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SELECTIVE BREEDING OF CARP and INTENSIFICATION OF FISH BREEDING IN PONDS

(Selektsiya karpa i voprosy intensifikatsii prudovogo rybovodstva)

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Edited by A. Isseroff

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PREFACE

This volume of the Bulletin contains articles on various problems of pond pisciculture. The first section is devoted to the genetics and selection of carp. This field of fishery science was greatly harmed in the USSR after 1948 by the monopoly given to T. D. Lysenko's conceptions, which forbade study of the genetics of commercial fish. The assumptions that new breeds of fish could be produced in an unusually short time (V.A. Movchan), that the characteristics of a breed could be shaped rapidly by educating (F. M. Sukhoverkhov), etc., dominated the field of selective breeding.

Nevertheless, work on selection and hybridization of carp continued, albeit under very difficult conditions, in several parts of the Soviet Union: in the Ukraine, the Moscow Region, the northwest regions of the RSFSR, and in Belorussia. During this period, work on creating a Ukrainian breed of carp was completed (A. I. Kuzema,UkrNIIRKh). Many fish breeding farms conducted large scale carp-"eastern carp" hybridization, producing large numbers of 1st generation hybrids. Work began on creating a new hybrid breed of carp which could withstand the severe conditions of the north-western districts of the Baltic, northern Belorussia, Karelia, and Western Siberia, by a research team under V. S. Kirpichnikov (GosNIORKh). Concurrently, Poliksenov (BelNIIRKh) conducted some fundamental investigations in the selection of local mirror carp in Belorussia. The investigation of D. D. Romashov, K. A. Golovinskaya, and their colleagues (VNIIPRKh and the Academy of Sciences of the USSR) on gynogenesis in crucian carp and carp should be noted also. Recently, A. I. Kuzema (UkrNIIRKh) succeeded in crossbreeding carp with 2 species of crucian carp and produced fertile hybrids by selection.

At present, the end of dogmatic concepts and authoritarianism in science points up the urgent need to summarize the accumulated experience of selective breeding in carp pisciculture. The primary aim of this collection is to state the theoretic principles of carp selection. Several articles deal with the theory of selective breeding, drawing both on the experience of Soviet scientists and on the comparatively scant non-Soviet literature on this problem.

Hitherto, Soviet scientific and applied science journals have not discussed characteristics of the various breeds of carp raised in the USSR, and data on carp genetics were ignored for a long time. To fill this gap, we have included an article by Kirpichnikov and Golovinskaya, which briefly describes the major breeds of carp in the USSR and the main genotypes, and tabulates the most important hybrids.

The first part of the collection also includes articles on variability of carp as well as on intraspecific and interspecific hybridization and heterosis. Articles on the organization of fish breeding in the northwestern

RSFSR end the section and vindicate the policy of dividing fish breeding farms into three types: research stations, fish breeding nurseries, and commercial fish farms, first proposed by GosNIORKh and VNIIPRKh.

The second, briefer, section of this collection consists of articles on intensification of pond pisciculture. V. P. Lyakhnovich lists the essential principle of classifying ponds according to their biological productivity. Zlokazov and Ignat'ev discuss the state of carp breeding and the outlook for its development in Siberia. Two studies report fish pond diseases and control measures. Konradt and Sakharov report a new commercial method of hatching larvae of carp and other thermophilic fish, involving removal of the egg from its surrounding mucous envelope and incubating it in special apparatus. The method is being tested in reservoir hatcheries and in some fish-breeding farm ponds, and offers much promise.

Sergeeva presents data on the food intake of fingerlings of northern hybrid carp. These data are useful in determining the optimum stocking density for ponds in the northwestern RSFSR.

We hope that the collection will be useful both to pond pisciculture specialists and to pisciculturists in general. The articles on genetics, selection, and breeding are very important; there is a great need for serious scientific literature on these problems now.

The lag in selection and breeding should be overcome as soon as possible because it hampers the further development of pond pisciculture in the USSR. This collection is intended to remedy the present situation.

Part One

SELECTIVE BREEDING OF CARP

GOALS AND METHODS IN CARP SELECTION

V. S. Kirpichnikov

Introduction

Carp pisciculture was known in Europe over 6-7 centuries ago. The ancestor of the cultivated European carp was the Danube wild carp, which still inhabits the Danube and its adjacent lakes. Pisciculture is most ancient in China, where it began about 2000 years ago. Carp cultivated in the People's Republic of China apparently belong to 2 East Asian subspecies of wild carp (Cyprinus carpio haemotopterus Temm. et Schl. in eastern China and C. carpio viridiviolaceum Lac. in the south; see Berg, 1949). In contrast to most East European countries, China stocks carp now as a secondary fish in ponds occupied by 2 species of grass carp and by 2 species of silver carp.

In addition to its culture in China, carp is also raised in the following Asian countries: Vietnam,* Laos, Korea, Japan, Indonesia, Malaysia, and the Philippines; and recently, Israel's carp breeding has been progressing fast (Jones, 1956).

Although carp was introduced into the western hemisphere at the end of the last century, very little selective breeding is done there as yet. To date, Africa has done only experimental work with carp.

European cultivated carp differs from its ancestor, the Danube wild carp, in that it grows faster, has a different body shape, larger mouth, and elongated intestine, and utilizes vegetable food mixtures better (Schäperclaus, 1958; Rudzinsky, 1961). Even though these differences are well established and carp has been cultivated in ponds for centuries, unlike domestic animals, pedigreed and well studied breeds of carp in Europe were not established there until recently.

In the East, so far as can be determined from scarce and incomplete information, local breeds of carp exist in Indonesia, on Java (Buschkiel, 1933, 1937; Jashouv, 1955; Steffens, 1962), in some districts of China (verbal communication by Kozhin), and in North Vietnam (verbal communication by Chen Din Chzhong). As yet, no detailed descriptions of these breeds have been published.

In the USSR, a group of Ukrainian geneticists headed by A. I. Kuzema (UkrNIIRKh) received the State Prize for the 2 new breeds (frame-scale and scaly Ukrainian carp) resulting from more than 35 years' work on

* The carp collected in 1963 in Vietnam by Chen Din Chzhong, which we have examined, apparently belong to the subspecies C. carpio viridiviolaceus Lac. , which differs distinctly from the typical C. carpio L. in its small number of scales, long barbels, and other features.

their creation. Work continues on creating a new northern hybrid breed of carp ("Ropsha" northern hybrids) in the Leningrad, Pskov, and Novgorod regions of the RSFSR. Selective breeding programs have been initiated in other areas of the Soviet Union also, particularly in the western Ukraine (Kuz'oma, 1962b). In all these areas, however, including the Ukrainian, the resulting breeds should be considered transitory rather than completed and established. The work continues, and at best, several more or less separate breed groups can be distinguished (Kirpichnikov and Golovinskaya, present collection).

In the several centuries in which Europe has been breeding carp, insufficient attention has been paid by pisciculturists to selection of carp, as well as to the methodical and technical difficulties involved in selective breeding. These are major reasons for the lack of true breeds and the comparatively slight improvement in the commercial qualities of carp. Mass selection was almost the only method of selective breeding applied and while it may be quite effective, provided that selection is highly intensive and selected fish are tagged and separated, even these requirements were usually not observed. As a rule, selection was not strict enough, and the selected carp got mixed with others. The efficiency of mass selection was lowered also by the low heritability of the desired properties.

In the past, the exterior of carp changed more rapidly than did the growth rate, probably because the external characteristics were more heritable. These changes did not induce substantial improvement in commercial qualities, however.

Generally, in Asia, carp has been raised without selective breeding so that there has been little improvement despite 2000 years of carp breeding experience. Indonesia was most successful in developing several breeds of carp varying in coloration, body shape, and type of scale cover (Huet, 1956; Steffens, 1962).

Pond pisciculture is developing very rapidly in the USSR, and an acute need has risen for improving and intensifying selection of carp, which can be met only by applying modern, more efficient methods of genetic selection.

Several reviews of these methods have appeared recently (Shaskol'skii, 1954; Schäperclaus, 1955, 1958, 1961; Kirpichnikov, 1957, 1958a, 1958b, 1959a, 1959b, 1960a, 1960b, 1960c; Moav and Wohlfarth, 1960, 1963; Wohlfarth, Moav, and Lahman, 1961; Kuz'oma, 1961, 1962a; Stegman, 1956b, 1957, 1959; Kirpitschnikow, 1961).

In addition to the USSR's programs, intensive selective carp breeding is done by Poland, East Germany, Israel, and North Vietnam. This article attempts to summarize the results of recent selection experiments and considers the application of modern selection methods to carp raising and improving selective breeding.

Goals of carp selection

Today, the main goal of Soviet pisciculture is to increase the productivity of carp ponds. The planned goal of commercial production from pond farms of 7-8 million centners [1 centner = 100 kg] by 1980 can be reached only by raising the average productivity of ponds to 10-12 centners per hectare.

This may be accomplished by improving the ponds, introducing polyculture, and improving the breed. We shall consider only the latter approach here.

The following are the most important methods of selecting carp:

1) Creating breeds that utilize food more efficiently for growth, i. e., have higher conversion ratios.

2) Creating breeds that can eat a maximum of the food present in ponds.

3) Improving the taste and lessening the proportion of inedible body parts so as to improve marketability.

4) Creating breeds resistant to such unfavorable environmental factors as oxygen deficiency, extreme temperatures, etc.

5) Creating resistance to parasitic and infectious diseases, especially infectious dropsy.

Polyculture has recently become more popular in carp breeding farms. Thus, selection method 2 of the foregoing does not appear to be applicable at present. Optimum food consumption is undoubtedly profitable, but the easiest way to achieve it is by stocking several breeds in the same pond.

Although improving marketability of carp is very important, selective breeding for characteristics leading to that state is quite complicated and is not likely to achieve rapid results.

Apparently, the selection work should focus primarily on optimum conversion ratios and tolerance of unfavorable environment. However, in different countries with various climatic zones, desirable selection traits may be quite different. Thus, in the northern USSR, we must develop breeds that feed and grow well at low temperatures and work out means of speeding up maturity and increasing fecundity. On the other hand, more southern countries, e. g., China, Korea, Vietnam, Israel, and Japan, must develop breeds which are more tolerant of heat and mature late (Kessler et al, 1961). Carp pisciculture in the Transcaucasian and Central Asian republics will probably have similar needs.

All these general and specific needs can be satisfied quickly by using new and more efficient selection methods and by proper application of the old, tested method of character selection. We shall first consider, and then attempt to evaluate, various methods of selection.

Methods of selection

1. Mass (character) selection

In character selection, only specimens with the most wanted characteristics are allowed to reproduce (according to phenotype).* In fish farms, selection according to weight and length is easiest to carry out. Selection by external characteristics requires a clear understanding of which habitus is the best, but this is not a simple matter. Selection by viability is efficient when special conditions (increase in the relevant factor) exist, in which only a few of the most resistant specimens would survive. Direct character selection on the basis of conversion ratio, etc. is technically very difficult. These characteristics are improved, however, by selection for rapid growth. Because selection by biochemical composition of the meat and its taste

* In the English selective breeding literature (Falconer, 1960) this is often called "individual selection."

qualities is even more difficult, these characteristics can be improved through other methods of selection. The simplicity of selection by growth rate is rather illusory, however.

The efficiency of selection (R) is known to depend on selection differential (S) and heritability (h^2):

$$R = S \cdot h^2. \quad (1)$$

Selection differential, i.e., the difference between the arithmetic mean of the selected group of specimens and that of the initial population, can be increased by increasing the variability or by stricter selection, i.e., by reducing the number of specimens preserved for breeding. We shall deal with the former method somewhat later. Because of the great fecundity of commercially raised carp, the strictness of selection may be up to 1% (keeping 1 specimen out of 100) and sometimes even up to 0.1% (1:1000). More stringent culling is usually impractical as it does not guarantee a sufficient number of specimens.

As to heritability , the matter is more complex. Index of heritability h^2 is determined by the formula:

$$h^2 = \frac{\sigma_A^2 *}{\sigma_P^2}. \quad (2)$$

where σ_A and σ_P are respectively r. M. S. Variance [S. D.^{2}] of the distribution of additive genotypic variability and of the phenotypic variability of the selected character. Heritability of differences in weight is low in carp; according to our data it does not exceed 0.20-0.30 (Kirpichnikov, 1958a, 1959a), and according to other researchers, it is only 0.09-0.18 (Moav and Wohlfarth,1963). There are reasons to assume that heritability of weight in the group of "record breaking" fish, distinguished by their faster growth, is still smaller (Nakaroku and Kasahara 1955, 1957; Moav and Wohlfarth, 1963). In this situation, heritability selection acts very slowly; h^2 can be increased either by increasing genetic variability (σ_A^2) or by decreasing phenotypic variability

1) Genetic variability may be increased by sufficiently remote matings (outbreeding) utilizing spawners from unrelated populations, including crossing of various breeds, groups, and subspecies. Schäperclaus (1961) recommends mass crossings of carp by breeding 10 females and 10 males simultaneously to increase genotypic variability. In artificial insemination, the sperm of many males can be applied to the eggs of several females.

2) The phenotypic component (0_p^2) may be reduced by decreasing the paratypic variation through breeding conditions. With carp, these are:

a) Spawning as rapidly and continuously as possible, even simultaneously, and fertilizing artificially. Either method is aided by pituitary extract injections.

b) Maintaining incubation conditions (temperature, light, water circulation, etc.) as uniformly as possible.

c) Establishing uniform conditions for raising the young. Thus, large

Instead of 0_A^2 ,some investigators use a summative variance for the entire genotypic variability (σ_G^2) which usually is slightly larger than the additive variance, i. e. , variance of the sums of the genetic differences. For approximate calculation of heritability, the replacement of one variance with another is usually permissible (Lerner, 1958; Falconer, 1960; Plokhinskii, 1962).

ponds (100 hectares or more) are unsuitable because they tend to allow fish to form subpopulations.

d) Keeping fish of different ponds and age separate until after the selection period.

e) Ensuring adequate and good food supply to minimize competition.

