area, the necessary number of ponds, and also a trained continually available working force would be lacking. Furthermore, since hibernation could not follow in the same pond for reasons of fertility and hygiene, and other special preliminary conditions are also required, which in most cases are not given in the small pond fishery, it is logical to regard fish holding in a one summer rotation and of course mostly the one year growing of table fishes as the simplest, surest and most profitable kind of revenue from small ponds.

Only in exceptional cases, in which stock fishes can be used and disposed of in the neighborhood, is it possible for the small pond operator to grow and sell younger age classes in a one summer rotation advantageously.

The short term of this one summer thrifty rotation is therefore also especially valuable, because it favors the interest and a rapid production of profit. This factor is psychologically very important for the promotion of the small pond fishery by larger scale business.

When several small ponds close together are to be operated and there is another available small pond which fulfills all the preliminary conditions of a good hibernation pond and can be used exclusively for hibernation, then I would like to advise despite this to deviate from the one summer rotation and to supply instead, two summer fishes with a one time hibernation of the fingerlings. It is just the relatively high price of two-year carps and tenches and one-year brook and rainbow trout which often nullifies the monetary success of the small pond fishery. Trout brood and one-summer carps and tenches are always far cheaper, the stock expenses are not very heavy. For the hibernation of several hundred fingerlings a pond of only 50 square meters (538 sq. ft.) is sufficient if it has a small spring brook of suitable size for an inflow (see Chapter X).

Two summer rotation with two summer term of water coverage is only to be recommended with deep, winter safe, but difficult to drain ponds.

The two summer rotation in carp holding can be conducted in three ways: First, all ponds can be stocked with a mixed stock of about 50 percent one-summer carps and 50 percent of two-summer carps. Secondly, in one or several ponds, about 30 percent of the total available area can be used for growing one and two year carps and the remaining 70 percent for two and three year carps. Thirdly, one and two year carps can be grown without feeding in the first year, and in the second year with feeding, the same carps can be grown to table carps.

In the small pond management, obviously the same rules for stock calculation, feeding and pond care which were detailed in Chapters VI, VII, and VIII are to be applied.

Of all the kinds of fishes which can be kept in the small pond management, the carp occupies the first place. It grows very quickly and is so resistant that it cannot be all too easily injured in handling even by relatively inexperienced small pond operators. Two year stock carps for the one summer rotation should not be selected too large (up to 400 grams, 14.1 ounces at most) in order that they do not become too expensive and have not too high a maintenance requirement (see Chapter VI). As for the rest, they can be fed in the same manner as in the growing pond of the large scale operation of carp culture, and in addition can be stocked with not too small tenches. The tenches must naturally be so heavy that they likewise will have grown to table fishes in the autumn.

The setting in of rainbow trout is only exceptional and is advantageous only in deep, cool, hard soil ponds, since trout are too sensitive in every respect for the small management. An intensive feeding of the trout is too troublesome and can be profitable only in medium and large managements.

A special position is taken by many permanently water covered naturally dammed ponds of the intermediate mountains. In the Upper Harz Mountains, these "ponds" are centuries old, about 6 to 14 meters (19 to 46 ft.) deep at the plug, mostly hard bottomed, and were formerly used for water supply purposes. The area of the smallest of them amounts to about 6 hectares (14.8 acres), the water is extremely deficient in lime. The hard bottom ponds are stocked with rainbow or brook trout vitellin-sac brood 4,000 per hectare (1620 per acre) of which about 600 one-year rainbow or brook trout are again caught in the autumn. The muddy ponds receive in part a stock of about 80 one-year carps per hectare (32 per acre) of which about 60 two-year carps of 350 grams (12.3 ounces) are harvested in the autumn. For the other part the muddy ponds are stocked with two-year carps. The growth increase per hectare (water surface and pond area vary frequently) with two-year carps amounts to about 20 kilograms (17.8 pounds per acre), in stocking with two-year rainbow or brook trout about 10 kilograms (9pounds per acre). The losses are normal, at the same time the piece growth-increase of the two-year carps is moderate. To be sure, these ponds of the Upper Harz today can hardly be called small pond managements, because the ponds are very numerous and are operated in conjunction. At my suggestion, they are now used preponderantly for the production of spawn trout and trout fingerlings which are later fed up in small normal ponds to table-fish size.

Non-drainable ponds can be stocked with trout, especially rainbow trout, if they have formerly deep gravel pits and cool water. The trout are relatively easy to hook and to catch with weir baskets and nets. Carps must not be placed in non-drainable ponds unless these can be very well fished out with drag nets, or when as sometimes happens they can be pumped out cheaply. Under such conditions the carps even produce very good yields and are to be preferred above all other kinds of fishes, as was shown to me among other things by the operation of the extremely numerous turf pits in Warthebruch with two and three-year carps. Almost every small proprietor there, has his turf pit in which he successfully produces carp flesh.

The stock fishes are mutually purchased through an association organized for this purpose by numerous pond owners. This is a procedure which also deserves to be recommended to the small pond owners of other localities. In non-drainable ponds especially, operations must, of course, be conducted as cheaply as possible. Large expenses for catching equipment and transportation must not be incurred. Unfortunately good fishing out cannot be done with the drag net in many small ponds. The village ponds are especially known as gathering places for trash of all kinds, which retards the fishing. Warm, poorly fishable, non-drainable ponds consequently had best be operated with tenches, also crayfish or eels or if there are moor ponds also with crucian carps and pikes, which can be readily trapped in standing appliances. This kind of operation already borders on lake operation. Its treatment, strictly speaking, no longer belongs in the problems of this book, which deals with "pond" operation. I shall only point out, that with operation in such cases the ruling principle must be to thoroughly and continually fish out these non-drainable small waters with weir baskets, regulating nets, pole nets, adjustable and laying hooks. Marketable fishes should be utilized as soon as possible. Only then can the yield be satisfactory. Unfortunately there are still many small waters which can be used only incompletely or not at all. It would be a profitable policy for all fishery societies to bring about an increased well planned operation of these waters by proper information and instruction.

Chapter XIV

ENEMIES OF THE POND FISHES

Of the lower fish enemies to be found in the pond, several have already been discussed in the introductory chapters on production biology: the predatory water insects and water insect larvae and the water spider. All these animals are of immediate danger only to brood and to very small fishes, but they are at the same time very noteworthy food competitors. Their control and elimination in brood ponds, where they cause the greatest injury, is brought about by the draining and liming of the ponds during the time they are not in use and by water coverage immediately before stocking them. The only plants among the fish enemies, the bladderworts (Lentibulariaceae) are also prevented by these methods from occurring as pests in the brood pond.

Counted among the higher fish enemies from the race of vertebrates which for the most part directly devour fishes, are several amphibians and their larvae, various fish devouring creeping animals, birds and mammals. Rats (water rats, brown rats, mush rats) need hardly be considered here, but they often are quite destructive to dams and other pond structures. They are caught with wire baskets, small spring traps, or box traps, or with strychnine and phosphorus (in meat bait).

Anura, particularly the water frongs and various toads rarely devour fish brood, the predatory activity of their larvae is insignificant, although all larvae become injurious by eating up the food and cause extreme difficulty in fishing out carp and trout brood ponds. The detriment is often very considerable, because of extremely large larval swarms consisting of thousands of individuals. I have often seen many barrels of tadpoles caught even out of small ponds. The addition of narrow mesh wire fences around the brood extension ponds is expensive. The fences also do not keep out frogs completely, but only moderate the damage. The catching of spawning frogs, removing of the jelly-like spawn, netting out the swarms of larvae, baiting with meat on fixed hooks and continuous netting out of accumulated larvae are methods of control which are more or less worthy of recommendation and more or less effective according to local conditions.

The larvae of salamanders and amphibian lizards and the tailed amphibians also are brood robbers and competitors of the fishes for natural food. In contrast to frog anuras these animals hardly have mass accumulations of larvae.

Of all birds, the heron is justly the most feared in the carp pond fishery. In many pond fisheries it causes yearly losses up to 40 to 50 percent among the one-summer carps and the smaller two-summer carps. I know of fisheries, where 40 to 50 herons are destroyed in almost every summer.

The setting up of covered spring traps on elevations and of gun traps, the shooting off, the destruction of the nests, and in amall ponds the stretching of wires serve for control. The dwarf reed bittern which causes considerable losses in brood and brood extending ponds, is controlled by similar methods. Migrating fish eagles are frequently observed in many localities in the act of catching carps. They can best be eliminated by shooting them or by setting up spring traps on supports 4 meters (13 ft.) high. Perhaps at times the setting up of frightening-shot apparatus on supports, may be sufficient, as Weigold has announced.