The foregoing requirements are designed to keep to a minimum differences resulting from environment or competition. The role of food competition is particularly significant. An analysis of weight variance of carp raised in one pond (Moav and Wohlfarth, 1963) showed that the paratypic component of variability influenced by interrelations between individuals ("social" interactions) was very large because the effect of individual differences accumulates. Larger specimens have an initial advantage in food competition, thus growing faster than the others. Japanese researchers found that removal of the markedly larger "record breaking" carp from high density ponds led to their immediate replacement in the ecological position by others which then grow much larger than carp of the same age group (Nakaroku and Kasahara, 1957). Kryazheva (present collection) discovered that an increase in population density when food is scarce appears to increase the coefficients of variability of weight and external characteristics. Under starvation conditions, larger carp larvae take food away from smaller larvae, causing the latter to stop growing. The initial distinctions that cause this differentiation, however, and the subsequent low heritability of weight in carp, are caused largely by early environmental differences. Thus, competitive conditions increase phenotypic variability, and hence decrease heritability.

The initial difference may also be due to genetic variety, i. e., presence of genes that influence growth differently. If so, the extent to which differential hereditary factors are expressed will be somewhat dependent on the influence of environmental factors, i. e., abundance of food supply. Some observations indicate that for carp, this dependence correlation is small. The confirmation of these observations would not invalidate what has been said about the need to lessen food competition prior to selection.

Even if all possible steps are taken to minimize food competition, and even when all the aforementioned conditions are fulfilled, variability of carp both in weight and in external appearance remains fairly high. Even fingerling carp from one paired crossing, raised in one pond under the most favorable conditions, exhibited variability in excess of 20% (Kirpichnikov, 1959a). Undoubtedly, random nonheritable differences account for most of this variability. Because it is difficult to obtain a substantial increase in weight heritability in carp without hybridization, efficient selection depends primarily on genetic heterogeneity of the original population and on strict selection.

For purposes of illustration, indexes are given of the following values: average weight of fish (M)— 600 g; standard deviation $(\sigma)-90$ g (15% of average weight); strictness of selection $(P)-0.1\%$ (1:1000); heritability of differences in weight $(h^2)-0.1$.

Assuming normal variation, the selective improvement of this generation will be about 30 g. If the calculated value is halved to account for the possible influence of various random factors which diminish the efficiency of selection, 10 generations of selection should produce approximately 25% acceleration of the growth rate of yearling carp. This would be a great improvement; unfortunately, the history of carp culture shows that carp breeders have never attained such efficiency of selection. After several centuries of pond pisciculture, the weight of yearling carp has increased no more than 30-40% over that of wild carp.* Furthermore, this difference becomes apparent only under conditions of superabundant nutrition; otherwise, the growth rates of pond carp and wild carp are almost identical during the first years of their life (Cherfas, 1933, Kirpichnikov, 1943; Rudzinsky,1961; and others).

What could reduce the effectiveness of character selections? Excluding easily corrected errors in technique (unsuitable conditions of rearing, mixing of populations, etc.), the 4 major causes are: 1) insufficient correlation between the growth rates of carp of various age groups; 2) selection of most "aggressive" specimens; 3) decrease of heterogeneity in inbred populations; 4) increased growth rate of heterozygotes (presence of "heterozygous equilibrium").

We shall consider herewith the significance of each factor successively.

1. Selection of large carp aged 3 + or 4 + may not improve the growth rate of yearlings in succeeding generations. Similarly, selection of the best fingerlings may prove useless for the improvement of yearling and 2+ carp. Either of these situations occurs if growth at different age is influenced by different factors, e. g., sexual maturity may influence individual growth differently.

According to published data (observations of Wunder as cited by Schäperclaus, 1961), the correlation between the growth of fingerlings, yearlings, and 2 + carp is not very great. Our experiments (data not published) established the fact that exceptional fingerlings generally maintained their advantage in the second year, although some fish (10-25%) selected in the autumn subsequently grew more slowly, and joined the medial group. Conversely, about 5% of the unselected fish caught up with the exceptional fish by the end of the second year. The Polish investigator Stegman (1960) obtained similar figures.

It would seem best to select fish only at the age that is directly significant commercially. However, this is often unprofitable because strictness of selection is limited by the smaller numbers of yearling and 2 + fish in each pond. This paradox can be resolved as follows:

a) Making very strict selection (0.2-1.0%, i.e., 1:500 to 1:100) among fingerlings or yearlings after removing exceptional specimens, making a more liberal selection among the remaining fish (from 1:2 to 1:10); then, tagging and stocking in the same pond both the specimens and those selected after.

b) Making final selection from the yearlings of this pond in the autumn of the second year, keeping most of the exceptional specimens and those fish that were selected more liberally and that have caught up with the exceptional specimens.

Similarly, Schäperclaus (1961) recommends selecting about 50% in the first year, about 10% in the second year, and keeping several thousand yearlings and a few hundred 2-year-olds for breeding.

In the southern districts of the USSR and in countries with a hot climate, where carp grow fast and mature early, selection in the second year may

Steffens' (1964) data show a considerably greater difference between wild and cultivated carp; however, the wild carp used in these experiments were taken from Lake Velencei in Hungary, and it may be that their growth rate is subnormal.

prove hazardous because of sexual dimorphism connected with intensified growth of females. In such cases, selection should be made largely from the yearlings and even younger fish, before mass maturation of the males. After the second year, only separate selection of males and females is feasible.

2. Although unavoidable "errors" during selection are possible because of the correlation in the relative growth rate of the fish at different ages, these should have little effect on selection efficiency.

The second factor, inadvertent selection of aggressive individuals rather than those with the optimum conversion ratios, was probably more detrimental than was low correlation of growth rates at various ages. Moav and Wohlfarth (1963) showed that individuals that found food fastest or could take it away from their competitors were selected. Thus, differences in food assimilation and conversion ratios become of secondary significance in the face of clearly expressed aggressiveness. Increased aggressiveness of successive generations, however, will be of little use because it will increase uniformly in all individuals, and there would be no long-range improvement in weight and growth rate if fish were selected for aggressiveness only.

One way to reduce the effect of this factor is to lessen food competition in populations to be selected, guaranteeing an excess of food for all fish in the habitat. In carp breeding, however, it is impossible to eliminate entirely the effects of aggressiveness when making mass selection. Only selecting individually, i. e., assessment of progeny of families reared separately, can eliminate the influence of aggressiveness.

3. The reduction of genetic variability of carp resulting from inbreeding could have still greater significance. Inbreeding inevitably leads to homozygosis; some hereditary factors disappear completely, while others become fixed. As of present, it is firmly established that inbreeding may increase phenotypic variability (Falconer, 1960). This increase, however, is due to the organism's decreased resistance and the genetic component of variance decreases. In the past, carp were often bred in small, local populations without the introduction of new genetic material. The subsequent intensive inbreeding led to sharp limitation of genetic variability.

We know that the present German carp are descended from a few related ancestors, so that the outlook for carp breeding in East Germany is considered to be rather poor; pisciculturists believe that little increase in their growth rate will result from selection (Schaperclaus, 1961).

Careful planning can prevent reduction of genetic variability due to inbreeding.

4. One more possible cause of the low efficacy of mass selection in carp breeding can be indicated. As our experiments have shown (Kirpichnikov, 1958b), carp populations are naturally very heterogeneous. Apparently, heterozygosis of many genes is necessary for optimal carp viability and growth. Thus, several generations of selection would apparently establish a state of equilibrium (homeostasis, see Lerner, 1954). More heterozygous specimens, which would have superior qualities, would be selected. Selection of the most heterozygotic specimens, however, would only maintain the existing level of growth and viability. Further improvement could be produced only by new, sufficiently remote crossings which would increase genetic heterogeneity by disrupting the established balance.

What can be expected of mass selection in carp breeding in the long run? Improvement of such indexes as growth rate still can be fairly high if unrelated populations are used to start the breed, and if aggression can be minimized. Because the influence of aggression can be lessened by decreasing food competition, selection according to growth and weight should be made under favorable feeding conditions.

Evidently, mass selection is most effective in selecting hybrid groups of carp, including crossbreeds, and hybrids of "eastern carp."

Mass selection also may be useful for breeding for external characteristics and resistance to diseases. Breeding for resistance to infectious dropsy may be quite effective because fairly strict selection may be made in fish farms where the disease occurs. If we begin with hybrid populations, selection may be fairly efficient, at least in the 1st generation.

It is most expedient to combine mass selection and individual selection for growth, external characteristics, and resistance to disease.

2. Individual selection

We shall examine 3 of the various methods of individual selection used in animal husbandry:

1) Family selection proper (preservation of best families).
2) Family selection by sibs or sibmating (selection of sibships).
3) Evaluation of spawners by progeny.

The first 2 methods save much time by selecting evaluated progeny for raising. Because carp selection for breeding purposes by progeny evaluation takes 2 years, the selective breeding process is retarded for that period. This delay is justified because superior carp in commercial quantities can be obtained from qualified parents for many years. Thus, in 6 years of service, 1 female carp can produce hundreds of thousands of centners of fish for the market.

The following material reviews these methods successively.

Family selection. This requires several crossings, comparative evaluation of the progeny, and selection of the best progeny for further raising. Family selection is generally used when heritability of selected characteristics is low. Chief limitation on the efficacy of this method is the presence of paratypic (nonheritable) variability for all progeny. As we have seen, a very low individual heritability of growth rate (in any case, less than 0.2) is characteristic of carp. However, the progeny of each pair of carp spawners generally grow in specific uniform conditions which exert a similar influence on all the members of that group. Therefore, interfamilial genetic differences are less easily manifested. This reduces heritability of family mean values, and hence, the efficacy of selection.

From the very beginning, life conditions for all families being compared must be as similar as possible to minimize interfamilial variability. The following techniques of family selection are suggested:

a) producing 20 or more crossings at one time by means of artificial insemination; females must be of uniform age and come from uniform conditions of raising;

b) removing the mucous coating from the eggs, which should be incubated separately in Weis microapparatus or in crystallizing pans under similar conditions; each group to be incubated in at least 2 incubators to provide statistical balancing;

c) raising larvae in large aquariums, basins, or small (50-100 m^2) ponds until they weigh 300-500 mg; progeny of different mates to be raised in different ponds which are similar in dimensions, depth, and density of stocking, as well as with uniform feeding conditions, so that statistical balancing is possible;

d) stocking the tagged progeny jointly or separately in ponds after they have reached a uniform weight and are aged **1+.** Joint raising requires fewer ponds but is complicated by food competition among fish, particularly dangerous when great initial differences exist. About 10 ponds are required for double and triple replication of the study so that 5-6 progeny groups of 20 crossings can be raised jointly in one pond at a time. Separate rearing is preferable, but has not been possible to date because it requires 60-80 experimental ponds.

Technical difficulties in family selection force us to seek alternatives, one of which is combined mass and simple family selection.

Combined (mass and family) selection. Combined selection finds little application in animal husbandry because its usefulness is limited by the low fertility of domesticated animals. However, in carp breeding farms, the great number of offspring of one crossing allows simultaneous mass and individual family selection.

The following scheme of combined selection appears to be the most expedient:

a) Mass crossings of unrelated spawners to yield maximum initial heterogeneity.

b) Stringent mass selection among progeny for raising with abundant food.

c) Crossbreeding 5-6 pairs of the best progeny of the 1st generation.

d) Raising 2 families of the best 2nd generation progeny after careful comparison nf all 2nd generation progeny by results of their raising. Separate raising and triple replication require 3-4 ponds. Both in work with the 1st generation, and in joint maintenance of the 2nd generation, food competition should be minimized to avoid selection of aggressive families.

e) Mass selection should be made among the 2 best families in the 2nd year, when superiority will be accurately established.

At this time, 5-6 crossbreedings of the best progeny of the 2nd generation should be carried out, beginning anew the whole cycle.

This variant reduces the number of progeny crossings from 20 to 5-6, and thus, the efficacy of family selection is nearly halved. Such family selection is profitable, however, if heritability of family mean values is much greater than heritability of individual values. Effectiveness of mass and family selection is determined by formulas:

$$R_m = S_m \cdot h_m \qquad R_f = S_f \cdot h^2_f \qquad \text{respectively,} \qquad (^3)$$

where h and h^2 are the heritability of individual differences and family mean values respectively, and S_m and S_f are the respective selection differentials. If, for example, $h_m = 0.1$ and $h_f = 0.6$, then even when the

3-4 ,

$$S_f \cdot h^\circ_f > S_m h^\circ_m.$$

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evaluations were based on the growth of larvae in aquariums. Figure 1 is the genetic diagram of this experiment.

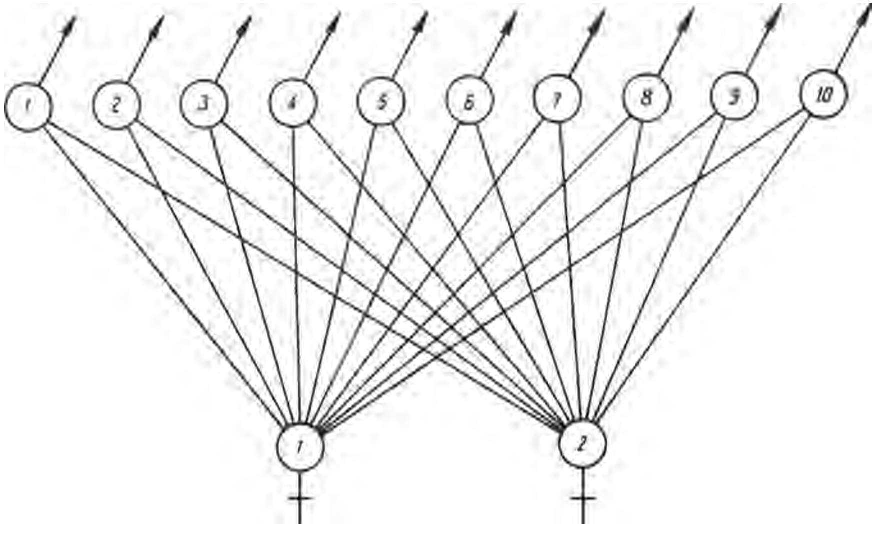

FIGURE 1. Diagram of progeny evaluation of spawners ("Ropsha," 1958).

In 1959, 1960, and 1961, we evaluated females according to their progeny (7 females in 1959, 5 in 1960, 7 in 1961) in experiments in which each female was crossed with 2 males; each of the males was crossed with all the females. Finally, a small test of males was made in 1962 again.

Briefly, the procedure was as follows:

a) The spawners were given injections of pituitary extract, tagged, and their description was recorded.

b) All eggs were fertilized under uniform conditions.

c) Eggs of each crossing were spread on gauze frames to remove the mucuous envelope.

d) The eggs were removed from the frames and placed in crystallizing pans at uniform density for incubation (replicated 3 times).

e) Until they weighed 150-300 grams, the groups of larvae were raised separately in aquariums under uniform conditions of population density and abundant food (replicated 3-5 times).

f) Fingerlings were tagged and raised jointly in ponds.

g) Yearlings were tagged and raised jointly in ponds.

Our experiments led to the following conclusions, which are significant in reference to methodology (Kirpichnikov, "Metody proverki proizvoditelei po potomstvu v karpovykh khozyaistvakh [Methods of Progeny Testing Spawners in Carp Fish Farms], in this collection):

1) Larvae should be raised under uniform conditions.

2) Larvae and yearlings from various crossings must be of uniform weight when they are stocked in their respective ponds.

3) No less than 3 replications of experiments must be made.

4) Males may be evaluated on the basis of the survival and growth of their larvae, but it is desirable to make the comparison of each year's young.

5) Females may be evaluated only by their progeny of the year and yearlings because larvae growth and survival depends largely on the egg size

6) There is a correlation between dimensions of spawners and the growth rate of progeny, although it is not always high. A particularly high correlation was found in the 1957 tests of males and the 1960 tests of females.

In Belorussia, Poliksenov (1962) conducted several experimental evaluations of parents, using the "general control" method and natural spawning. The same control fish, which were clearly distinguished from the experimental specimens by their scale cover, were stocked in each pond. Unfortunately, when applied to carp, this method presents almost insurmountable difficulties. It is very difficult to ensure the uniform mean weights of experimental and control fish in all the ponds, and it is impossible to eliminate differences among spawning ponds.

In summary, evaluation of spawners according to progeny requires artificial insemination of eggs; progeny are first compared under laboratory conditions, and then in ponds; raising of progeny must be repeated for several spawnings. Evaluation of females requires testing progeny over a 2-year period.

The foregoing indicates the complexity of evaluating spawners by their progeny. Therefore, we recommend such evaluation as an adjunct to combined selection. Before making family selections, it is most practicable to note the best males aged 1-2 years, on the basis of their progeny, and select them for spawning. Selecting males in this way before using them in crossings (5-6, as recommended earlier) increases the efficacy of combined selection and saves much time.

Similar selection of females is advisable only if they are to be chosen for subsequent prolonged commercial utilization. Of course, where highly productive breeds are wanted, females may be selected on the basis of progeny.

Thus, we believe that combined selection, which includes mass and family selection, evaluation of male spawners according to their progeny, and, sometimes, sib selection should be the major methods of carp selection.

3. System of crossing and utilizing heterosis

Recently, an increasing accumulation of data indicates that the genetic composition of any breed should be heterogeneous. Highly heterozygotic specimens frequently prove to be the most viable and the largest (Lerner, 1954; Kirpichnikov, 1958 b, 1960 a; and others).

In checking by progeny, the spawners of northern hybrids, specimens that were heterozygous by the S factor (male 26 in 1959; females 2 and 8 in 1960) frequently not only proved to be larger, but their progeny were distinguished by increased resistance and rapid growth. Heterosis, found in hybrids of 1st generation carp and "eastern carp," as well as in hybrids of 3rd and 4th generations of hybrids of various strains (Kirpichnikov, 1957, 1959b;

Andriyasheva, this collection),is undoubtedly linked with the increased heterozygosis of hybrids. This fact also explains the strong growth rate and resistance found by Kuzema and Tomilenko (1962) in descendants of a cross between northern "Ropsha" hybrids and Ukrainian carp.

Inbreeding, which decreases heterozygos is, is accompanied by considerable retardation of growth in carp progeny. This kind of "inbreeding depression" was observed in carp in various countries (Moav and Wohlfarth, 1963). Therefore, in carp selection, the system of crossing deserves special attention.

Application of the familiar scheme of commercial hybridization, i. e., creation of highly inbred lines, subsequent crossing of them, and choice of best combinations, is of little promise in carp culture. The major difficulty is that a very long time is needed to reach a fairly high coefficient of inbreeding in carp propagation. It takes at least 40-50 years in temperate zones; in the south, the required time is shorter, but even in the subtropics, proper inbreeding requires 15-20 years. Because it is not known how great the inbreeding depression will be, the assumption can be made only that it will be high. Profits that might be obtained from crossing would hardly compensate for the expense of prolonged maintenance of these inbred lines.

Our experience shows that crossing only relatively slightly inbred sublines of carp can produce considerable heterosis. This was found in crossing carp hybrids of the Novgorod and Kursk strains (Kirpichnikov, 1957). Novgorod hybrids were inbred for only one generation, and the Kursk hybrids not more than 2. This proved sufficient to establish heterosis; there was only a most remote affinity among the spawners of the strains utilized.

On the basis of theoretical concepts and of the accumulated experience of selection work, a system of breeding can be suggested: the system applied when selection begins from crossing different varieties or breeds. It is based on parallel maintenance of 2, 3, or 4 strains of carp within which moderate or strong inbreeding is permitted. Part of each generation of these strains is crossed to create large numbers of commercial fish with desirable heterosis. After 2-3 generations, spawners of the most remote unrelated strains are crossed to create new isolated strains or stock.

The following should be considered in choosing a specific system:

1) Synthetic crossing entails prolonged selection to stabilize the combination of characteristics required for the breed.

2) A sufficiently high level of heterogeneity within the breed should be preserved both in synthetic selection and in selection without initial remote crossings. The alternate inbreeding and outbreeding required can be maintained only by conducting several parallel stocks or strains. Breed selection carried out simultaneously on several farms is best.

• 3) Because carp are characterized by high fecundity and prolonged spawning life (up to 7-8 years and more), heterosis is particularly significant and should be stressed in each generation when breeding.

4) In any breeding plan, and particularly in close breeding, a mass selection, or still better, a more stringent and effective combined selection should be carried out in each generation.

The system we used in selection of north ("Ropsha") hybrids fulfills the foregoing requirements in general (Figure 2). Two strains were selected to the 3rd generation. Further crossings established 3 new separate strains; the 5th generation appeared in 1964.

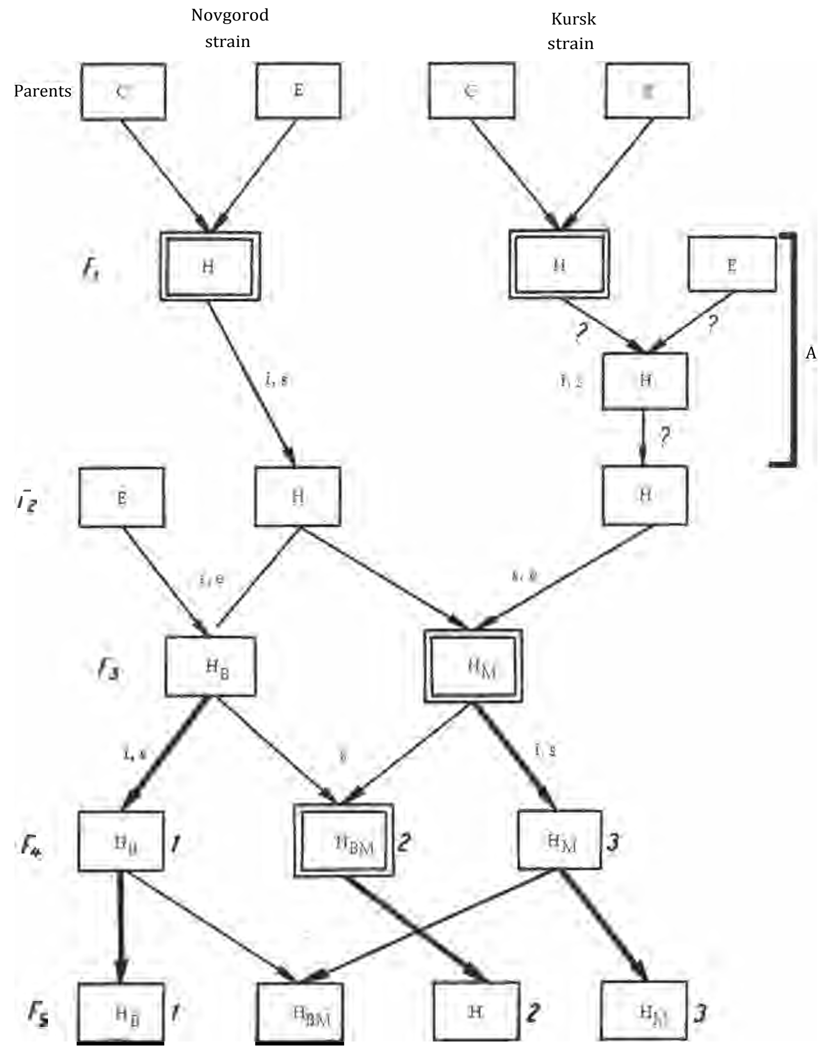

FIGURE 2. Genetic diagram of selection of northern hybrid carp:

C — carp, E— "eastern carp," H—hybrids of strains B, BM, and M (double frame outlines heterozygous combinations of commercial value); i —inbreeding, s — mass selection. e — estimation of spawners by progeny; 1,2, and 3—main branch strains of hybrids (bold type arrows); A—uncontrolled crossings in 1941-1945 (assumed).

The degree of inbreeding within each strain was kept to a minimum by using several spawners as parents. Beginning with the 2nd generation, we made stringent mass selections among fingerlings and yearlings; in the 3rd generation, some of the best spawners were checked on the basis of their progeny. Combined selection was used from the 4th generation.

The superior qualities of northern hybrid carp bear witness to the success of our breeding system and selection methods.

4. Special methods of selection

Direct utilization of data on genetics in selection work with carp. This problem has been examined previously in detail (Lieder, 1957; Kirpichnikov, **1959** a, 1960b; Kirpitschnikow, 1961). It is worth repeating, however, that the genetic determinants of the scale cover (genes Aa and Nn after Kirpichnikov (1937) or Ss and Nn after Probst (1953)) is clarified fairly accurately. By reference to the firmly established patterns of inheritance of these factors, we can introduce any desirable combination into any breed.

In 1956-1962 at "Ropsha," mass tests of spawners of hybrids of 3rd and 4th generations were carried out to find specimens that were homozygous and heterozygous by factor S (see Table).

Altogether 425 spawners have been checked thus far. Back-crossing was usually used for analysis:

Snn X ssnn;

sometimes it was replaced by another:

Snn X Ssnn.

In the first case, we crossed a scaly hybrid with a sparse-scale or frame-scale male; in the second case, we crossed the scaly hybrid with a heterozygous hybrid, previously checked.

The table below summarizes the test results. On the whole, we succeeded in eliminating the undesirable sparsity already in the 4th generation of "Ropsha" hybrids, both at "Ropsha" and at the "Opochka" and "Yazhelbitsy" hatchery-nurseries.

Because of their better growth and exterior, the scaly hybrids are better than the mirror-sparse for the northwestern zone and for Siberia. Sparse-scale hybrids, however, may be of some interest in the future for several districts with milder climates, and perhaps for the northwest, too. It should be kept in mind that a small quantity of scales is a desirable market quality The selection of sparse-scale hybrids was begun in "Ropsha" in 1963. Knowing the genetics of carp makes it possible to predict that all the progeny of selected hybrids will have sparse-type scaling because all these hybrids are homozygous in factors s and n (ssnn). On the basis of our unpublished data and of German material, we may assume that strains with a minimum quantity of scales can be created comparatively quickly. The great genetic variability for scale cover, characteristic of sparse-scale carp, further allows this assertion.

The better we know the genetics of a characteristic, the greater significance the characteristic acquires in selection work, and the easier it becomes **to** carry out selection. Thus, studying peculiarities of heritability of various carp characteristics, including physiological characteristics, should be conducted parallel with other selection work at all selection stations.

Accelerating mutation by means of radiation and chemical mutagenic agents has not been used in pisciculture so far. This method of increasing genetic variability may prove useful in the future. We feel that in carp breeding, the most promising uses of this method are in the search for mutants that are resistant to dangerous diseases, primarily dropsy.

TABLE. Testing spawners for heterozygosis according to factor S

Breed group	Sex	Year of test	Number of spawners	
			homozygous	heterozygous
	males	1956	31	41
		1957	5	16
		1958	15	16
		1960	7	18
		1961 and 1962	6	2
		Total	64 (40.8%)	93
3rd generation hybrids, strain M	females	1958	1	2
		1959	19	24
		1960	14	18
		1961	8	9
		1962	1	5
		1963	3	2
		Total	46 (43.4%)	60
	males	1956 and 1957	33	4
		1958	7	1
		Total	40 (88.9%)	5
3rd generation hybrids, strain B	females	1958 and 1959	6	0
		1960 and 1961	3	0
		Total	9 (100%)	0
	males	1962	8	3
		1963	22	3
		1964	1	0
		Total	31 (83.8%)	6
4th generation hybrids, strain M	females	1963	1	0
		1964	2	1
		Total	3 (75.0%)	1
	males	1962	22	17
		1963	19	18
		1964	6	11
		Total	47 (50.6%)	46
4th generation hybrids, strain MB	females	1964	7 (38.9%)	11

Polyploidy will have hardly any significance in carp breeding, particularly because carp and wild carp have very many chromosomes (2n= 104). Evidently, wild carp underwent this stage of polyploidization in the past (probably as early as in the Tertiary); in some Cyprinidae, the diploid number is half as large (2n=52; Lieder,1956 a).