There are almost always various species of diving birds on larger ponds, especially the crested grebes. Dwarf divers also establish themselves on small ponds. Shooting off, and destruction of the nests are the best methods of destroying divers. Red neck divers, eared grebes, and black neck divers are without greater significance. Gulls and similarly crows and magpies like to devour sick fishes, whereby they very frequently become carriers of worm cataract (see Chapter XV, E, 2) in trout fisheries. Poisoning them by fishes filled with strychnine is said to work best. Furthermore the ice bird becomes quite destructive in trout ponds by catching little fishes 4 to 7 centimeters (1.5 to 2.75 inches) mostly while perched on overhanging branches or stakes. It is easiest caught in small spring traps set on and chained to stakes. Water ouzels can also be caught in the same trap. They are rare in North Germany however.

Domestic ducks should be kept away from brood ponds, as they frequently become versatile spawn and brood robbers. Wild ducks like to get food from the feeding places in carp ponds. To prevent this, the feeding places can be protected by simple roofs made of twigs. The goosander occasionally establishes itself on hibernation ponds and can best be driven off by shotgun shells or by destroying the nests in breeding time. Dwarf mergansers and intermediate mergansers are rare in Germany. Fish losses from ice divers, arctic puffins, North Sea divers, white storks, duck hawks, kites, sea eagles, and sea swallows (terns) can seldom be complained of. Almost all fish eating birds, besides their activities as fish robbers, become injurious to a considerable extent as carriers of parasitic worms. The strap worm (Ligula simplicissima) which especially attacks tenches and crucian carps among the pond fishes, seldom occurs in regulated management of pond fisheries.

Of the mammalia, foxes, pole cats, and house cats are opportunity robbers. The fish otter, being an exclusive fish eater, must on the other hand be caught where he is found, by spring traps set up under water. The water shrew also causes considerable damage in trout ponds and hibernation ponds.

The possibility of controlling the higher fish enemies is restricted in all countries by various stipulations which are subjected to frequent momentary changes. The regulations of the Fishery Law and the "Regulation for the Protection of Animal and Plant Species in Prussia" of December 16, 1929, in Mitteilungen der Fischereivereine, Bd. 34, 1930, (Communications of the Fishery associations, vol. 34, 1930), must be observed in Prussia. According to the latter all birds in Germany are protected with the exception of the tufted grebe, the fish heron and others, also the fish eagle and others, which can be killed only by licensed hunters in definite seasons (fish eagle from September 1st to February 28th). Fishery pests can, according to this law, be trapped "on artificial fish ponds".

In this connection, I shall suggest as a remedy against losses by human fish thieves, that, in addition to watching over the ponds, thorny twigs should be place along the pond shores and stumps should be allowed to remain standing in the ponds. Excessive fishing and fishing with nets is thereby prevented. The management of fish growing establishments in the immediate vicinity of large cities is almost always impossible in spite of all these remedies.

If there is a suspicion that fishes have been poisoned by fish-berries (Cocculus indicus) at the hands of thieves (staggering fishes on the surface), it is recommended to send in the bait or the poisoned fishes to the Agricultural Institute for Fisheries in Berlin-Friedrichshagen, Müggelseedamm 310, for examination. In regard to injuries to fishes due to water pollutions, see Chapter I, E, 4. Fish mortality caused by explosions is recognizable according to recent researches of Gennerich by the frequent presence of a ruptured swim bladder and frequently of wounds.

Chapter XV

DISEASES OF POND FISH AND OF THEIR BROOD

A. Symptoms, distribution and importance of diseases. Direction for forwarding diseased fish to laboratories.

Mortality among fish is not always caused by some kind of fish disease. Quite often it is caused by various kinds of deteriorations of the water. If such is the case, it is easily detected. If the water, that is, its purity has become impaired, the mortality will in most cases, occur quite suddenly and fish of all sizes and species will be effected. Mortality, caused by some sort of a disease will afflict only some of the fish, often only a certain variety or fish of a certain size. In case of disease, this also is recognized by certain symptoms, such as unusual movements (continuous turning around, for instance) or by a general apathy. Also, a sick fish will isolate itself from the rest and in other cases--while the fish is still alive--such a fish may be seen lying upon its back or sides. Bodily changes may become noticeable, such as discoloration, or a film-like covering of the skin, or blisters, or swellings, or spottings, etc. Inflation of the belly, a great accumulation of parasites, etc. may be apparent, and in cases of severe affliction the eye revolving reflex may be absent.

A really clean-cut distinction between general mortality caused by water conditions, and mortality due to disease is not always possible. I have found from experimental observations that water deterioration may cause typical diseases of certain varieties of fish, lasting for days, sometimes for weeks, leading eventually to either death or recovery. Such an occurrence may take place, for instance with the sudden appearance of free chlorine (up to 1 milligram per liter) in the water and which will lower the pH value to about 5. (Ebeling and Schräder, 1929, Schaeperclaus, 1926).

As director of the Division for Fish Diseases of the Prussian Institute for Fishery in Berlin-Friedrichshagen, I have repeatedly found that fish diseases occur especially frequently in pond operations. Therefore fish diseases are of the highest practical significance for every pond manager. But, it is also known that the fish diseases have quite general and specially broad and favorable possibilities of origin and dissemination. The reasons for this are:

(1) Extraordinarily good possibility of dissemination of fish-parasites and disease instigators in the water (in contrast to air which offers much greater obstacles to the parasites of land animals in transferring from one host to another).

(2) Possibility of chemical alterations in the living medium, the water (very rarely given in the air), which alterations alone can become causes of disease, and can very frequently become the "cause for aggravation of disease", by unfavorably influencing the course of the disease. Also, the necessary handling in the catching gives with fishes a "cause for aggravation of disease", which is not the case to the same degree with other animal species.

The special reasons for the strong dissemination of fish diseases in pond fisheries are:

(1) The enlargement of the fish stock density in ponds, which enters with intensification of operation, and which favors the spread of the disease.

(2) The living conditions becoming poorer due to the intensification (especially of the frequent fishing out, hibernation in small ponds, of feeding, etc.).

(3) The increasing danger, when growing single or fewer kinds of fishes, of the beginning and rapid spreading of special diseases peculiar to a species.

Also in horticulture it is well known that pure stock plants are in greater danger from parasites than are the mixed stocks of the meadow.

The pond manager can only gradually accumulate sufficient experience for the recognition and control of frequently recurring fish diseases. The purpose of the following compilation of the most frequent and economically important diseases of the pond fishes can therefore only be to support the pond manager in this direction.

In every case, in which a fishbreeder is not absolutely sure of the kind of a disease present in his stock, or is at a loss of how to best combat it under existing conditions, the consultation and advice of an expert or specialist becomes imperative.

The large fishery institutes, like the National Institute for Fishery in Berlin-Friedrichshagen, Müggelseedamm 310, and the Biological Experimental Institute for Fishery in Munich are especially qualified to advise and aid in new kinds of and difficult cases. Besides these, there are in Germany also several smaller Institutes of Fishery and also fishery biologists who for their part cooperate actively with the above named central institutes in the field of fish pathology. It is quite useless to consult with chemists, druggists, veterinarians, etc., or to turn to food testing laboratories, agricultural stations, bacteriological institutes, hygienic institutes, etc.

Health controls, which can be undertaken in the autumn fishing out, spring fishing out, in the fishing out of the brood ponds or also on net sample catches (partly on location, partly on sent-in material), often make early prophylactic measures possible. They also promote a well timed cooperation between pond managers and fish pathologists, which will be very useful to both the investigator and to the pond manager in case diseases occur. I have compiled the following instructions to serve as a guide for sending in samples for the Investigation of Fish Diseases by the Prussian National Institute for Fishery.

It is requested, in the shipping of fishes for investigation for diseases or for health control, to observe the following:

(1) The live shipment is mostly always to be recommended, since many diseases can only be determined on living fishes. Fishes to be examined had best be shipped in fish cans of about 10 liters (2.6 gal.) capacity (milk cans, marmalade buckets, pouring cans) and according to their size, the distance of location, and weather conditions in numbers of two to ten fishes. Fishes which are distinctly sick but capable of living for some time should be sent in.

(2) Dead fishes should be shipped only if live shipment is impossible or distinctly visible evidences of disease make live shipment superfluous. Dead fishes must not be packed in fresh plants (grass, nettles, weeds), but should be wrapped singly in parchment or wax paper and placed in excelsior or in paper cuttings. In the hot season the addition of ice in a tight closing metal box or on sawdust is very desirable. Only living fresh, not yet putrefied fishes can be examined. Formalin preservation (1 part formalin to 9 parts water) should be done only in exceptional cases upon request.