Diploid parthenogenesis (gynogenesis) in carp was reproduced (Romashov et al., 1960; Golovinskaya et al.,1963). Destruction of sperm nuclei by means of massive doses of X-ray (100,000-200,000) does not deprive them of their ability to stimulate the onset of egg cleavage. Most of these eggs perish, having a haploid (female) set; up to 6% of them develop normally due to doubling of the set of maternal chromosomes. The mechanism of this doubling is as yet unknown. Diploid gynogenesis is of great interest to selective breeders because it makes possible almost complete homozygosis of hereditary characteristics (without prolonged inbreeding) and steady maintenance of breed properties. Already, there is a small number of gynogenetic carp in the experimental farms at "Yakot'" near Moscow, and at "Ropsha" near Leningrad.

Commercial hybridization, i.e., crossing 2 lines, strains, or subspecies of carp for commercial use of heterotic hybrids of the 1st generation has been, and undoubtedly will continue to be, of great significance. This article has examined many problems connected with commercial hybridization; it remains only to add that the experience of commercial hybridization of carp with "eastern carp" in the northwestern RSFSR, the central regions, the Baltic area, and Belorussia makes us very hesitant to recommend one or another commercial crossing. In all the fish breeding farms where hybridization was conducted, the result was an overrun of the maternal population with hybrid spawners. Due to the absence of tags, the "eastern carp" could not be distinguished from hybrids after a few years, and commercial hybridization became pointless.

Commercial hybridization of carp requires that the maternal population be under well organized control. Such control is simple if breeding is organized according to the new scheme we suggest (Kirpichnikov, 1960b, and in this collection; Golovinskaya, 1962), in which commercial fish farms receive ready selected spawners, and do not breed from their own stock.

Remote (interspecific and intergeneric) hybridization is also very interesting, but it takes a long time to restore the fertility of the hybrids. Crossing carp with crucian carp gives good results, but only a 1st generation of hybrids is available for commercial use because almost all the hybrids are sterile. According to a verbal communication from Kuzema, he was able to get fertile hybrids and to increase fertility considerably in succeeding generations. Viktorovskii (this collection) obtained from carp and tench interesting hybrids which were very close in morphological characteristics to carp; we do not yet know how fertile they are. All other attempts to cross carp with other Cyprinidae have failed. These are the most general outlines of prospects for utilization of some special techniques in selective breeding of carp.

CONCLUSIONS

1. The principal aim of carp selection is to create breeds with the highest conversion ratios and resistance to unfavorable effects of environment and disease.
2. Mass selection remains the most important method for selecting carp by growth rate and exterior. Low efficacy of such selection in the past was due to several causes, of which the major ones are:

a) low heritability rate of selected characteristics;

b) selection at an age other than one which is to be improved;

c) selection for aggressivity' rather than for optimum conversion ratio, i. e., those most successful in competing for food;

d) inbreeding which decreases genetic heterogeneity;

e) the presence in carp of a high and steady heterozygous equilibrium.

Some methodological errors which are easily avoided should be mentioned: absence of tagging, mixing fish of various origin, age, and weight; insufficient strictness in selection.

3. In carp breeding, 3 methods of individual selection may be used, i. e., family selection, sib selection, and selection by progeny. Because of technical difficulties in family selection, it is expedient to combine it with mass selection and selection of males tested by their progeny. Such combined selection may be the most effective.

In family selection, it is preferable to replicate separate raising of families 2, 3, or 4 times. This allows the best evaluation of the families for their productivity potential.

4. Heterogeneity of breed and the possibility of utilization of heterosis in each generation should be preserved in both synthetic selection and selection without remote initial crossings. Parallel breeding within the breed group of several more or less inbred strains, and periodic crossing between them are advisable. Creation of closely inbred lines is not expedient in carp breeding.

5. Some other selection techniques that may be useful in carp improvement are: a) use of specific data on genetics in carp selection; b) search for mutations that increase resistance to disease; c) obtaining homozygous specimens by means of radiated diploid gynogenesis; d) finding heterotic commercial hybrids among various lines, breeds, and subspecies of carp; e) selection of interspecific and intergeneric hybrids.

Bibliography

Publications in Russian

And riyashe va, M. A. Geterozis pri vnutrividovykh skreshchivaniyakh karpa (Heterosis in Intraspecific Crossings of Carp). In this Collection.

Berg, L. S. Ryby presnykh vod SSSR i sopredel'nykh stran (Freshwater Fishes of the USSR and Adjacent Countries). Vol. 2. Moskva-Leningrad. 1949.

C he rf as, B. I. Sazan kak ob ekt prudovogo khozyaistva (Wild Carp as an Item of Pond Culture). — Rybnoe Khozyaistvo SSSR, No.2. 1933.

G olo v ins k a ya, K. A. Plemennoe delo v prudovom khozyaistve (Breeding in Pond Culture). —Rybovodstvo i Rybolovstvo, No.3. 1962.

Golovinskaya,K.A.,D.D.Romashov,andN.B.Cherfas. Oradia-tsiormom ginogeneze u karpa (Radiation Gynogenesis in Carp). — Trudy VNIIPRKh, Vol. 12. 1963.

K ir pi chnik ov, V.S. Osnovnye geny cheshui u karpa (Major Genes of the Scale in Carp). —Biologicheskii Zhurnal, Vol. 6, No. 3. 1937.

Kirpichnikov, V. S. Eksperimental'naya sistematika sazana (Experimental Taxonomy of the Wild Carp). —Izvestiya AN SSSR, Seriya Biologicheskaya, No. 4. 1943.

Kirpichnikov, V. S. Sozdanie novoi severnoi gibridnoi porody karpa (Creation of a New Northern Hybrid Carp Breed).— Trudy soveshchanii po rybovodstvu, Moskva. 1957.

Kirpichnikov, V. S. Geneticheskie metody individuaPnogo otbora v karpovodstve (Genetic Methods of Individual Selection in Carp Raising).— Doklady AN SSSR, Vol. 121, No.4. 1958a.

Kirpichnikov, V. S. Stepen' geterogennosti populyatsii sazana i gibridov sazana s karpom (The Degree of Heterogeneity of Wild Carp Population and of Hybrids of Wild Carp with Carp).— Doklady AN SSSR, Vol. 122, No. 4. 1958b.

Kirpichnikov, V.S. Geneticheskie metody selektsii ryb (Genetic Methods of Fish Selection). —Byulleten' Moskovskogo Obshchestva Ispytatelei Prirody, Vol. 64, No. 1. 1959a.

Kirpichnikov, V. S. Gibridizatsiya karpa s amurskim sazanom primenitel'no k zapadnym oblastyam SSSR (Hybridization of Carp with Eastern Carp as Applied in the Western Regions of the USSR). — Trudy V konferentsii po rybokhozyaistvennomu osvoeniyu vnutrennikh vod Pribaltiki, Minsk. 1959b.

Kirpichnikov, V. S. Geneticheskie osnovy geterozisa (Genetic Bases of Heterosis). —Voprosy evolyutsii, biogeografii, genetiki i selektsii, sbornik pamyati akademika N. I. Vavilova. 1960a.

Kirpichnikov, V. S. Organizatsiya plemennogo dela v karpovodstve (Planning of Breeding in Pond Culture). —Nauchno-Tekhnicheskii Byulleten' GosNIORKh, No.11. 1960b.

Kirpichnikov, V. S. Geneticheskie metody selektsii gibridov ryb (Genetic Methods of Selection of Fish Hybrids). —Trudy soveshchaniya po otdeleniyu gibridnykh rastenii i zhivotnykh, Moskva. 1960c.

Kirpichnikov, V. S. Pervye itogi i zadachi rabot po organizatsii plemennogo dela na Severo-Zapade RSFSR (Preliminary Results and Further Tasks of the Organization of Selective Breeding in the Northwestern RSFSR). In this Collection.

Kirpichnikov, V. S. Metody proverki proizvoditelei po potomstvu v karpovykh khozyaistvakh (Methods of Progeny Testing Spawners in Carp Fish Farms). In this Collection.

Kirpichnikov,V.S. and K.A.Golovinskaya. Kharakteristika proizvoditelei osnovnykh porodnykh grupp karpa, razvodimykh v SSSR (Characterization of Spawners of the Major Breeds of Carp in the USSR). In this Collection.

Kryazheva, K. V. Vliyanie plotnosti posadki na rost, izmenchivost' i vyzhivaemost' molodi gibridnykh karpov (The Influence of Stocking Density on the Growth, Variability, and Survival Rate of Young Hybrid Carp). In this Collection.

Kuz'oma, 0. I. Do pytannya perevirky plidnykiv za yakistyu yikh potomstva u koropivnytstvi (The Problem of Evaluating Spawners according to their Progeny in Carp Raising). —Naukovi Pratsi Ukrayins'koho Naukovo-Doslidchoho Instytutu Rybnoho Hospodars'tva, Vol. 13. 1961. [In Ukrainian.]

Kuz'oma, O.I. Perevirka plidnykiv koropa za yakistyu potomstva (Evaluation of Spawners of Carp for Quality of their Progeny). —Naukovi Pratsi Ukrayins'koho Naukovo-Doslidchoho Instytutu Rybnoho Hospodars'tva, Vol. 14. 1962a. [In Ukrainian.]

Kuz'oma, O.I. Vyvedennya novoyi vysokoproduktyvnoyi porody koropa dlya rybgospiv zakhidnykh oblastei URSR (Raising Highly Productive Carp Breeds for Fisheries of Western Regions of the URSR). —In Sbornik: "Pidvyshchennya produktyvnosti rybnykh stavkiv." 1962b. [In Ukrainian.]

Kuz'oma, O.I. and V.G. Tomilenko. Rezervy zbil'shennya ryboproduktyvnosti stavkik (Increasing Reserves of Fish Productivity in Ponds). —Naukovi Pratsi Ukrayins'koho Naukovo-Doslidchoho Instytutu Rybnoho Hospodars'tva, Vol. 14. 1962. [In Ukrainian.]

Plokhinskii, N.A. Nasleduemost' po ottsam (Heritability from Fathers).— Izdatel'stvo Sibirskogo filiala AN SSSR. 1962.

Poliksenov, D.P. Sozdanie vysokoproduktivnogo i zhiznesposobnogo plemennogo stada karpa v tselyakh vyvedeniya novoi porody ego v Belorussii (Creation of Highly Productive and Viable Spawners of Carp with a View to Raising a New Breed in Belorussia). —In Sbornik: "Voprosy rybnogo khozyaistva Belorussii." 1962.

Romashov, D.D., K.A. Golovinskaya, V.N. Belyaeva, E.D. Bakulina, G.L. Pokrovskaya, and N.B. Cherfas. O radiatsionnom diploidnom ginogeneze u ryb (On Radiation Diploid Gynogenesis in Fishes). —Biofizika, Vol. 5, No. 4. 1960.

Shaskol'skii, D. V. O rodstvennom razvedenii karpa v promyshlennykh prudovykh rybkhozakh (Inbreeding Carp in Commercial Pond Fisheries). —Trudy Vserossiiskogo Nauchno-Issledovatel'skogo Instituta Prudovogo Rybnogo Khozyaistva, Vol. 7. 1954.

Stegman, K. Voprosy selektsii karpa v Pol'she (Problems of Selection of Carp in Poland). —Trudy V konferentsii po rybokhozyaistvennomu osvoeniyu vnutrennikh vod Pribaltiki, Minsk. 1959.

Viktorovskii, R. M. Morfologiya gibridov karpa s linem (Morphological Traits of Hybrids of Carp and Tench). In this Collection.

Publications in Other Languages

Buschkiel, A.L. Teichwirtschaftliche Erfahrugen mit Karpfen in den Tropen. —Z. Fisch., Vol. 31. 1933.

Buschkiel, A.L. Lehren aus tropischer Teichwirtschaft. — Z. Fisch., Vol. 35. 1937.

Falconer, D.S. Introduction to Quantitative Genetics. Edinburgh and London. 1960.

Huet, M. Apercu de la pisciculture en Indonesia. —Bull. agric. Congo Belge, Vol. 47, No. 4. 1956.

Jashouv, A. The Punten Carp and its Attributes. —Bamidgeh, Vol. 7, No. 3. 1955.

Jones, S. Pond Fish Culture in Israel. —Bamidgeh, Vol. 8, No. 4. 1956.

Kessler, S., G. Wohlfarth, F. Lahman and Rom Moav. Monosex Culture of Carp. —Bamidgeh, Vol. 13, Nos. 3—4. 1961.

Kirpitschnikow, V. S. Die genetischen Methoden der Selektion in der Karpfenzucht. -Z. Fisch., Vol. 10, Nos. 1-3. 1961.
Lerner, I. M. Genetic Homeostasis. Edinburgh. 1954.
Lerner, I. M. The Genetic Basis of Selection. New York. 1958.
Lieder, U. Ergebnisse und Probleme der Chromosomenforschung bei unseren Nutzfischen. -Thaer.-Archiv, Berlin. 1956a.
Lieder, U. Über einige genetische Probleme in der Fischzucht. -Z. Fisch., Vol. 5, Nos. 1-2. 1956b.
Lieder, U. Die Bewertung des Beschuppung des Karpfens bei der Zuchtauslese. -Dt. Fisch Ztg., No. 7. 1957.
Moav, Rom and G. Wohlfarth. Genetic Improvement of Carp. I. Theoretical Background. -Bamidgeh, Vol. 12, No. 1. 1960.
Moav, Rom and G. Wohlfarth. Breeding Schemes for the Genetic Improvement of Edible Fish. —Prog. Rep. 1962. Jerusalem. 1963.
Nakaroku, N. and S. Kasahara. On the Earliest Stage at which the Shoot Carp Appears. -Bull. Jap. Soc. Scient. Fish., Vol. 21, No. 2. 1955.
Nakaroku, N. and S. Kasahara. On the Result of Culturing the Modal Group and the Growth of Carp Fry Reared Individually. -Bull. Jap. Soc. Scient. Fish., Vol. 22, No. 11. 1957.
Probst, E. Die Beschuppung des Karpfens. —Münchn. Beitr. Abwass. — Fisch. -Flussbiol., Vol. 1. 1953.
Rudzinsky, E. Vergleichende Untersuchungen fiber den Wildkarpfen der Donau und den Teichkarpfen. -Z. Fisch., Vol. 10, Nos. 1-3. 1961.
Schäperclaus, W. Die Bewertung des Karpfens bei der Zuchtauslese. — Z. Fisch., Vol. 4, Nos. 7-8. 1955.
Schäperclaus, W. Stand der Leistungsprüfungsverfahren in der Karpfenteichwirtschaft. -Dt. Fisch Ztg., Vol. 5, No. 2. 1958.
Schaperclaus, W. Lehrbuch der Teichwirtschaft, 2nd edition. Berlin. 1961.
Steffens, W. Der Karpfen. 2nd edition. Wittenberg, Lutherstadt. 1962.
Steffens, W. Der heutige Stand der Zuchtleistungen beim Karpfen in unseren Teichwirtschaften. -Dt. Fisch Ztg., Vol. 11, No. 11. 1964.
Stegman, K. Metodyczne planowanie wychowa karpia w wieloletnim cyklu jego wzrostu. -Rybactwo, No. 1. 1960.
Wohlfarth, G. Rom Moav, and M. Lahman. Genetic Improvement of Carp. III. Progeny Tests for Differences in Growth Rate, 1959-1960. -Bamidgeh, Vol. 13, No. 2. 1961.

CHARACTERIZATION OF SPAWNERS OF THE MAJOR BREEDS OF CARP IN THE USSR

V. S. Kirpichnikov and K. A. Golovinskaya

Introduction

In conformity with resolutions of the Central Committee of the CPSU and the Council of Ministers of the USSR in 1962, pond pisciculture must be developed more rapidly than other branches of fishery management. By 1970 the pond fish farms of the USSR should produce 1.4 million centners of high-quality live and fresh fish.

Until recently carp has been the main-stay of pond pisciculture in the USSR. To date, only small numbers of other species of pond fish (wild and crucian carp, tench, grass carp, black carp, silver carp, bighead, rainbow trout, and others) have been raised in ponds. There are various carp breeds in the pond farms of the USSR which have not yet been described. This paper presents some morphological and physiological characteristics of the main carp breeds cultivated in the USSR. Because all the carp breeds are still in the formative process, the indexes given may change and cannot be considered as obligatory standards.

As cultured carp —"eastern carp" (C ypri nu s carpio ha e ma topterus) hybrids have become widely distributed and are significant in the USSR. We have included a characterization of commercial carp and "eastern carp" spawners.

Among carp cultivated in the USSR are 4 genetic groups (scaly, sparse-scale, linear, and bare carp). Their distinguishing characteristics have been thoroughly checked by many researchers in various countries (Kirpichnikov, 1937, 1945, 1948; Kirpichnikov et al., 1937; Golovinskaya, 1940, 1946; Probst, 1949, 1953; Menzel and Steffens, 1957; Schäperclaus, 1955, 1961) and may almost be regarded as standard; they are listed in the second section of our article.

Breeds and hybrid groups of carp in the USSR

Cultured carp of mixed origin
(mongrel cultured carp)

Origin. The major groups of cultured carp of the USSR come from the regions adjacent to the Danube River: Western Ukraine [Transcarpathian Region, Galicia, Bohemia. Lausitz scaly carp might reach the USSR through the Baltic. There are no exact data on the origins of Soviet cultured carp. Certainly, during the last 30 years, the differences between mongrel carps of certain republics and regions were minimized by numerous crossings, and they can now be regarded as one group.

Areas of breeding. Cultured carp are bred in many republics and regions of the USSR. In Belorussia, Latvia, Lithuania, several central and southern districts of the RSFSR, Siberia, the southern republics, and partially in the western Ukraine breeding sparse-scale carp is done. Some places raise scaly carp together with the sparse-scale. In the south and partially in the central districts of the RSFSR and in the Ukraine bare carp are also raised.

Scale cover. All 4 main types of scale cover are encountered in cultured carp of the RSFSR: scaly, sparse-scale, linear, and bare. According to a special regulation, linear carp is to be eliminated. Sparse-scale and scaly carp are the main objects of breeding.

Age. Cultured carp can be used to spawn at the following age: females, 6-12 years; males, 3 or 4-11 years (central and northern USSR); females, 3 or 4-10 years; males, 2 or 3-10 years (southern USSR).

Sex differences. Sex characters in spawners in the prespawning period should be quite clear. Females should have a soft, bulging, elastic abdomen, males a light "rash" on the surface of the operculum, on the anterior spine skin, and on fins. The male's head and spine should appear rough, and slight pressure on the abdomen should release drops of thick white milt.

Weight. Nominal desirable weights for cultured carp spawners before their transfer into stock population in autumn are as follows (in grams by zone):

Age group	North, Baltic, and Siberia		Center, West, and South	
0+	30-50		50-70	
1+	600-800		750-1000	
2+	1,400-1,700		1,700-2,000	
	female	male	female	male
3+	2,400— 2,600	2,200— 2,400	2,700— 3,000	2,500-2,700
4+	3,000-3,300	2,800-3,000	3,300— 3,800	—
5+	3,500— 3,800	—	—	—

Weight gain over the previous year is more significant than present weight. Little or no weight gain in the spawners indicates that they are in poor condition, and that fertility, particularly in the females, is probably quite low.

Indexes of habitus. External characteristics of carp depend not only on breed peculiarities but also on sex, age, and environment. Selection by body build supplements selection by weight, which is a major selective feature in carp breeding.

For spawners of mongrel scaly and sparse-scale carp in the USSR, the following values of the most important indexes of body build can be accepted tentatively:

Sex	Fulton's condition factor—K	Body area— 1/H	Body thickness — B.100 / 1 (in %)
Females	3.0-3.4	2.8-2.6	18-23
Males	2.7-3.1	2.9-2.7	17-22

Condition factor is calculated by the formula: K g, where g is weight of fish in grams, 1 is length of body in centimeters to the end of scaly cover. To calculate the other indexes, the values H (maximum body width in cm) and B (the maximum body thickness in cm) must be obtained.

In selecting spawners by body build, the main requirements are a thick, wide back, small head, strong fins of normal structure and a correct, straight lateral line.

Other indexes. Mongrel spawners should also meet the following requirements: good health, absence of deformities, great activity during spawning period, high fertility rate. The latter is assessed by the weight difference in either sex before and after spawning, by number of larvae from 1 female, and, finally, by the number of young of per year from 1 female.

Experimental data yield the following findings about fertility of females, based on the number of larvae weighing 10-40 mg: in the northwestern and Baltic areas and Siberia, to 50-100 thousand per female, in the central, western, and southern areas, 100-200 thousand per female.

2. Ukrainian frame-scale and scaly carp*

Origin. Ukrainian carp were bred by Kuzema in 1920–1930 (Kuzema, 1950; Ku z' oma 1962; Kononov,1952), using local carp from the "Dombal" pond farm in the Vinnitsa Region of the UKrSSR, and carp from the western Ukraine.

Region of breeding. Frame-scale and scaly carp are bred in eastern parts of the UKrSSR and to some extent in the western area.

Scale cover. Frame-scale carp are characterized by a row of giant mirror scales along the upper edge of the back (from head to caudal fin) and a few scales at the head, on the ventral side of the abdomen, and on the caudal peduncle. Most of the body is free of scales.

About 25-75% of the progeny of frame-scale spawners are frame-scale type; the rest are of the common "sparse" type.

Ukrainian scaly carp have a continuous scale cover, the scales being arranged in regular rows running in 3 directions; the shifting of rows of of scales is an indicator of abnormality. All Ukrainian scaly carp should breed true.

Age. Ukrainian carp are used as spawners at the following ages: females, from 4 to 10 years; males, from 3–10 years.

Sex differences. Sex differences between Ukrainian carp are similar in general to those in mongrel cultured carp,but the male breeding coloration appears somewhat later and it is not always possible to obtain drops of milt by pressing the abdomen during the prespawning period.

Weight. The following autumn weights are recommended for spawners:

Age group	Weight, g	
0+	60-100	
1+	1,000-1,500	
	female	male
2+	2,900 – 3,400	2,700-3,000
3+	3,800-4,200	3,500 — 3,800
4+	4,800-5,200	4,500— 4,800

* Data on Ukrainian carp were kindly given to us by Kuzema.

Weight gain of spawners is as significant in Ukrainian carp as it is in mongrel cultured carp.

Indexes of habitus. For spawners of Ukrainian carp, the following are acceptable values of the most important body build indexes:

Sex		1/H
Females	3.1-3.6	2.7-2.2
Males	3.0-3.5	2.8-2.3

The major requirements in spawner selection are similar to those for mongrel cultured carp.

Other indexes. Fertility indexes of Ukrainian carp, by larvae of 10-40 mg is nominally 150,000-250,000 per female.

3. Hybrids of 1st generation cultured carp and "eastern carp" (Cyprinus carpio haematopterus)

Origin. Hybrids of 1st generation cultured carp and "eastern carp" have been used in pond farms of the USSR since 1935 (Kirpichnikov and Balkashina, 1935; Kirpichnikov et al., 1936; Savel'ev, 1939, 1941; Arnol'd, 1939; Kirpichnikov, 1943, 1949, 1954, 1959a; Golovkov and Ekaterinoslavskaya, 1955). These hybrids are distinguished by high tolerance to cold, general viability, rapid growth, intensive utilization of the pond supply, and their excellent taste (Kirpichnikov, 1959a). Heterosis is clearly expressed in their high growth rate and viability.

Cultured carp and "eastern carp" (C. c . ha emato pt e rus) spawners must be raised to maintain an annual yield of hybrids. The characteristics of carp spawners were listed earlier. "Eastern carp" were brought from the Amur River for the first time in 1937, and were acclimatized in pond farms of the northwestern RSFSR and in Belorussia. The following are standard specifications for "eastern carp."

Breeding area. 1st generation hybrids are raised in the northwestern RSFSR, the northern districts of Belorussia, Latvia, and some parts of the central districts of the USSR.

Scale cover. "Eastern carp" must have a continuous scale cover with regularly arranged rows of scales. Cultured carp should be sparse-scale or scaly. Crossing linear or bare carp with "eastern carp" is not desirable (segregation in progeny has been observed).

Age. "Eastern carp" spawners can be crossed with carp at the following ages:

females, from 5 to 12-14 years; males from 3 to 10-12 years.

Sometimes 15-16-year-old females, and 14-year-old males may be used for spawning.

Sex differences. Sexual characteristics are very distinct in "eastern carp." All the males develop intensive coloration by spawning time, and abdominal pressure releases fairly large amounts of milt. In females the abdomen becomes very wide, and the mature eggs are easily seen by turning over the female's abdomen.

Weight. "Eastern carp" grow slowly in ponds from their 3rd (sometimes 2nd) year of life. The following autumn weights for the spawners are recommended:

Age group	Weight, g	
0+	30-50	
1+	450 — 600	
	female	male
2+	1,000 — 1,200	900 — 1,100
3+	1,600— 1,800	1,400— 1,600
4+	2,000 — 2,300	1,800 — 2,000
5+	2,300— 2,500	

Indexes of habitus. The following are nominal indexes for habitus of "eastern carp" for the spawners (age 5-7):

Sex		1/H	B.100 / l
Females	2.4-2.8	3.6-3.2	15-18
Males	2.2-2.6		

The slowdown of growth of "eastern carp" spawners in ponds causes their bodies to streamline with age, so that by 10 years, their bodies have altered considerably. This is particularly true of the 1/H ratio, which reaches 4:1 or more.

Other indexes. "Eastern carp" are distinguished by high fecundity. Fertility by larvae is nominally 75,000-125,000 specimens per female for females weighing 2-3 kg.

4. Northern ("Ropsha") carp

Origin. Northern or "Ropsha" carp are 4-5th-5th generation hybrids of selectively bred carp-"eastern carp." The hybrid was created by a system of planned crossing, and intensive selection. Judging from chromosomal composition, northern carp owe 60-75% of their genetic inheritance to "eastern carp." (Kirpichnikov, 1957, 1959b, 1960; Kirpitschnikow. 1961).

Area of breeding. Northern carp are the main breed group in the northwestern RSFSR (Novgorod, Pskov, and Leningrad regions), where they were created. Breeding northern hybrids has begun in Estonia and Siberia, and in the Ukraine, where cross-breeding northern hybrids with Ukrainian carp has produced a vigorous heteros is evidenced by quite good growth.

Scale cover. The body of northern carp is entirely covered with scales, and all progeny are also scaly. Progeny with sparse scaling indicate abnormality.

Age. Northern carp females can be bred from age 5 or 6 to 12-14 years; males can be bred from age 3-4 to 10-12 years.

Sex differences between females and males are as distinct in northern carp as in "eastern carp." Males display their breeding colors clearly, and all secrete milt before spawning time, as do most of them in autumn, as well. The females' abdomen is well developed although less so than that of cultured carp and lacking wild carp lines.

Weight. The following are the recommended autumn weight indexes for spawners of the two principal strains of northern carp:

Age group	Strain B		Strain M	
	Weight, g			
0+	30-50		30-50	
1+	500-700		600-800	
	female	male	female	male
2+	1,400 — 1,600	1,300 — 1,500	1,500— 1,700	1,400— 1,600
3+	2,200— 2,400	2,000 — 2,200	2,400— 2,600	2,200 — 2,100
4+	2,700-3,000	2,400 — 2,700	3,000-3,300	2,700 — 3,000
5+	3,100 — 3,400	—	3,500 — 3,800	—

Strain B, which inherited many characteristics of "eastern carp" (about 75%), grows more slowly than strain M, but is better able to withstand cold.

Indexes of habitus. The following are acceptable indexes of body build for spawners of 2 main strains of northern carp at 5-7 years:

Strain	Sex		1/H	$\frac{D \cdot 100}{1}$
	Males Females	2.2-2.6 2.4-2.8	3.3-3.1	15-18
	Females Males	2.5-3.0 2.3-2.7	3.2-2.9	16-20

As is the case with "eastern carp," all the indexes of body build change with growth and age; the condition factor decreases, the body becomes more streamlined and the 1/H ratio approaches 3.5—4.0:1.

Other indexes. Northern carp is almost as fecund as Ukrainian frame-scale and scaly carp. Fertility judged by number **of** larvae of **10-40** mg is **75,000-150,000** specimens per female; large females may yield up to 175,000 specimens.