(3) Every shipment must be accompanied by a report as detailed as possible on the observed disease manifestations and the course of the disease, also about the local conditions, or such a report should preferably be sent in advance. Only then can purposeful advice be given.

(4) If a water pollution may have been acting together with a fish disease, a sample of water should be taken at the location of death of the fish, placed in a clean bottle and sent along with the fish (see Chapter I,E,4).

(5) All shipments should be by shortest route, preferably by express or by special messengers. If possible, packages should be shipped on fast night trains. Shipments must not arrive unannounced on Saturday noons or Sundays.

(6) With larger fish mortality, local investigations are recommended, and are undertaken by agreement. The investigation fee is in accordance with the existing extent of the investigation. The minimum fee is 3 marks ($0.71), unless a public interest is involved.

Prussian National Institute for Fishery, Division of Fish Diseases, Berlin-Friedrichshagen, Müggelseedamm 310, Postal and Railroad Station Friedrichshagen at Berlin.

B. Classification of Pond Diseases.

From causative viewpoints, the different fish diseases may be divided as follows:

I. Non-parasitic diseases.

II. Parasitic diseases:

A. Fungus diseases:

(1) Mold-parasitic diseases (Mycoses)
(2) Bacterial-parasitic diseases.

B. Animal-parasitic diseases:

(1) Protozoan-parasitic diseases.
(2) Worm-parasitic diseases.
(3) Crustacean-parasitic diseases.

Various other principles for the classification of the fish diseases and for simplifying the review, can be applied. The diseases may be differentiated by the nature of the afflicted organ into diseases of the skin, gills, kidneys, etc. There are carp, tench, and trout diseases, spring, summer and winter diseases, brood diseases and diseases of larger fishes, storage diseases, diseases caused by external or internal parasites, individual sickness and mass epidemics of larger stocks.

C. Non-parasitic Diseases.

Diseases, caused by "sour water". In heath and moor regions, with very calcium-poor water, carp are easily exposed to severe epidemics, especially in winter or after heavy rains. Losses can be great and the cause lies in the gradually, and naturally, increasing acidity of the water, with a corresponding drop of the pH value below the safety point. In many cases, sulfuric acid is the cause, while in others organic acids are responsible for these conditions.

A long-lasting pH value of about 4.8, causes in carps (according to Schaeperclaus 1926) a milky turbidity in the skin and gills, destruction of the gills with succeeding fungus infestation and the formation of brown surface coatings (similar to that following gill rot). Frequently the skin becomes more or less reddened. In the presence of iron, higher pH values of about 5.5 become dangerous for carps, according to Schaeperclaus. Iron then precipitates in large flakes upon the alkaline gills (see Chapter I,E,4). However, in accordance with local conditions, the total pathological manifestations can be more or less lacking. Trout are more sensitive, pikes and tenches less sensitive to lowerings of pH values, than are carps.

The movements of the carps during the course of the typical illness become more and more apathetic. It is characteristic that the fishes frequently remain stationary in a normal position at the shore even after death.

Not seldom, even at temperatures of 4 to 5°C, a secondary attack of constipation is added to the illness by acid water, which strongly aggravates the course of the disease. The control of the "acid sickness" is accomplished with liming according to methods discussed in Chapter VIII. Fishes already strongly sickened can no longer be saved. Also trout eggs, according to Schaeperclaus, perish and become moldy (see Fig. 30) with a long continued pH value of 4.8, and again a content of iron in the water aggravates the condition.

Gill cover Perforation. The highest point of the large gill cover—in carp—appears often more or less gnawed at. In some pond fisheries real perforations of the gill cover "attack" great numbers of these fish. The primary cause for this affliction according to Schaeperclaus is the brushing of the fish against rough pond walls. The irritated parts finally become perforated, especially in slightly "sour water", or in water, rich in carbonic acid (pH is smaller than 7). The indicated therapy is obvious. The perforations heal--in suitable water--upon primary intent within about 7 months, leaving slight scars upon the skin.

Rachitic Shortenings and Deformities of Gill covers and Bones. A peculiar affliction, quite often of epidemic proportions. It will be noticed among carp fingerlings but also among strongly fed rainbow trout fingerlings. The gill covers are shortened, at times, the edges of the covers are "rolled up", at other times the covers become arched. Neither parasites nor hereditary factors alone are the cause of this affliction, according to Schaeperclaus(1929). It seems obvious that rachitic disturbances of the juvenile bone structure bring on this sickness. In the first place, various forms of contracted ventral fins and anal fins, quite often even numerous deformations of the spinal column appear regularly in combination with the different gill cover defects. And then again, the fish will recover from all of these defects by fall, which could not be the case with defects conditioned by heredity. Still, it is to be presumed that a rachitic tendency is hereditary. There is also the possibility that these defects already start in the egg as the result of yolk swelling due to chemical-physical influences. It has also been occasionally supposed that overripeness of the eggs causes a rolling in of the gill cover in carps. The outbreak of the disease is greatly favored by supplementary feeding (lack of vitamines) and neglect in the proper maintenance of the ponds (shaded ponds). For prophylactic reasons, parent fish of sickly disposition are to be eliminated. The brood ponds ought to be properly cared for and feeding of the youngest brood should be avoided. Scheuring sees in rachitis the cause of gill cover swelling.

Faulty skeleton development through hereditary disposition. One will find, in almost every carp fishery a few fish which through hereditary disposition are lacking in some fins or are without fins altogether. Wunder lately called special attention to this. From my own observations of such cases, I would say that lack of ventral fins predominates. Abundant other hereditary malformations occur often. Occasionally, I found numerous contractions and deformities of the spinal column. Schräder has dealt with this subject exhaustively. Such carps, just like those with one or multiple kypholordoses can therefore become fatalities, because they are regarded as being especially compact and high backed and therefore of particularly high value. It is self-evident that all fish with hereditary deformities and with latent hereditary tendencies are to be summarily eliminated.

Deformities in trout brood. Deformities of the heads and tails, occasionally multiple heads and tails are observed in trout brood. Mrsic ascribes the condition to abnormal maturity of the eggs and Willer sees lack of oxygen and other injurious factors during the development stage as the cause.

Dropsy of the vitelline sac. The cause for this frequent phenomenon in the trout brood (see Fig. 63) is mostly ascribed to a change of water and injury to the eggs during transportation. Scheuring found 100 percent of vitelline sac dropsy in the progeny of a rainbow trout which had been injured by a heron.

Injuries from cold temperatures. According to Staff and Scheuring, if the water temperature drops below 4°C, which can easily be the case in hibernation ponds with melting ice and snow, then the carps which up to this time have been remaining on the bottom in a state of semiconsciousness (winter sleep, change into a state of paralysis and rigor). They lose their equilibrium and are carried up and away by the slightest current. In this way they easily come into contact with the ice on the surface, whereby they receive skin injuries. But even without contact, strong excretions of mucus and nose affections easily occur and are followed by the attacks of one-celled skin parasites and mold fungi, especially in the case of one and two year old carps.

I have never been able to determine, in spite of my many investigations on sick fishes, a chilling of the skin with separation of the musculature as described in textbooks of fish pathology and said to be caused by the transferring of fishes out of warmer water into 4 to 5°C. colder water. I also doubt that that kind of chilling occurs or is of importance in practice. Very strong temperature differences are naturally injurious, as the carp eggs also show (see Chapter IV,B,2).

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The sudden transfer of the fishes into water more than 3 to 5° cooler is to be avoided on account of resulting shock reaction. Especially when setting out brood, the transportation water must previously be brought to the same temperature as the pond water.

Bursting of trout eggs. At times, among the trout eggs shortly before hatching, are to be found many ruptured eggs from which whitish masses exude. This phenomenon is to be observed especially after transportation and shortly before hatching and is due to an injury and the bursting of the egg shell whereby portions of the vitellus exude and coagulate.

Gas bubbles (gas bubble disease). Observed in trout broodlings. Symptoms: Gas bubbles under the skin, especially around the head and along the fins. According to Plehn, it is due to an over-supply of oxygen (all to plentiful vegetation). Mrsic has shown that at temperatures of 14°C. and over, this affliction will occur even without oxygen super-saturation, especially in narrow storage containers.

Accumulation of egg shells in the abdominal cavity. Over-aged three year and older masted female trout perish easily, because the shells of unlaid eggs of previous years fill the abdominal cavity. Then there is a lack of space for the development of new eggs. The fishes, according to experience, thereby become feeble. For this reason the over-aging of the masted female trout is to be avoided.

Inflammation of stomach and intestines. Both diseases are caused through unsuitable foodstuffs. They are among the most frequent trout diseases and will cause great losses.

Inflammation of the stomach, leading to a reddening of the mucous membranes of the stomach lining, is due to a too high salt content of the food (see Chapter VII).