In addition to the carp breeds listed on preceding pages, "Kursk hybrids" are bred in several districts of the USSR. Their origin is similar to that of northern hybrids (strain B). As they are not a homogenous strain, however, no characteristics can be given as yet.

The principle genetic groups of carp, distinguished by their scale cover

1. Differences in scale

Soviet genetic-pisciculturists established the fact that the main breeds of carp—scaly, sparse-scale, linear, and bare—differ not only in their external anatomical, constitutional characters, but also in the most important properties for fishery management, growth and viability (Kirpichnikov, Golovinskaya, and Mikhailov,1937; Kirpichnikov, 1945, 1948; Golovinskaya, 1940). An accurate diagnosis of these 4 hereditary types, therefore, is of essential practical importance.

Scaly carp, like wild carp, have a continuous scale cover. The scales are small, even, and cover the entire body in rows (in three directions), the number of which is strictly regulated. Some small irregularities in the arrangement of scales ("shifting") are permissible, but great abnormalities are undesirable because they frequently indicate retarded growth or decreased viability.

Of all the breeds, the scale cover of sparse-scale mirror carp is the most variable. We suggest that sparse-scale carp with the fewest scales should be designated sparse-scale carp of group I. Their scales are disposed in 1 row along the spine, and in separate groups at the base of fins and on the tail. The rest of the body is either devoid of scales or has isolated scales of varying size.

The most common sparse carp in the USSR has more or less developed rows of scales on the side of the body, primarily along the lateral line. Of these, carp with a complete or incomplete, distinct, double lateral row of scales constitute group II. Those with large scales along the lateral line ("large middle row") we designate group III. This group grows somewhat more rapidly than group II. There are also carp with continuous scale cover forming regular horizontal rows on the body. They differ from scaly carp in having a smaller number of larger scales, fewer scales in the middle row, and an absence of clearly expressed diagonal rows.

The selective significance of the various groups of sparse-scale carp has not yet been established. Group I is usually considered most desirable, but judging by some data on properties of carp in group III, there are not yet sufficient grounds for recognizing group I as the best under all conditions.

Linear mirror carp form a more definite group. In addition to a dorsal row of scales beginning at the head or at the dorsal fin base, the linear carp always has a very even row of scales along the lateral line. These scales usually extend vertically and are compressed horizontally, their number being a diagnostic characteristic. In addition to the main "linear" row, more or less complete additional rows of very even scales are sometimes disposed above or below the lateral line. The bodies of some linear carp are covered with continuous handsome rows of scales. These are difficult to distinguish from group III sparse-scale carp. The only distinguishing method is counting the number of scales along the lateral line.

There is no uniform standard for linear carp as the entire breed is to be eliminated.

Bare carp have few scales on their body, usually an incomplete row of small scales over the spine, beginning at the base of the dorsal fin, and isolated scales near the head and on the tail. There may be a few scales on the sides of the body. The skin of bare carp is thicker than that of sparse-scale carp. The lateral line is thinner, being a narrow many-branched strip. Bare carp are sometimes difficult to distinguish from group I sparse-scale carp.

TABLE 1. Most important diagnostic characteristics of scaly, sparse-scale, linear, and bare carp

Characteristic	Scaly	Sparse-scale	Linear	Bare
Fin structure	Normal	Normal	Partly reduced	Partly reduced
Number of soft (branched) rays in fins:				
in D	16-24	16-24	10-21	4-20
in A	5(4)	5(4)	3-5	3-5(2)
Number of gill rakers on 1st arch (external row)	23-30	22-28	16-23	16-21
Formula of pharyngeal teeth	1.1.3 — 3.1.1 (rarely 1.1.3-3.1)	1.1.3-3.1.1 (rarely 1.1.3-3.1)	1.1.3-3.1; 1.3-3.1; 3-3.1 and others	1.1.3 — 3.1; 1.3-3.1; 3-3.1 and others
Number of scales along the lateral line	34-41	< 32	32-39	—
1/H index in young of the year (mongrel carp)..	2.5-2.7	2.45-2.65	2.65-2.85	2.6 — 2.8

* The 1/H index is given for ponds with moderately developed food resources which are sufficient for raising young of the year (in the climate of the central and northern USSR).

2. Diagnostic morphological characters

Linear and bare carp differ greatly from scaly and sparse-scale carp in the structure of fins, gills, pharyngeal teeth, and in some other characters (Table 1).

The dorsal and anal fins are much smaller in linear and bare carp. Most frequently one or more rays are absent in the middle part of the dorsal fin (sometimes the posterior part is reduced). The anal fin generally has fewer branched rays, and the fin itself may be smaller.

There are about 4-5 fewer gill rakers in linear and bare carp.

Linear and bare carp have 1-3 fewer pharyngeal teeth, set in 2 or even one row rather than 3.

Linear carp have somewhat fewer scales along the lateral line than do scaly carp. Sparse-scale carp of groups II and III almost never have over 32 scales in the lateral row.

The body shapes of the linear and bare carp have altered greatly; their bodies are elongated, and the 1/H increased. According to their dorsal fin height, underyearlings can be arranged in the following order: sparse-scale > scaly >bare >linear.

There are also slight differences in the circumference of body, in length of dorsal fin, length of intestine, and some other characteristics.

3. Differences in ecological-physiological characteristics

Scaly carp grow fastest; the growth rate of sparse -scale, linear, and bare carp is less rapid in that order. If the weight of scaly carp is taken as 100%, the weights of carp of the various groups raised under standard conditions are:

for underyearlings:	100, 93, 85, 79, accordingto Probst (1953), and
	100, 96, 88, 80, according to Kirpichnikov (1948);
for yearlings:	100, 96, 86, 84 (Probst, 1953).

Under unfavorable conditions the differences increase greatly.

Similar differences are observed in the total survival rate: scaly carp are in 1st place (by underyearlings) for survival. Bare and particularly linear carp have a considerably lower survival rate.

Scaly carp are also distinguished by their cold endurance. Bare and linear carp have little ability to withstand cold, and linear carp do not winter in the north at all.

Scaly and sparse-scale carp are more productive than the other breeds, but here, the differences between them are slight.

Linear and bare carp that are crossed ("linear)< linear," "linear X bare," "bare X bare") are 25% less fertile than scaly and sparse-scale carp because of the mortality of embryos with NN genes (see following).

4. Patterns of inheritance of scale cover

Two pairs of nonlinked hereditary factors determine the breed groups.

SSnn and Ssnn—scaly carp;
ssnn —sparse-scale carp;
SSNn and SsNn— linear carp;
ssNn —bare carp;
SSNN,SsNN and ssNN are not viable (Kirpichnikov,1937; Golovinskaya , 1946; Probst, 1953).

Knowing the genetic determinants, we can predict the result of any crossing. Table 2 lists 2 variants for most crossings. The 1st is for spawners homozygous in S, the 2nd is for heterozygous spawners. Only scaly and sparse-scale carp can be homozygous in the main factors and breed true for scale cover. It is impossible to obtain homozygous progeny from linear and bare carp; bare carp always have bare and sparse-scale young; linear carp have linear and scaly progeny or all 4 types of carp.

In the USSR, linear carp are being eliminated, so that only 3 groups of carp are being raised, of which 2 groups (scaly and sparse-scale) can be purebred. It is undesirable to cross fish from which progeny will have linear scale cover.

In the last 3 crossings (see Table 2), fertility is decreased by 25% owing to the death of embryos with the lethal NN combinations.

Application of the radiation gynogenesis method revealed the genetic nature of linear and bare carp to be apparently more complex than had been assumed until recently (Golovinskaya et al., 1963), but this does not affect the diagram of results of crossings (Table 2).

TABLE 2. Results of crossing carp of different scale cover

Parents	Progeny, %			
	scaly	sparse-scale	linear	bare
Scaly × scaly	100	—	—	—
	75	25	—	—
Scaly X sparse-scale	100	—	—	—
	50	50	—	—
Scaly × linear*	50	—	50	—
	37.5	12.5	37.5	12.5
Scaly x bare*	50	—	50	—
	25	25	25	25
Sparse-scale × sparse-scale	—	100	—	—
Sparse-scale X linear*	50	—	50	—
	25	25	25	25
Sparse-scale × bare*	—	50	—	50
Linear X linear*	33.3	—	66.7	—
	25	8.3	50	16.7
Linear × bare*	33.3	—	66.7	—
	16.7	16.7	33.3	33.3
Bare X bare	—	33.3	—	66.7

* "Undesirable" crossings.

Ukrainian frame-scale carp have the genetic formula ssnn, and hence are identical in this respect with sparse-scale carp.

Bibliography

Publications in Russian

Arnol'd, I.N. Prodvizhenie karpovoi kultury na Sever (Movement of Carp Culture to the North). -Izvestiya VNIORKh, Vol. 21. 1939.

Golovinskaya, K. A. Pleiotropiya genov cheshui u karpa (Pleiotropy of Genes of Scales in Carp). -Doklady AN SSSR, Vol. 28, No. 6. 1940.

Golovinskaya, K. A. 0 lineinoi forme kul' turnogo karpa (On the Linear Form of Cultivated Carp). -Doklady AN SSSR, Vol. 54, No. 6. 1946.

Golovinskaya, K.A., D.D. Romashov, and N.B. Cherfas. O radiatsionnom gipogeneze u karpa (Radiation Gynogenesis in Carp). - Trudy VNIIPRKh, Vol. 12. 1963.

Golovkov, G.A. and N.G. Ekaterinoslavskaya. Opyt proizvodstvennogo vyrashchivaniya zimostoikikh segoletok gibridov (karp X amurskii sazan) v prudakh Latviiskoi SSR (Experiment in Productive Raising of Winterhardy Underyearling Hybrids (Carp with "Eastern Carp") in Ponds of the Latvian SSR). - Rybnoe Khozyaistvo Vnutrennikh Vod Latviiskoi SSSR, No. 1. 1955.

Kirpichnikov, V. S. Osnovnye geny cheshui u karpa (Major Genes of Scale in Carp). -Biologicheskii Zhurnal, Vol. 6, No. 3. 1937.

Kirpichnikov, V. S. Eksperimental'naya sistematika sazana. I. (Experimental Taxonomy of Wild Carp. I.). -Izvestiya AN SSSR, Seriya Biologicheskaya, No. 4. 1943.

Kirpichnikov, V. S. Vliyanie uslovii vyrashchivaniya na zhiznesposobnost', skorost' rosta i morfologiyu karpov razlichnogo genotipa (Effect of Raising Conditions on Viability, Growth Rate, and Morphology of Carp of Different Genotypes). —Doklady AN SSSR, Vol. 47, No. 7. 1945.

Kirpichnikov, V. S. Sravnitel'naya kharakteristika chetyrekh osnovnykh form kul'turnogo karpa pri ikh vyrashchivanii na severe SSSR (Comparative Characteristics of 4 Principal Forms of Cultivated Carp during their Breeding in the North of the USSR). —Izvestiya VNIORKh, Vol. 26, No. 2. 1948.

Kirpichnikov, V. S. Amurskii sazan na severe SSSR ("Eastern Carp" in the North of the USSR). —Rybnoe Khozyaistvo, No. 8. 1949.

Kirpichnikov, V. S. Prodvizhenie karpa i sazana na sever (Movement of Carp and Wild Carp to the North). —Trudy Soveshchanii po Problemam Akklimatizatsii Ryb i Kormov Bespozvonochnykh, No. 3, Moskva. 1954.

Kirpichnikov, V. S. Sozdanie novoi severnoi gibridnoi porody karpa (Creating a New North Hybrid Breed of Carp). —Trudy Soveshchanii po Rybovodstvu, No. 7. 1957.

Kirpichnikov, V. S. Gibridizatsiya karpa s amurskim sazanom primenitel'no k zapadnym oblastyam SSSR (Crossbreeding of Carp with "Eastern Carp" as Applied to Western Regions of the USSR). —Trudy V nauchnoi konferentsii po izucheniyu vnutrennikh vodoemov Pribaltiki, Minsk. 1959a.

Kirpichnikov, V.S. Geneticheskie metody selektsii ryb (Genetic Methods of Fish Selection). —Byulleten' Moskovskogo Obshchestva Ispytatelei Prirody, Otdel Biologii, Vol. 64(1). 1959b.

Kirpichnikov, V. S. Geneticheskie metody selektsii gibridov ryb (Genetic Methods of Selecting Fish Hybrids). —Trudy soveshchaniya po otdalennoi gibridizatsii rastenii i zhivotnykh, Moskva. 1960.

Kirpichnikov, V.S. and E.I. Balkashina. O khozyaistvennom ispol' zovanii gibridov kul'turnogo karpa i dikogo sazana (Commercial Use of Hybrids of Cultivated Carp and Wild Carp). —Rybnoe Khozyaistvo, No. 3. 1935.

Kirpichnikov, V.S., F.N. Mikhailov, and K.A. Golovinskaya. O proizvodstvennoi gibridizatsii karpa s sazanom (On Productive Crossbreeding of Carp with Wild Carp). —Rybnoe Khozyaistvo, No. 6. 1936.

Kirpichnikov, V.S., K.A. Golovinskaya, and F.N. Mikhailov. Vazhneishie tipy cheshuichatogo pokrova u karpa i ikh svyaz' s khozyaistvenno-tsennymipriznakami (Major Types of Scale Cover in Carp and their Connection with Commercially Valuable Characteristics). —Rybnoe Khozyaistvo, Nos. 10-11. 1937.

Kononov, V.A. Dostizheniya ukrainskogo prudovogo khozyaistva (Attainments of Ukrainian Pond Culture). — Rybnoe Khozyaistvo, No. 5. 1952.

Kuzema, A. I. Organizatsionnye osnovy porodnogo uluchsheniya karpa v rybkhozakh Ukrainskoi SSR (Planning Principles for the Improvement of Carp Breeds in Fisheries of the Ukrainian SSR). —Trudy Instituta Prudovogo i Ozerno-Rechnogo Rybnogo Khozyaistva UKrSSR, Vol. 7. 1950.

Kuz'oma, O. I. Perevirka plidnykiv koropa za yakistyu potomstva (Progeny Testing of Carp Spawners). —Naukovi Pratsi Ukrayins'koho Naukovo-DoslidchohoInstytutuRybnohoHospodarstva, Vol. 14. 1962. [In Ukrainian.]
Savel'ev, V. I. 0 gibridizatsii taparavanskogo sazana i kul' turnogo karpa (On Crossbreeding Taparavanskii" Wild Carp with Cultivated Carp). — Izvestiya VNIORKh, Vol. 22. 1939.
Savel'ev, V. I. Vyrashchivanie standartnogo segoletka v severnykh raionakh SSSR (Raising Standard Underyearlings in the Northern Districts of the USSR). —Izvestiya VNIORKh, Vol. 24. 1941.

Publications in Other Languages

Kirpitschnikow, V. S. Die genetischen Methoden der Selektion in der Karpfenzucht. — Z. Fisch., Vol. 10, Nos. 1-3. 1961.
Menzel, H. U. and W. Steffens. Über das Wachstum von Spiegel und Nachtkarpfen. — Z. Fisch. , Vol. 6, Nos. 1-7. 1957.
Probst, E. Vererbungsuntersuchungen beim Karpfen. —Allg. Fisch Ztg., No.21. 1949.
Probst, E. Die Beschuppung des Karpfens. —Miinchn. Beitr. Abwass. — Fisch. —Flussbiol., Vol. 1. 1953.
Schäperclaus, W. Die Bewertung des Karpfens bei der Zuchtauslese. — Z. Fisch., Vol. 4, Nos. 7-8. 1955.
Schäperclaus, W. Lehrbuch der Teichwirtschaft. 2nd edition. Berlin and Hamburg. 1961.

METHODS OF PROGENY TESTING SPAWNERS IN CARP FISH FARMS

V. S. Kirpichnikov

Introduction and review of the literature

Individual selection or appraisal of spawners by qualities of their close relatives (appraisal by genetic type) has been employed recently in carp breeding. Selection by progeny is the only form of individual selection used. Kuzema was the first to work out methods for appraisal of spawners. Thirty years ago he conducted the first experimental polyallel crossings to select the best females and males of Ukrainian carp, using artificial fertilization. To compare males, the eggs of one female were divided into 10 equal portions and each portion was fertilized by milt of each of the 10 males being tested. To compare females, only one male was utilized, and its milt was divided into 10 portions. After fertilization, the eggs were placed on a substrate and incubated in slightly running water until the larvae emerged. These were then reared in special wooden troughs (raising apparatus).

The technical difficulties of ensuring feeding conditions for the larvae in those raising troughs were formidable. In some troughs, predatory invertebrates devoured many larvae; differences in density made it impossible to give an accurate estimate of the relative growth rate and viability of the larvae. Though Kuzema (verbal communication) isolated the record-breaking spawners at the end of his experiments, his evaluation could not be accurate.

After the war, Kuzema repeated his experiments several times; the results of experiments done in the late 1950's are presented in 2 reports (Kuz'oma, 1961, 1962). This time he employed 4 estimation methods:

1. Appraisal of male qualities by growth rate and survival in pools of progeny (underyearling) resulting from crossing separately 10 males with 1 female.

This method remained essentially the same as in his first experiments. The eggs were fertilized artificially, and then larvae and underyearlings were raised in pools of uniform area (the experiment was carried out without replication). Progeny of 2 males were distinguished by their rapid growth, but the absence of replication of the experiment made it impossible to establish whether this was due to a higher quality of spawners or environmental differences.

2. In another experiment, frame-scale males were evaluated by the quality of their progeny (8 males crossed with 1 female) with scaly carp stocked in the same ponds as "general controls," the fingerlings being raised together to before the year stage.

In the 1957 experiments, males Nos. 10 and 43 distinguished themselves, particularly as specimens the progeny of which had improved their growth rate as shown by the difference in the mean weight between frame-scale carp and the control scaly carp in the same pond. Young of the year from male No. 10 were 27% heavier, and those of No. 43 were 7% heavier, than the controls.

The absence of replication of the experiment casts doubt on Kuzema's results. As we will show later, the "general control" method is frequently unreliable, as there is little uniformity in the weight of the fingerlings at stocking. Initial weight differences can greatly affect the growth of the groups to be compared.

3. Males were appraised by crossing with 2 females (6 males, 2 females) and by rearing their progeny in ponds, again using scaly carp as "general controls."

In 1959, of 6 males tested with 2 females, No. 637 and No. 960 proved to be the best spawners. Unfortunately, each progeny group was reared in a separate pond, and the ponds were different. Thus, comparison was very difficult. Mortality was high in some ponds, further reducing the reliability of this "general control" method.

4. Groups of spawners were evaluated by rearing the young of the year in ponds under "general control" as in the other series of experiments.

Altogether 7 groups were chosen for evaluation, 1 group consisting of exceptional specimens isolated in 1957 (males Nos. 10 and 43). The best results by weight, viability to 1 year, and productivity were found in groups Nos. 23, 25, and 27. The males from the exceptional group were in the 4th-5th place.

On the whole, Kuzema's experiments again illustrate the pitfalls of evaluating spawners by progeny and the necessity of no less than triple replication.

D. P. Poliksenov, in Belorussia, conducted experiments of evaluating spawners by progeny estimation. He used natural spawning and, like Kuzema, stocked controls of different scale cover in all ponds. The controls were scaly carp, and mirror sparse-scale carp were tested. Poliksenov's experiments showed that the "general control" method requires strict adherence to several conditions, the most important of which are:

a) Controls must be absolutely distinguishable from the experimental fish, by their scale cover or some other characteristic.

b) Weights of the experimental and control groups must be uniform when they are stocked so that comparable data on growth and survival rate are accurate.

c) Conditions of raising all the fish must be uniform prior to stocking.

Several researchers (Schäperclaus, 1958, 1961; Moav and Wohlfarth, 1963) have emphasized the importance of the last 2 requirements. The difference at the start in the quality of fish being evaluated, even if they have equal weight, may greatly affect their subsequent growth and viability.

It is extremely difficult to meet all these requirements using natural spawning in ponds; thus, it is understandable that Poliksenov could not do so. Even when comparison seems legitimate, it can be complicated by the differing capacities for competition among different families in relation to each other and to the controls. Joint rearing always reflects to some degree the aggressiveness of those sib groups that can find food faster or take it from others (Moav and Wohlfarth, 1963).

Working to improve the breeding qualities of northern ("Ropsha") carp hybrids, we began a series of experiments in 1957 to develop methods of individual appraisal of hybrid spawners. The results of the 1957 and 1958 experiments have been published (Kirpichnikov, 1960; Kirpitschnikow, 1961). Briefly, they are:

1. In 1957, the eggs of 1 hybrid female were divided into 8 portions and fertilized with milt taken from 8 male hybrids of the 3rd generation. Progeny were evaluated only as larvae before they weighed 200-300 mg. The experiment included both separate and joint raising (in pairs) in aquariums of progeny groups, one group tagged with Ca". The raising in aquariums of the latter made it possible to isolate several of the best progeny. Larvae of male No. 52, which was the largest male, grew fastest. No distinct differences in survival rate were found.

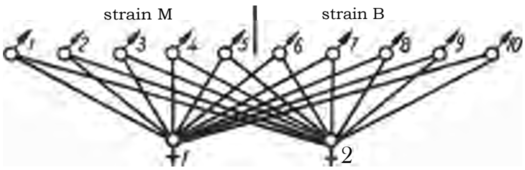

FIGURE 1. Diagram of crossings in selection by progeny evaluation of 3rd generation male hybrids ("Ropsha, " 1958).

2. In 1958, 5 males of each of the 2 main strains of 3rd generation "Ropsha" hybrid carps (M and B)* were tested, as diagrammed in Figure 1.

Because it is impossible to ensure uniform conditions for all 20 crossings, embryos and larvae were at first compared only within the following groups of 5 crossings each.

9 No. 1,ddfrom strain M	9 No. 2, ♂♂ from strain M
No. 1, ♂♂ from strain B	♀ No.2, ♂♂ from strain B

The following conclusions were the results of numerous experiments with many replications and uniform population density in the aquariums:

a) At the embryonic and larval stages of development, the progeny of the largest males (M3 and B26) proved most viable in crossing these males with one or another female.

b) The growth rate of young larvae of males M69, M74, B5, and B19 was outstanding; this superiority was usually evident in crossings with both females.

c) Males M69 and B19 proved the best in growth rate of larvae, as shown in experiments using radioactive tagging of larvae and ensuring uniform weight at stocking;

d) The overall results on raising progeny of the better M strain males were generally the same for both females. In order of quality of progeny from being crossed with the 2 females, the males are:

No. 1; M69, M74, M65, M10, M3
No. 2; M69, M65, M74, M10, M3

* A. G. Konradt participated in the 1958 experiments.

Interestingly, the progeny of the largest male (M3) grew slowest. In part, this occurred because both females and male No. 3 were he rozygous in factor S, and almost 25% of their descendants were slow-growing, sparse-scale fingerlings. All the remaining males were homozygous in factor S.

These are the results of the first 2 years of work on progeny evaluation of spawners. The experiments enabled us to work out unified methods of testing which we followed subsequently. These methods can be summarized as follows:

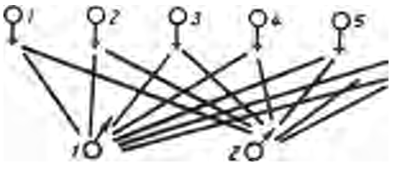

FIGURE 2. Diagram of crossings in progeny evaluation of females ("Ropsha," 1959— 1961).

1. The spawners to be tested receive pituitary extract injections and are stocked in tanks until maturity.

2. All eggs are fertilized simultaneously by the dry (Russian) method; the eggs are then wetted and placed on gauze frames.

Each male to be tested is crossed in succession with 2 females, and each female to be tested is crossed with 2 males (Figure 2).

3. After eggs are removed from the frames, they should be incubated in crystallizers with double or triple replications.

4. Larvae may be raised in aquariums, at first separately according to sib-groups, then tagged mechanically or radioactively and reared jointly.

5. Underyearlings, and sometimes yearlings of different crossings, are tagged mechanically and reared jointly in ponds.

Evaluation of female carp by quality of progeny

In 1959, we conducted the first, small-scale experiment on selection of females at "Ropsha." In this, 7 hybrid females were crossed (by artificial fertilization) with sparse-scale male carp.

Embryonic development observations revealed that the eggs of 2 females were not sufficiently viable, and the 2 carp were excluded from the experiment. Of the remaining 5 females, one, B2, proved to have the best eggs (larval emergence 80.1% including 69.1% normal) female M77 the next best (70.1% larvae, 55.9% normal). Females B12, M26, and M74 had 43.4, 53.7, and 53.0% normal larvae, respectively. The most viable eggs were those of the larger of the 2 sparse-scale carp females and the largest of the females from an interlinear crossing.

Subsequently, 6 series of studies investigated the growth rate of larvae and fingerlings of various females. Results are presented in Table 1. In all the cases, the initial stocking weight of the larvae was made as uniform as possible.

Females M77 and B2 were superior in producing viable eggs and progeny with excellent growth rate (up to 180 mg). The differences are significant only when comparing B2 and B12, however. Subsequently the differences gradually lessened. In series **II** and III of the experiments, the young of

TABLE 1. Growth of larvae in aquariums and ponds as an indicator of the quality of females ("Ropsha," 1959)

Series of experiment	Date	M26	M74	M77	B2	B12	Conditions of experiment
				Average weight in aquariums, mg			
I	5—23 July	178.7	175.3	.5	18 3±8.1	16 ± .6	plications, separate rearing
II	28 July—4 Sept.	1201±81	1158±49	1 5 ±67	8±74	—	1 rep cation, joint rearing
III	28 July—4 Sept.	1384±78	1224±101	2 6	—	1314±68	he . me
				Difference in weight gain with control crossing, mg			
IV	28 y—8 Aug	+11 ± 5	−13±62	+77±23	Control	Co ol	3 replications, joint rearing
V	28 —3 A g.	+72 2	−24±68	+67±76	—	Co ol	The same
				Weight gain in ponds, mg			
VI	4 Sept.—31 Oct.	83	628	402	—	—	1 replication, joint rearing, 25 specimens in each group

[illegible] B2 [illegible] M26, [illegible] IV [illegible] V, [illegible] M26, [illegible]. I[illegible] A[illegible] N[illegible].6 [illegible] S[illegible]; [illegible] M77 [illegible].

T[illegible]:

1) E[illegible].

2) T[illegible].

3) T[illegible].

F[illegible] M26 [illegible] S, [illegible]. N[illegible], M26 [illegible] 4 [illegible] 6 [illegible] ([illegible] T[illegible] 1).

T[illegible] 1959 [illegible].

1960 [illegible]. T[illegible]. O[illegible] 5 [illegible] M [illegible] 6-7. T[illegible]. O[illegible] 6 J[illegible] 1960, [illegible] "Ropsha," [illegible] M9 [illegible] B9 [illegible] 5 [illegible]. D[illegible], [illegible]: [illegible]; [illegible] 5 [illegible]; [illegible] 5 [illegible] 5 [illegible] 15-20 [illegible]; [illegible], [illegible]. T[illegible] 2 [illegible] characteristics of the females and results of the experiments. Egg size varied greatly; a very large female, M2r, spawning for the first time, produced very small eggs with a low rate of fertilization. The differences in the survival rate of embryos from the gastrula stage until the transition to active feeding were also considerable, and statistically significant in several cases.

TABLE 2. Characteristics of tested females, quality of eggs, and survival rate of progeny in the embryonic development period ("Ropsha, 1961)

Female identification No.	Age of female	Weight of female, g	Body length (l), cm	Average weight of 1 egg, mg	Percent of fertilization*		Mortality before transitionto active feeding (two replications).%	
					in crossing with ♂M9	in crossing with ♂B9	M9	B9
M8	7	3,060	50.5	0.88	79.0	76.0	23.2 ± 1.00	15.7 ± 1.05
M28	7	3,730	53.0	0.97	81.5	73.5	18.7 ± 0.92	18.3 ± 1.12
M37	7	2,660	48.0	1.15	73.0	55.5	14.3 ± 0.82	11.4±0.92
M65	7	2,890	49.5	0.99	–	83.5	16.2 ± 0.87	21.7 ± 1.19
M2r**	6	4,200 †	51.0	0.76	20.0	26.5	27.1 ± 1.05	29.1±1.31

* Was calculated at the end of gastrulation, therefore lowering the percent of fertilization somewhat.