Inflammation of the bowels. Symptoms: Hyperemia of the intestinal blood vessels, intensive reddening of the rectum. (These symptoms are not characteristic for the disease in dead fish, since reddening of the intestinal tract is usually always observed in dead fish.) The bowels are full of a yellowish mucus, there is a reddened vent, and prolapsus occurs quite frequently. In chronic cases, the mucous membrane may be noticeably darkened and in very severe cases the trout execute violent swim movements, may even be seen jumping about.

Cause: In the majority of cases spoiled food, also indigestible food or food hard to digest, such as too much fat altogether, too much protein, overfeeding, etc., may lead to inflammation of the bowels. Aside from this, certain infections and parasites may be responsible. These causes will be discussed later on. It is of interest that even a natural diet (too fatty chironomus larvae from sewage water, for instance) may bring about intestinal disorders and inflammation of the rectum (Miegel). It is characteristic that these inflammations, accompanied by great losses occur mostly during the first warm summer days. The accompanying chart, Fig. 64, shows that within two days the losses increase greatly and then slowly decrease within about six days.

The only remedy lies in an immediate cessation of feeding for about 14 days, that is, until losses stop completely. When feeding is taken up again, only the best available and best suited food is to be given.

Lipoidal degeneration of the liver. This disease occurs in trout only and especially in chronic form among older fish. Cause: Faulty diet, such as lack of variety of food combined with lack of vitamines; may also be caused by over-feeding at low temperatures. Symptons: Yellowish-grey or quince-yellowish, often spotted liver. The gallbladder is frequently clear and colorless, the fish are anemic, feeble and occasionally of darkish color. A gradual recovery can be attained by proper diet, to wit: not too concentrated food, frequent changes of food mixtures rich in vitamines.

Fatty degeneration of the liver. Occurs among carp-like fish, especially among "display" fish, kept in garden ponds, for instance and strongly fed with bread. Over-feeding of older fish will also cause the affliction.

Fig. 63. Sea trout brood with Vitelline-sac Dropsy. An accumulation of fluid has formed between inner and outer vitelline sac membranes.

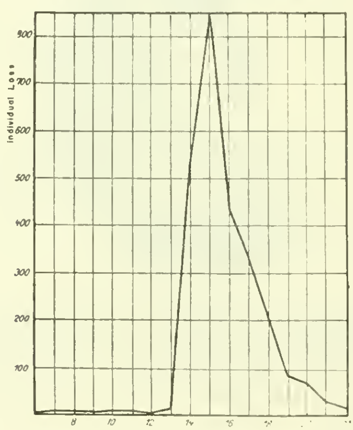

Fig. 64. Graphic representation of the piece loss of rainbow trout in a case of acute intestinal inflammation. The feeding was stopped immediately. The total loss in 10 days was 2600 table trout. The stock consisted of about 38,000 trout, which were kept in 34 ponds of 100 square meters (1076 square feet) each.

Variola (Pocks). Symptoms: In carp, hard, white spotted pimples of milk glass-like appearance, in tench, a thin but firm and evenly distributed whitish covering of the skin. They are to be regarded as cancer-like neoplasms of the epidermis. The fins become especially affected and thereby deformed. The causes of the disease can obviously be variable. I disagree with Haempel to regard the disease merely as a case of avitaminosis, and neither is lack of calcium the sole causative factor. I know personally of two fisheries, especially rich in calcium and continuously exposed to variola. In one of these fisheries, the fish are only occasionally fed, while at the other, the fish are not fed at all. I have also found variola among non-fed fish in ponds and lakes.

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It seems certain to me that injuries, retardations of the growth by overstocking, certain hereditary characters, carp lice, too muddy pond bottoms, seldom draining and neglect of ponds as well as strong feeding favor the occurrence of pocks. Occasional observations also lead to the conclusion that a lack of animal nutrition also favors pock formation. Furthermore, I do not want to deny that a lack of lime can favor pock formation. The addition of fish meal to the food provides aid in both cases and actually works advantageously.

The fishes in general do not perish from an attack of pocks, but according to Staff and Sawicki, the growth is retarded up to 50 percent. Transferring into other ponds or into running water, even transferring into reservoirs will often in a few weeks cause the disappearance of the epidermal proliferation, which make the fishes unsalable, as I have frequently determined in experiments. Pond sanitation prevents renewed occurrence.

D. Fungus Parasitic Diseases.

1. Filamentous fungus (mold) parasitic diseases.

Saprolegnia attack. The well known, cotton-like water mold or fish mold (Saprolegnia and Achlya) is not an actual disease producer, but rather a "parasite on weakness". It always settles only on sick, injured and stored fishes which, of course, are soon destroyed by it. It naturally is more injurious to the gills than to the skin. The Saprolegina also occur on the eyes, in the mouth and on the fins. They also attack perished fish eggs (Fig. 30), and in extensive mold attacks they even transfer quickly to living eggs. The more tender the tissues of the host, the more profound is the attack and penetration. All injuries of the fishes especially in fishing out and in transferring are to be avoided, diseases are to be avoided at the right time, perished eggs should be removed every two or three days from the brood apparatuses (see Chapter V,B,5).

Gill rot. There are two known forms of gill rot caused by Branchiomyces sanguinis Plehn on the one hand, and Branchiomyces demigrans Wundsch on the other hand. The former occurs in carps and tenches (carp gill rot), the latter in tenches and pikes (pike gill rot). In the tench, therefore, two distinctly different kinds of gill rot occur. In both forms and with all species of fishes, the gill filaments become colored partly white, partly blackish-red (especially the upper ones, Fig. 65), because the gill-filament veins are penetrated and obstructed by fungus filaments which have a width of about 9 to 15 mu (microns). The external picture is quite changeable. Branchiomyces sanguinis occurs only in the vessels and in the tissue of the gills; the otherwise very similar Branchiomyces demigrans forms strongly refractive branched tube-bundles on the outside of the gills. With a strong obstruction of the veins, rapid destruction (Fig. 65) and a saprolegnia attack of the gills, takes place, similar to sickening by acid water. The molds thereupon form spherical spores of about 5 to 7 mu (microns) which fill the tubules everywhere. The hemoglobin content of the carp blood can be about 20 to 30 percent over the normal value of 55 to 60 percent, and the blood can have an increased coagulability.

Gill-rot is a summer disease, which in by far the most cases, occurs shortly after very hot days during the period from May to August, when the water is about 23°C. There are exceptions of course. Scheuring and Gaschott observed a case at 14° to 16°C. in May. Wundsch observed a mortality with pikes at 21°C. Another tench mortality from Branchiomyces demigrans started as early as the 6th of May. The losses during the first days are mostly very great, in the course of about eight days they again subside. The disease therefore runs a very rapid course. Small and large fishes are attacked. Perished carps at times remain in a natural position at the pond shore. The total losses mostly amount to 10 to 50 percent according to Schaeperclaus.

Particularly endangered are the "too good" ponds, whose water shows an increased content of organic substances or is even turbid. Gill rot occurs preponderantly when mowed over-water plants, or cultivated ground fertilization plants in the pond or grasses rot in the water. The oxygen content at this time is as high as usual, the occurrence of the molds in the oxygen rich blood of the gill lamellae veins obviously indicates a high oxygen requirement. Also variations of the pH value from the normal which are especially well tolerated by the molds in general, stimulate the occurrence of the gill rots. In ponds in which gill rot has once been present and in neighboring ponds it will easily recur in succeeding years.

The attack by this instigator is not always deadly. There are cases in which no illnesses are observed at any time. Besides this, diseased gill parts can slough off, so that sharply defined gaps are formed in the gills which gradually heal again in the course of more than one year (Schaeperclaus). Until that time the fishes are feeble and less capable of growth, hence of lesser value as stock. The sloughing of gill parts at the same time serves the distribution of the spores.

Fishes which have been sick for several days, have an empty intestine and often gather at the inflow. Sometimes the beginning of the sickness is also indicated by the refusal of food. A control is possible by the introduction of cool water, removal and prevention of water turbidity and organic pollution, temporary discontinuation of feeding especially in warm weather, liming and thorough drainage of the bottom immediately after the fishing out. A liming of the water is also recommended (see Chapter VIII), but I have been able to determine that losses stopped just as quickly when no liming was done.

Fig. 65. Gills of a two-summer carp with gill rot. Exposed by the removal of the gill cover. The ends of the upper gills are completely destroyed by the infection, the diseased portions have already cast off to a large extent.

2. <u>Schizomycete Parasitic Diseases</u>.

<u>Red plagues</u>. There are various, often individual, metabolic-physiological diseases which are accompanied by red coloration (Schaeperclaus, 1929). The true red plagues, in which inversely the red coloration can also be lacking, have their origin in bacterial infections. Two instigators for carps have thus far been described: <u>Bacterium cyprinicida</u> Plehn and <u>Pseudomonas plehniae</u> Spiekermann and Thienemann. Both diseases are not very frequent at present. The control must be the same as with the following plagues.

<u>Furunculosis</u>. Furunculosis is the most dangerous plague of the trout, and especially of the brook trout, less of the rainbow trout. Its instigator is the bacterium salmonicida Emmerich and Weibel, a nonmotile short bacillus, which produces a characteristic brownish-black pigment when grown on artificial culture media. The bacterium prefers organically polluted water and sojourns for longer periods in mud. The disease manifests itself partly in muscle ulcers which can break out to the exterior (see Fig. 66), partly also only in blood-shot places, intestinal disorders, etc., and even all external symptoms may be lacking. The losses are mostly very great. The plague may be easily introduced by purchased

fishes, or from brooks with endemic furunculosis by means of latently infected fishes. The complete eradication of the furunculosis from a fishery is extremely difficult, and it can only be accomplished by the continuous removal, burning or burying of all diseased or dead fishes, by prevention of spreading, through removal of mud and disinfection of infected ponds, reservoirs, and the disinfecting of appliances (with lysol, potassium permanganate, etc.). Sick fishes convalesce best in strongly flowing water.

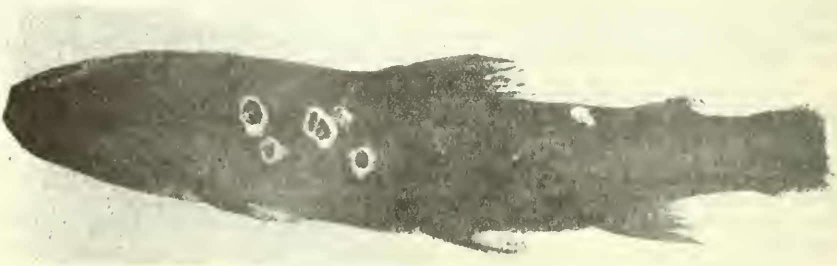

Fig. 66. Brook trout with furunculosis. Part of the muscle ulcers are still closed, part of them are broken open and washed out.

Fig. 67. Above: Two-summer carp with infectious abdominal dropsy. The abdomen is distinctly distended, the vent somewhat everted. Below: A healthy carp from the same stock.

Infectious Abdominal Dropsy. The infectious dropsy of the belly or abdominal cavity is, according to Schaeperclaus the most dangerous plague and disease of carps existing at the present time. It attacks not only carps but also all carp-like fishes. Its instigator is Pseudomonas punctata, genus ascitae, a single-flagellated bacterium, which liquefies gelatin, and which strongly ferments dextrose and very weakly ferments lactose. The disease usually starts in the intestine. To an intestinal inflammation in which long intestinal shreds are separated out, is added as a rule an illness of the

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liver which leads to dropsy of the abdomen (accumulation of fluid in the abdominal cavity, Fig. 67) in the spring, general infection and thereby to great losses. The carp-like fishes with their strongly lobed livers are naturally very susceptible to this disease. In the chronic course of the disease, flat ulcers of the skin and muscles, which open to the outside, can occur, and the accumulations of fluid in the abdominal cavity, which have given the name to the disease, may be lacking. The peak of the mortality occurs each year in April and May. The primary infection may have already taken place in the previous year. The main danger of illness exists in the hibernation pond, when the cold-loving bacteria can increase undistrubed in the intestine and cannot be carried away by food constituents traversing the intestine.

Sometimes the disease does not become evident until many weeks after the infection starts. The best methods for control in addition to those mentioned with furunculosis, general measures for epidemic control are: The care of hibernation ponds by drainage throughout the entire summer, protection of the fishes in the autumn and with every fishing out, not too narrow hibernation, hibernation of one-year carps in brood extending ponds (see Chapter IV), feeding in winter, avoidance of too strong feeding, especially with brood of only few centimeters length, avoidance of long storage, well planned culture of resistant races. Infected ponds must be limed as thoroughly as possible because the disease instigators can endure a long dryness. Mud is to be removed by suitable measures (see Chapter VIII). Diseased animals recover quickest in flowing water. A spread of the disease into natural waters must be avoided as it can easily cause a new infection.

If the plague has once become firmly established in a pond fishery, whereby the bacteria presumably pass through an occasional saprophytic mode of life in the mud, then their removal is practically impossible for years. A rapid, thorough interference, removal of all sick stocks, drainage of the ponds for longer periods must therefore not be avoided at the first appearance of the plague. Under no circumstances may fishes out of infected stocks -- no matter how healthy they seem -- be mixed with healthy stocks and new generations (for example with hibernation). They mostly always have a latent (hidden) infection. The losses have (according to Schaeperclaus) often been 90 percent and more, the danger of infection of the remaining fishes, and the danger of the obscure infection of the total fish stocks in greater than with all other diseases. The simultaneous existence of secondary skin diseases caused by one-celled animal parasites, can mislead the investigator in the determination of the kind of disease.

E. Animal Parasitic Diseases.

1. Protozoan Parasitic Diseases.

Contagious Skin and Gill Turbidity. A whitish-bluish turbidity (often associated with reddening) and a disease of the epidermis is caused in pond fishes of every kind and size in by far the most of cases by the strong attacks of one-celled parasites of various kinds: The flagellate Costia necatrix up to about 20 mu long, the heart-shaped ciliated animal Chilodon cyprini of about 70 mu length and the circular ciliated animal Cyclochaete (various species) of 9 to 50 mu diameter. All three parasites react about the same. They especially prefer to become established as secondary phenomena with other diseases, with skin injuries or with the deterioration of the general living conditions of the fishes. Turbidity of the skin is often rightfully regarded as a "storage disease" and is in many respects a secondary disease similar to the saprolegnia infection.

Chilodon still in first place, and with brood, of course, also Costia and Cyclochaete are to be regarded as primary, dangerous disease instigators. In many cases of disease the gills are attacked in stronger measure than the skin, and then likewise show an easily visible whitish coating. The parasites have a tendency to take up a temporary life of freedom in the water, even though they are true parasites, and in this way they can seek out and infect a new host and can be transferred by outflowing water (see Chapter IV). A weak latent attack by one or the other parasite happens continually in most of the pond fisheries and does no harm. It only becomes dangerous with the appearance of injuries and with the deterioration of living conditions. A stronger attack always leads secondarily to invasion by molds, invasion by bacteria, to attack by the microscopic trematode worm Gyrodactylus and finally even without this to a more or less rapid death. Costia and Chilodon may occur equally abundantly in the winter or in the warm summer. Chilodon attack is a frequent late winter disease of the carps. I have personally found an abundance of Costia even at temperatures below 2°C. This can then also lead especially to the disease of the carp noses with a secondary mold infection. Chilodon is to be found very seldom in trout. It is not yet known whether Costia can form resistant cysts which will endure hibernation on the pond bottom. The question is also less important practically, with the discussed character of the diseases. Cyclochaete is the least dangerous of all three of the parasites.

For the control of the contagious skin and gill turbidity the fishes are bathed for 15 to 30 minutes in a 2.5 percent solution of table salt (2.5 kilograms of salt in 100 liters of water). Zinc or zinc coated utensils must not be used for this purpose, because poisoning of the fishes by zinc chloride would result. A temperature increase of about 2 to 3°C. is particularly effective according to Plehn (1927). After the bath the fishes may be rinsed in water which is about one degree warmer. Then they must be set out in unobjectionable, richly nutritive ponds. In a reservoir the disease would soon revive, inasmuch as all the parasites can never be completely removed. The lysol bath also works very well against chilodon. The bathing of the spawn fishes immediately before setting them into the spawning ponds and catching them outright after they have spawned, feeding of the brood ponds out of fish-free waters, the keeping out of wild fishes which are often parasite carriers, protects the brood against the first infection. Good and effective nutrition decreases the danger of illnesses.

Amoeba Infection. Amoeba infection of the trout kidney is an infrequent disease. I observed it once in the autumn in a large natural pond, where many rainbow trout showed a fat abdomen due to considerable kidney swelling.

Ichthyophthirius-attack. Ichthyophthirius multifiliis, a relatively large, spherical parasite having a diameter of mostly 200 to 400 mu, but often up to 1000 mu or 1 millimeter, lives in the skin and in the gill epithelia. It may occur in all pond fishes. Large fishes are mostly so weakly attacked, that the parasites do them little harm. Among the brood of carps, tenches and trout, however, ichthyophthirius frequently causes great destructions. Gritty pimples can then be detected on the skin and gills (Fig. 68). A stronger attack of ichthyophthirius most always leads to the loosening of more or less large epidermal shreds, to bacterial infection and to mold invasion of the skin.

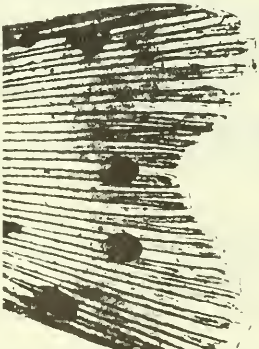

Fig. 68. Tail fin of a tench of 4 cm. length with ichthyophthirius. Photograph of a stained preparation. The parasiste contains a horseshoe-shaped nucleus.

When the ichthyophthirius has reached maturity in the skin, which at 10°C. according to my observations may require three weeks and longer, it separates from the fish, falls to the bottom, fastens itself in the pond and divides itself into about 1000 progeny of 30 mu size, which as "swarmers" begin to swim about freely 24 hours after their release and seek new fishes. They can easily be carried away by flowing water. Sixty hours after release and encystment, I have not been able to observe any living swarmers. Obviously they die very soon, as surmised by Buschkiel 1910. Little fishes in densely stocked brood ponds are naturally very much endangered with the occurrence of ichthyophthirius.

Furthermore, it often happens that brood ponds and brood channels which are fed out of non-drainable village or mill ponds, in which there are fishes with a latent infection of ichthyophthirius become so infested every year that the rearing must be given up. Ichthyophthirius easily becomes so firmly established even in experimental basins and ponds that it will not disappear for years. It then easily causes epidemics of sickness.

An epidemic must be avoided from the very beginning by the health maintenance of the spawn fishes, and the avoidance of parasite containing inflow water. Holding of the diseased brood in boxes which have a strong through flow at the bottom, causes the parasites to wash away as fast as they fall off and thereby leads to recovery of the brood often within two to three weeks. By bathing the brood in a solution of 1 gram of quinine sulphate in 10 liters of water all the parasites which drop off are safely killed within one to two hours without injuring the fishes. But this bath can hardly be used practically, because it must last two to three weeks. In that case aeration would have to be provided for. The solution remains active.

Contagious Inflammation of the Cornea. In many localities, particularly in the Harz, a whitish clouding of the cornea occurs with trout, which slowly and progressively injures the vision of the attacked fishes. It is to be presumed according to Fischer, that protozoans are concerned as the instigators.

Trypanoplasma Infection. Infection of the blood with various species of trypanoplasma, a half-moon shaped, 15 mu length, parasite similar to the instigator of the sleeping sickness in man, occurs in carps but especially in tenches. On closer investigation, I found in 1 cubic millimeter of blood from a half pound tench up to 0.11 million trypanoplasma and only 0.96 million red blood cells, whereas normally there are about 1.7 million red blood cells present with tenches. The hemoglobin content was at the same time lowered from the normal value of 65 percent down to 55 percent. The fishes are very weak from such an attack, and often assume a lateral position with a bent down head, become anaemic and emaciated. The eyes in particular are as a rule deeply sunken, the skin is pale. Since the parasites are transferred by the fish leech, the destruction of all the trypanoplasma harboring fish leeches and weak fishes is necessary for combatting the disease.

Nodule diseases. On the skin of tenches and carps there are often many pinhead-sized elevations between the two rows of gill lamellae of the individual gill arches of carps. These are white and the size of farina (see Fig. 69) in carps. On the ends of the gill lamellae of tenches, bead-like cysts, "nodules" with sporozoa (various species of Myxobolus, and *Myxobolus piriformis*) may be observed. Occasionally cysts of sporozoa also occur in inner organs. The spores are mostly up to about 20 mu in size and disk shaped. They are recognized under the microscope by their strong refractivity and the possession of one to two egg-shaped polar cells. With a strong attack great losses can occur, especially when the respiration is retarded by the attack. With a weak attack, injuries of the fishes cannot be detected. Since several thousand or millions of spores develop in each cyst reactively formed by the fish, and each of these spores can again attack a fish and later cause the formation of a cyst, it is absolutely necessary to promptly remove all parasite carriers out of the pond fisheries before the total stocks and fishes are infected.

The sporozoa Eimeria, an intestinal parasite, often leads to severe intestinal diseases in carps during the hibernation period. It leaves the "yellow bodies" in the intestine.

Fig. 69. Nodule Disease of the Gills in a one-summer Carp. Farina sized, white cysts between the rows of gill lamellae.

Fig. 70. One-year Rainbow Trout with Rotary Disease. Shortened jaw, curvature of the spinal column and black coloration of the tail from the vent onward. (According to Schaeperclaus, 1931.)

Whirling Disease. The instigator of this most dangerous and economically most important disease of the brood of rainbow and brook trout, Lentospora cerebralis, is a very small sporozoa, whose spores have a diameter of about 8 mu. In contrast to the previously mentioned sporozoa which occurs preponderantly on the skin and gills, Lentospora is parasitic only in the interior and especially in the juvenile cartilages of the entire skeletal system. If the disease is once introduced, the bottoms and water of all ponds in which rotary diseased trout were formerly kept, become infected by the spores which are easily carried about by the water and are resistant to dryness and frost. Once the disease has been introduced it is extremely difficult to eradicate again.

The spores are stirred up from the bottom by the inflow water. They invade the newly set-out brood, especially when the broodlings are crowded at the overflow and come into intimate contact with the through current. The sporozoa then migrate into the most varied cartilages of the body, which they more or less destroy. In the course of about 40 to 60 days with rainbow trout brood they can arrive at the cartilage adjacent to the hearing and equilibrium organ. This causes injury to the functions of the adjacent nerves: the typical rotary movements which have given the disease its name, then occur. Almost at the same time remarkable black colorations of the tails occur for the first time, later deformities, spinal column curvatures, gill cover and head shortenings, etc. (see Fig. 70) occur. With brook trout, latent infections and black colorations occur most frequently, and rotary movements occur with less frequency.

In the autumn, about from October onward, spores develop in hardening and ossifying cartilages at the infected places. With the perishing of the infected trout, the soil from then on becomes again sown with spores. The healed-up fingerlings and older fishes are accordingly always the conveyors and distributors of the rotary disease, the germ carriers, without being sick themselves any longer. For with the increasing hardening of the cartilage, it is simultaneously the "feeding time", and thereby a goal is set for the activity of the lentospora. Naturally a very special danger lies in this phenomenon: It is not possible for the pond manager to determine whether a purchased, seemingly healthy fish is not a spore carrier and will sow the pond bottom with spores on perishing. Schaeperclaus, who recently exhaustively investigated the disease, emphasizes, that there is no panacea against the rotary disease, but that the correct application of the following precautions make a successful control possible:

(1) Avoidance of the taking in of fishes of every kind and size from fisheries or waters with rotary disease.

(2) Avoidance of the purchase of very far developed eggs from managements with rotary disease.

(3) The rendering innocuous of all trout healed from rotary disease, at least growing them in ponds which are in no kind of connection with the brood ponds.

(4) Brooding of the trout in spore-free water, if possible not coming out of ponds.

(5) Feeding in nursery ponds, in spore-free water during at least four weeks.

(6) Further brood growing in thoroughly calcium cyanamide (see Chapter VIII) treated ponds, having the least possible through flow.

(7) Complete separation of the brood ponds from the mast ponds, feeding directly out of brooks, never out of mast ponds, exclusive use for brood growing. Fishing out of the brood ponds by the end of September at the latest, keeping them drained until the next growing period.

2. Worm Parasitic Diseases.

Blood-worm Attack. The trematode worm Sanguinicola of up to 1 millimeter size very frequently occur in two forms, (S. inermis) with carps, and (S. armata) with tenches, and especially in the onion-like appendage of the aorta at the heart. Its eggs laid in the height of summer migrate with the blood into the gills and kidneys. Strong collections of eggs during the time from July to autumn cause frequent diseases and all sorts of secondary diseases with the carp brood. The larvae of the blood-worm bore through the gills and then as free-swimming ciliated larvae they penetrate into snails (Limnea-species). Here they develop into migrating larvae, tail bearing cercaria, which in turn again seek out fishes and there develop into the sex ripe worm. The destruction of the snails by draining and liming the ponds is therefore the most promising way for the control of the blood worm.

Worm Cataract. Worm cataract causes greater losses especially with trout brood. The instigators are the larvae of the trematode worm Hemistomum spathaceum which the trout preponderantly serves as the second intermediate host, whereas the snails (Limnaea) are the first intermediate hosts. In the snail the migratory larvae with forked tails, so-called fork-tailed cercaria are developed, which seek fishes swimming about freely in the water. According to Wunder (1926) they can remain alive in the water for only about a day. Carps of 5 centimeters length in small brooks can succumb in 15 to 30 minutes to the mass attack of forktail cercaria. With a weaker attack the larvae migrate to the eyes of the fishes and attack the lens chamber and the lens. The larvae on penetrating the fish have cast off their tails. The attack on the lens causes cloudiness and thereby "worm cataract". The blind fishes grow more poorly, perish in part, and fall easy victims to fish foes. The main hosts of the worms are gulls and other water birds. Since a sufficient eradication of the snails is often not possible in trout growing fisheries, it also becomes necessary to keep birds at a distance in order to control the disease.

Dactylogyrus diseases. The trematode worms of the genus Dactylogyrus are probably the most frequent gill parasites of the pond fishes. They are of many species, and occur with all species of fishes. As with other animal parasites a weak attack is completely harmless, a stronger attack not only by D. vastator, but also by all the species named below, causes strong injuries of the fish brood according to my observations. The dactylogyrae are identified by a four-tipped head which has four black eyes, and a large posterior suction disc with two characteristically formed "central hooks".

With carps there are frequently three varieties: Dactylogyrus vastator, size up to 1 millimeter, central hooks relatively small, with two processes at the root, D. anchoratus, up to 0.6 mm. long, central hooks very large, one root process, and D. minutus, up to 0.5 mm. long, central hooks relatively small, two unequally long root processes.

Dactylogyrus minutus is found above all in the autumn in larger carps and locates on the upper end of the gill lamellae, D. anchoratus is found throughout the entire year in large and small carps and locates in the middle of the gill lamellae, D. vastator attacks the gill ends and occurs preponderantly in the summer with carp brood. With tenches, I have often observed D. macracanthus, which is up to 1 mm. long and has two large central hooks in the adhesive disk each with two very broad root processes.

D. vastator was first described in 1924 by the Swede Nybelin, and was recognized as the main instigator of the dactylogyrus disease, the most frequent carp brood disease. Since then very much has been written about it. Nordquist believed he must conclude from observations and from experiments, that the infection of the carp brood originates from the pond bottom. Nybelin 1925, actually succeeded in proving, that with the beginning of lower temperatures (under 15°C.), D. vastator forms larger "winter eggs" which sink to the bottom, after which the gill parasites perish.

In 1929 Spiczacow pointed out, that the assumptions of Nordquist and Nybelin, which were also assumed by Wunder are not sufficiently proven. He furthermore states with justice, that even if winter eggs did occur there was no available reason to assume that the pond bottom was the only source of infection. I must also say that the few experiments of Nordquist are not conclusive. Many of my observations, such as the strong occurrence of the disease in newly constructed ponds contradict the theory of the Swede. Since the extending ponds are fished out beginning July, often even in June, it also is unexplainable how the winter eggs are to sow the pond bottom when they are first developed in September. Nordquist himself found moreover the presence of D. vastator in April in yearling carps, Wunder found it in spawn carps and in larger carps. In the winter and spring some Dactylogyrus larvae are always found on spawn carps, which can very well belong to the variety D. vastator. Finally Kulwiec in 1929 has verified, that D. vastator has free swimming ciliated larvae which just like Costia and other parasites which set in with D. vastator, can invade the brood ponds or can transfer from parent fishes to the brood during the spawning activity. Of course, they are not capable of living long.

Fortunately it has been shown from my own investigations, also from those of Buschkiel, Wunder and other authors in many pond fishery operations (Schaeperclaus, 1930) that the degree of illness through D. vastator depends in the most part upon the general conditions of environment and nutrition for the brood, in short, upon the resistance power of the brood. The mass mortality toward the end of the nursery period are explained simply from a shortage of nutrition, caused in part by the flight period of Chironomus flies or midges (see Chapter IV,B,2). The disease becomes dangerous almost exclusively only to carp brood of 2 to 6 cm. (0.79 to 2.37 inches) and occurs mostly at the end of June and in July. There may be a few isolated harmless worms but also several hundred deadly active worms parasitic on one small carp. The gill covers are often visibly spread, the gill rims appear gray. D. anchoratus, Costia and other gill parasites very frequently contribute to rapid aggravation of the disease. As Wunder showed for the first time, the gill lamellae react to the dactylogyrus attack by forming thin processes up to 1.8 mm. in length. Wunder's assumption, that this causes the disappearance of the parasites, seems doubtful to me, however. With carps of over 6 to 7 cm. (2.36 to 2.75 inches) length, D. vastator probably no longer plays any practical part as a disease instigator, as I have repeatedly observed.

Based on these above mentioned conclusions, the following measures for the control of dactylogyrus are to be recommended:

(1) Bathing of the spawners in a 2.5 percent solution of table salt (see Chapter XV,E,1) before setting them in the spawning ponds and the immediate removal after the egg laying.

(2) Water feeding of the brood extension ponds from nonstocked waters, if possible not out of carp ponds. Keeping out of invaders, which are mostly parasite carriers.

(3) Good care and correct stocking of the brood ponds, especially of the carp brood nursery ponds (see Chapter IV,B,2), for the provision of an excess of natural nutrition. The brood must have grown to a length of at least 5 to 6 cm. (2.0 to 2.36 inches) within four weeks. Immediate transfer of the extended brood in case of food shortage.

(4) The bathing of the brood in salt baths (see Chapter XV,E1) is quite useless, because it is hardly possible to carry out practically. If bathing is done, the brood should be placed in the best ponds immediately thereafter.

Strapworm attack and attack by several other parasitic worms. Although strapworm larvae (Ligula simplicissima) occur mainly in fishes out of lakes, they are also not exactly rare in larger fisheries with tenches and crucian carps. They also occur occasionally in carps. They live between the viscera of the abdominal cavity, retard the growth and make the fishes more or less unsalable. The principal hosts of the strapworms are fish-eating water birds. Within two days the worms become sex ripe in the birds' intestines. The ciliated larvae creep out of the eggs which are carried into the water with the bird feces. The second larval stage lives in copepods, the third in the abdominal cavity of the fishes. The methods of control are the control of fish-eating water birds and refraining from feeding sick fishes to water birds.

A similar, but annulated strapworm (Schistocephalus dimorphus) lives only in the three-pointed stickleback.

The second stage of the strapworm Triaenophorus, whose principal host is the pike, has occasionally led to liver diseases with trout, the so-called cysted liver.

The very frequent Acanthocephala (Echinorhynchus and Neorhynchus) about 0.5 to 3 cm. (0.2 to 1.2 inches) long, whose larvae live in the food animals of fishes, when present in great abundance in the trout intestine can cause intestinal inflammations.

Fish leech attack. The fish leeches, which are about 4 to 5 cm. (1.57 to 2.0 inches) long, are true blood sucking parasites. They live upon the skin of fishes and of batrachians. With both terminal suction cups, they attach themselves so firmly to the fish that they can hardly be removed without injury to the skin. When they have become satiated with blood, the fish leeches leave the fish for a while, at least for the repeated laying of eggs which occurs in the period from May to autumn. In Germany there are three species of fish leeches of importance: Piscicola geometra, Hemiclepsis marginata and Cystobranchus respirans. According to the investigations of Herter, Piscicola in its free life remains especially in close vicinity to the bottom on account of its stimulus physiological mode of reaction. There it takes up a kind of ambush position: With the large hind sucker it attaches to fixed objects, the remaining body is straightly extended and free. Fish slime is acented by the fish leeches, at least in the close vicinity. Hemiclepsis lives more in medium deep and in shallow water. The result of this difference is that Piscicola occurs mainly and more frequently on large carps, Hemiclepsis preponderantly on extended broodling carps and on one-year carps. Cystobranchus (spined leech) is a West and South German genus, which was also found in Thuringia, but it is generally of lesser significance in the pond industry.

While the mating may still take place upon the fish, Piscicola and Hemiclepsis deposit their eggs only on fixed objects. Hemiclepsis covers the eggs with its body and later carries the hatched embryos about on its abdomen. Piscicola deposits the eggs individually in hard shelled cocoons which are extraordinarily resistant. Strongly infested ponds must therefore be limed with caustic lime after the draining in order to destroy the cocoons (see Chapter VIII).

The leeches themselves can endure dryness for a short time only. During the free life Piscicola can starve for up to three months, Hemiclepsis up to ten months.

With stronger water currents, Piscicola is carried along in an inactive state by the current. Therefore the leeches accumulate, often in large quantities, in front of the sluice box during the draining of ponds and then attach themselves firmly on the fishes.

The fish leeches, next to the carp lice, are the parasites probably most frequently observed by the pond operator, and which occur in the pond fisheries in general. The injuries caused by them together with all the secondary manifestations are about the same in kind and degree as with carp louse attack. Only poisons are not given off by fish leeches. But to offset this, they are more injurious in other respects than are carp lice: they transmit the blood parasite Trypanoplasma (see Chapter XV,E,1).

The control and destruction of the parasite attached to the fish is the same as with the carp louse and is accomplished most conveniently and safely by the lysol bath.

3. Crustacean-parasitic Diseases.

Carp-louse attack. The carp louse (Argulus foliaceus) which is about the size of a lentil, is like the fish leech, a blood serum sucking skin parasite of the pond fishes and also of the water batrachians and their larvae. It is a crustacean, no insect, which latter could be supposed from its name. With stronger attacks on the carps and tenches, the carp louse becomes especially burdensome by the strong restlessness of the fishes and the skin destruction which leads to redness, mold invasion and bacterial infection, to attack by one-celled skin parasites, and even to the formation of wound pocks at punctured places. A weak attack is mostly not injurious to the fishes. Only small brood suffers from even a few punctures and from the simultaneous elimination of poisons into the skin with resultant severe pain. The brood may perish rapidly. Spawn fishes are therefore to be carefully freed of carp lice. On larger fishes, and of course, especially on tenches, I have found thousands of carp lice, without it having caused the death of the fishes.

The carp louse leaves the fish to mate and deposit the eggs. It can even live without a host for about three weeks during the height of summer. Its stimulus-physiological behavior to light and gravity causes it to remain near the shore about 5 to 10 cm. (2 to 4 inches) above the bottom, as Herter has shown. Here, of course, also live the hosts, the fishes, for which the carp louse does not possess a special scenting power operating at a distance. The eggs are deposited in small groups of up to 20 eggs or in bands of up to 250 eggs on fixed objects. In April, according to Herter, the development lasted about 45 to 55 days, in July 28 to 30 days until hatching. Four weeks after hatching the progeny are sex-ripe.

The eggs deposited in the pond, as well as the parasites also, may be easily destroyed by a draining of less than 24 hours (Loojen). The parasites can also not endure freezing for a few hours. A rise of the pH value by liming to over 9.8 likewise causes certain destruction. The parasitee may be most simply and completely removed from the fish by the lysol bath, for which Schaeperclaus gives the following directions.

Bathing directions for Lysol baths.

1. Fishes to be freed of carp lice are caught in a basket net. The basket net must not be smaller meshed than necessary and must not be filled too full in order not to hamper the free movements of the fishes when dipping.

2. The basket net with the fishes is dipped for 5 to 15 seconds (according to the size of the fishes) into a previously prepared 0.2 percent lysol solution. The dipping time is to be verified as exactly as possible by counting (21, 22, 23, etc.) or by means of a second timer. The lysol solution is best placed in a large, not too shallow, wooden tub, in which 2 cc of lysol are dissolved in each liter of water (2.43 fluid ounces of lysol in 10 gallons of water). The occurrence of a slight cloudiness is without significance.

3. After taking it out and draining off the lysol solution, the net is placed in the largest possible tub containing clean pond water. If larger quantities of fishes are to be bathed it is an advantage to have numerous tubs with clean water on hand, because the loosened carp lice swimming about in the water must be killed from time to time by the addition of caustic lime or lysol. Besides this it is to be recommended that the net should be briefly and vigorously rinsed in several tubs.

4. The bathed fishes are dumped on a sorting table and any remaining carp lice are removed with soft rags or soft brushes which have been saturated with some of the same 0.2 percent lysol solution. (In some cases partial dipping of the fishes is done in evaporating dishes containing lysol solution). Blunt tweezers may also be used to remove occasional especially contrary parasites.

5. After this the fishes are placed in another pond, ih the hibernation pond or --if they are to be sold-- in the reservoir. Temporary storage in strongly flowing water has a special advantage. As with all baths, temperature variations are to be avoided in transfer procedures.

Cases occur, where fishes are so strongly infested that it is advisable to undertake an emergency fishing out and to use the lysol bath, even in the middle of summer. Cramps, which may occur with the bathed fishes, disappear in the shortest time without leaving any injuries.

No fishes which are infested with carp lice or fish leeches must get into the hibernation ponds: The parasites would not let the fishes come to rest. Beside the carp louse, Chilodon especially is destroyed and removed by the above mentioned lysol bath. Costia, Cyclochaete and Gyrodactylus are more resistant.

Ergasilus disease. The "gill crustacean" Ergasilus sieboldi belonging to the family of the Copepoda, and parasitic on the gills of various fishes (especially of tenches, pikes, and bleaks is predominantly a parasite of lake fishes. In the most recent years it has almost completely destroyed the tench stocks of many lakes. Hitherto it could justly be said of tenches from ponds, that they are quite safely free from Ergasilus. But recently I have also found more and more Ergasilus on the gills of tenches even in several very large pond industries. Lehmann found quite a strong attack of Ergasilus sieboldi among rainbow trout. The pond operator must furthermore carefully

Fig. 71. Application of the lysol bath on two-summer carps in the large fishery. Large quantities of fishes can be bathed in a short time.

watch this dangerous parasite, since tench stock attacked by Ergasilus will be unsalable in the future. Ergasilus is about the size of a pinhead and in the spring it develops two small streak-like egg sacs on its hind end. From the eggs are hatched free swimming larvae, which again attach themselves on the gills (Neuhaus), especially in the height of summer. With a strong attack of one hundred to several thousand parasites, severe gill injuries and mold invasions occur even in larger fishes, which can lead to emaciation and asphyxiation.

All infected fishes must be removed, and in particular no parasite carrier must be present in tench spawning ponds, and the brood must not be later kept with infected fishes.

F. General Viewpoints for Combating Fish Diseases.

The foregoing detailed discussions of the most important pond fish diseases, show how closely related the comparison of diseases of fish and plant (as stated in Chapter XV) is to the combating of fish diseases also. The treatment of individual sick fishes plays no role, mass treatments of fishes cannot often be applied because of the small capital value of the individual animal and the difficulties of handling them.

More important therefore is the isolation of the resulting disease foci, the prevention of disease spreading by the rapid destruction (cremation or burial) of all dead and diseased fishes, of all disease carriers (snails, for example) immediately after the fish out.

Of the greatest significance, however, is the prevention of disease occurrence. This must begin with the selection of particularly disease-resistant parent fishes. The favorable hereditary factors are to be brought to development and to be further strengthened by the provision and maintenance of the best living conditions in summer as well as winter, by the best pond care, careful hibernation and feeding, protective handling of fishes with all transplantations. Finally it is the task of the manager to prevent the introduction of diseases if possible and the transfer of disease from one year to another by shutting off the ponds against wild fishes, systematic, well considered manner of brood growing, by keeping away of fish eating water birds and by caution in the purchase of fishes.

No other expedient can have the same high success as the prevention and control of fish diseases, without increased expenditures for the supply of food, fertilizer or labor. It thereby tends to increase the yields and forms a more economic management.

I shall emphasize in conclusion, that no fish diseases hitherto known are transferable to human beings. All sick, but still fresh fishes which must be removed from ponds for the control of parasites, may be made useable for human nutrition.

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ABBREVIATIONS

B	signifies:	Brook (brown) trout, as to the significance of B_o, B_1, etc., see C_o, C_1, etc.
gcal	"	Gram-colorie
C	"	Carps
C_o	"	Carp vitelline-sac brood
C_v	"	Carp pre-extended (nursling) brood
C_1	"	one-summer carps
C_2	"	two-summer carps, etc.
C_{1-2}	"	one-summer set in, two-summer fished out carps, etc.
Kcal	"	Kilogram-calorie
mu	"	micron = $\frac{1}{1000}$ millimeter.
n	"	Normal, e.g. $\frac{n}{10}$ HCL = $\frac{1}{10}$ normal hydrochloric acid
pH	"	pH-Value, q.v. Page 50
R	"	Rainbow trout, as to the significance of R_o, R_1 etc. see C_o, C_1, etc.
T	"	Tenches, as to the significance of T_o, T_1, etc. See C_o, C_1, etc.
A.C.V.	"	Hydrochloric acid combining power, see Page 53
No. 40 fishes	"	40 approximately equal sized fishes of this sorting weigh 50 kg (1 hundred-weight, cwt.).

Conversions of areas, weights, measures and monetary values have been based on the following equivalents.

1 are = 100 square meters = o.0247 acre = 1076.36 square feet.

1 hektare = 2.4709 acres. 1 acre = 0.4047 hektare.

1 dz = (double zentner) = 100 kilograms = 220 lbs. (Avd.)

1 liter = 0.2642 U.S. gallons = 1.057 quart.

1 U.S. gallon = 3.7854 liters.

1 Reichsmark (R.M.) = $ 0.238 U.S.