** Female M2r was obtained from another (reciprocal) crossing.

† The female was weighed in 1961 at the age of 6+.

Survival rate proved to be closely related to egg size. Thus, in crossing female M2r with male B9, the mortality of eggs was 29.1%, while that for female M37, which had the largest eggs, was only 11.4%. The correlation between egg size and embryo survival rate was a rather substantial +0.78. Also, larvae hatched from large eggs were heavier (Table 3). In some experiments, we studied growth of larvae, fingerlings, underyearlings, and finally yearlings.

TABLE 3. Testing females by growth of their larvae in aquariums (Ropsha, 1960)

Male identification No.	Date of observation	Number of replications	9 M8	9M28	9M37	9 M65	9 M2r
			Mean weight, mg				
M9 and B9	16 June (5 days after hatching)	4	1 75 ± 0.07	1.98 ± 0.07	2.22 ± 0.06	1.78 ± 0.03	1.60 ± 0.06
			Mean increment, mg				
M9	16 June - 10 July	4	58.9	70.9	64.8	59.5	63.1
	10- 19 July	4	88.9	99.6	97.4	93.0	91.1
B9	16 June- 10 July	3	66.6 ± 6.35	61.9± 2.97	2.2* 3.18	604± 1.39	63.3 ± 2.64
	10- 24 July	3	208± 12.5	188 ± 14.5	199 ± 10.0	185 ± 6.4	182±5.6

Of females crossed with male M9, female M28 had the best growing larvae. The progeny of female M37, which had the largest roe eggs, were only in second place. In crossings with male B9, female M37 had larvae that had an initial advantage, but which were subsequently displaced by those of female M8 (Table 3). In several cases, the differences proved to be sufficiently reliable with probability exceeding 0.95 and even 0.99.

Differences in egg size continued to affect survival rate of larvae although not so much as it did survival of eggs (Table 4).

TABLE 4. Testing females by mortality of larvae (%) in aquariums ("Ropsha," 1960)

Male identification No.	Date of setting up the experiment	Total number of larvae from each female	M8	♀ M28	♀ M37	♀ M65	♀ M2r
9	16 June— 10 July	300	12.0	13.7	4.7	10.7	7.3
9	16 June— 24 July	150	4.7	4.0	6.0	7.3	8.0

Numerous experiments were made to determine the differences in growth rate of underyearlings; the results are presented in Table 5. Progeny of the largest and the youngest female M2r grew best.

The differences among sib-groups sometimes reaches 20 and even 30%, this finding having proved reliable. The young of female M8 generally take second place, although those of M28 sometimes come second.

The young of M37 and M65, particularly the latter, grew slowest, frequently significantly slower than other young.

Thus, after 40 days, fingerling growth is not affected by the size of the eggs they left. Another, most probably genetic, correlation between dimensions of females and growth rate of progeny becomes more and more evident in the underyearlings.

The small experiment on underyearling hibernation did not give any clear results owing to the few wintering fish. In spring 1961, some of the yearlings that had hibernated were stocked in forage ponds, and autumn weighing confirmed the good breeding qualities of female M2r (Table 6). No significant differences between other females (by progeny growth) were obtained because the sample size was insufficient.

To summarize the results of the 1960 experiments, we may say that we succeeded in solving several important methodological problems, namely:

1) Maternal influence proves to be very strong in embryogeny and during the initial stages of postembryonic development (until larvae weigh 150-200 mg). Size and weight of eggs are of definite significance.

2) With sufficient (at least 3-4) replications, experiments on underyearlings reveal that the actual genetic differences between females that are similar in general outline are also seen in fish of age 1+

3) No perceptible difference was established for use of various males. This strongly supports the assumption that genetic differences ingrowth rate between males and females and between their progeny are largely additive.

4) A definite correlation between the weight of females and the growth rate of young (underyearlings and yearlings) was observed, and again, the best females, M2r and M8, proved to be heterozygous in factor S.

TABLE 5. Testing females through growth of their hybrid underyea ling progeny ("Ropsha," 1960)

Pond or aquarium	Stocking and removal date	Number of fish in each sib-group at time of removal	Mean initial weight, g	Male identification No.	♀ M8	♀ M28	♀ M37	♀ M65	♀ M2r
					Underyearling mean weight a removal, g				
Intermediate pond 3	18 July - 22 Nov.	59-92	0.1	M9	32.7	35.1	32.5	33.8	36.2
Hatchery pond 1	28 July- 12 Sept.	11-19	0.22	M9	11.77 ±0.51	10.55 ± 0.49	12.19 ± 0.51	10.28 ± 0.48	13.22 ± 0.46
" 2	29 July- 12 Sept.	9-15	0.26	M9	5.39± 0.38	4.69 ± 0.24	5.20* 0.28	4.43 ± 0.22	6.05 ± 0.23
5	4 Aug. -12 Oct.	8-16	0.32	B9	5.87 ± 0.19	5.65 ± 0.17	5.48 ± 0.24	5.27 ± 0.18	6.07 ± 0.33
6	9 Aug. -12 Sept.	14-18	0.26	B9	4.62± 0.18	4.53 ± 0.16	4.43 ± 0.20	4.19± 0.12	4.80± 0.18
					Underyearling mean weigh in % of the control weight (paired experiments)				
Aquariums 2,7, 9 and 11	30 July -8 Sept.	9-11	0.16- 0.20	M9	119.0 ± 8.5	111.5 ± 9.7	124.1 ± 7.1	Control, 100	120.2 ± 5.9
Aquariums 1,5, 6 and 8	6 Aug.- 8 Sept.	10	0.20- 0.26	B9	112.5± 6.3	92.7 ± 9.2	95.6 * 7.1	–	110.7 ± 7.5

Note. When the aquarium experiments ended, weight was 1.2- 1.5 g.

TABLE 6. Hibernation of underyearlings and growth of yearling hybrids of females tested from crossing with cf M9 ("Ropsha," 1960- 1961)

Female identi'- No.	Initial stocking, autumn 1960		Spring catch		Winter mor- tality, %	Removal of fish of age 1+ in autumn 1961		Criterion of reliability of difference with ♀M2r
	Number of specimens	Mean weight, g	Number of specimens	Mean weight, g		Number of specimens	Mean weight, g	
M8	61	32.7	27	30.5	55.7	21	392±14.6	<0.05
M28	58	34.8	41	28.4	29.3	18	360 ±16.4	0.01
M37	86	32.5	47	28.3	45.3	13	365 ±17.8	<0.005
M65	91	33.8	66	29.4	21.5	23	388 ± 14.4	0.01
M2r	92	36.2	64	33.0	30.4	35	430 ± 8.2	—

* Apparently, a small error was made while weighing the underyearlings in the autumn.

TABLE 7. Characteristics of females, quality of their eggs, and survival rate of progeny in the embryonic development period ("Ropsha," 1961)

Female identification No.	Age	Weight, g		Average di- ameter of eggs, mm	Mortality of eggs in crossings with male K			Mortality of eggs in crossings with male M9		
		at 7 years	at time of test		from neurula stage to onset of hatching, %	from on- set of hat- ching to beginning of active feeding, %	total, %	from neurula stage to onset of hatching, %	from on- set of hat- ching to beginning of active feeding, %	total, %
M1r	7	4,160	4,160	1.32 ± 0.020	7.3	19.3	26.6 ±1.2	7.3	22.7	30.0± 1.6
M50r	7	4,500	4,500	1.28 ± 0.023	5.2	14.4	19.6 ±1.4	11.4	24.6	36.0 ± 1.5
M2	8	4,150	4,860	1.17± 0.022	8.7	37.5	46.2 ±1.5	9.7	40.4	50.1 ±1.6
M12	8	2,910	3,300	1.33 ±0.019	23.9	37.1	61.0 ±1.7	33.7	30.8	64.5 ± 1.5
M21	8	3,360	3,910	1.24 ±0.018	7.6	25.1	32.7 ±1.3	4.9	46.1	51.0 ± 1.6
M37	8	2,850	3,520	1.39± 0.022	9.1	24.2	33.3 ±1.3	14.0	21.6	35.6 ± 1.5
M71	8	3,190	3,920	1.31 ± 0.029	10.3	14.2	24.5 ±1.2	8.4	22.5	30.9 ± 1.5

1961 **experiments.** The progeny testing of females was continued in 1961 to further perfect methodology.

Of the 7 females chosen. 1 (M37) was selected for the second time to make possible comparison of data of 1960 and 1961. A brief characterization of the females, as well as size (diameter) of fertilized eggs, is listed in Table 7. Uniform conditions were again maintained in the crossings which used 2 different males, a Kursk hybrid (K) and a hybrid of strain M, (the latter had participated in 1960). Females were from 2 age groups. To clarify further the comparison of females of different age, the weights of 8-year-old and 7-year-old females are those for May 1960 and May 1961, respectively. The size and weight of females varied greatly. The egg diameter also differed greatly, female M37 again having the largest eggs. This time we did not observe the close relationship between egg size and the survival rate of embryos that we noted in 1960. The most resistant young were those of females Mir, M71, and M50r, all of which had medium size eggs. Possibly, the weight of eggs is more significant than their diameter.

which includes the perivitelline space.

In 2 crossings with male K (females M2 and M12) and 3 crossings with male M9 (females M2, M12, and M21), mortality of eggs and larvae was very high. Female M12 had eggs which apparently were of very low quality. Only 5-10% of the eggs of females M2 and M21 died during embryonic development, but there was mass mortality (over 25%) of larvae at hatching and on transition to active feeding. Perhaps this is due to the appearance of recessive lethal genes; the genetic lines of the hybrid males and females give grounds for this assumption. The similarity in survival rates of the crossings with both males contradicts it, however. More probably, the cause of increased mortality was the poor quality of the eggs of females M2 and M21 (low accumulation of nutrients in oocytes). It is notable that their eggs were the smallest.

The growth rate of young at the larval stage (Table 8) showed, as in 1960, a correlation between the initial and final weights of larvae. Young females M37 and M12, which had large eggs and large larvae at hatching, grew best. These larvae also had a high rate of viability (total mortality did not exceed 2%).

Subsequently, the relation disappeared, and when the young weighed 0.5 — 2.0 g those from actually superior females became apparent, the females being M1r, M50r, and M71 (crossings with hybrid M9).

The growth rate no longer reflected the egg size (Table 9). Differences were not always significant, and the variability between replications was high.

Finally, the 3 experiments made to compare the growth rate of under-yearlings in ponds gave similar, but not identical results (Table 10). In the first case, M37 and M50r were the best of 5 females; in the second case, one female, M1r, proved to be the best of 5; in the third case, young of females M71, M50r and M1r were considered outstanding. Differences were not always significant, but the pattern that appeared in the preceding experiment continued; that is, the same best females stood out.

The experiments of 1961 confirmed the conclusions we reached in 1959 and 1960. Viability of embryos and growth of larvae depend greatly on the embryo size, and no genetic differences between females can be distinguished at this stage. By the end of the larval stage the picture has gradually changed, and the maternal influence disappears. When fry weigh about 1g, the growth rate reflects true genetic differences. These are preserved almost unchanged in underyearlings, and (judging from one small experiment) in yearlings. Changing the male has almost no effect, although in one case (1961 experiment) female M71 had good progeny in crossing with only 1 of the 2 males. In other words, nonadditive genetic variability in growth rate does occur, but its proportion is small. The most important fact is that big females usually produce better progeny. An analysis of correlation tables given in Figure 3 can prove it. The rank of the progeny was determined by careful comparison of results of all experiments on finger-lings and underyearlings presented in Tables 5, 9, and 10.

The correlation is also evident in 1960 and 1961 findings, in both cases exceeding + 0.6. Progeny of 2 females (M2r in 1960 and M50r in 1961) that had an exceptional weight (over 4200 g at age 7 years) were distinguishedby their maximum growth rate.

The 1959-1961 work not only isolated several good hybrid females, but also taught us important techniques in progeny testing carp spawners.

TABLE 8. Growth and viability of eggs and larvae of experimental females ("Ropsha," 1961)

Male identification No.	Date of observation	Number of replications	♀M1r	♀M50r	?M2	♀M12	♀M21	♀M37	♀M71
			Initial weight of larvae, mg						
K	16-18 June	3	2.09	1.74	2.09	2.35	2.09	2.33	1.89
M9	16 June	2	2.27	2.04	2.45	2.80	2.70	2.59	2.41
			Average increment of larvae. mg						
K	16 June-10 July	2	73.1	65.9	67.0	80.4	69.9	83.5	63.8
	16 June -10 July	1	78.7	—	76.1	—	85.9	96.5	78.4
	10-17 July	3	108.3 ±1.4	103.3 ± 4.6	101.9 ± 7.7	97.3 ±5.1	98.2± 8.4	108.7 ± 9.4	100.6+4.1
M9	16 June—11 July	2	97.8	96.5	99.4	114.8	102.8	111.4	98.7
	11 - 18 July	2	104.6	127.2	122.0	134.0	124.9	138.0	132.0
	16 June-18 July	1	168.9	178.1	191.3	169.7	187.2	181.4	177.0
			Mortality of larvae, %						
K	16 June-17 July	3	3.8	29.2	6.7	1.3	2.9	2.9	1.3
M9	16 June-18 July	3	2.3	14.2	4.2	0.4	18.8	0.8	1.9

TABLE 9. Growth in aquariums of young from tested females(experiments on paired raising with general control; "Ropsha," 1961)

Experi-ment	Male identifi-cation No.	Date of observation	Initial and final weight of fry, mg	Difference by average weight with control,%						
				♀M1r	♀ M50r	♀ M2	♀ M12	♀ M21	♀ M37	♀ M71
1		18 July-28 Aug.	150-230 → 1,200-1,600	106.1	105.9	Control, 100	96.3	91.6	99.7	88.3
2	K	19 July-22 Aug.	130-240 → 1,260-1,600	92.5	126.7	103.3	104.3	Control, 100	111.6	101.7
3		20 July-20 Aug.	140-180 → 660-800	Control, 100	93.9 ± 5.9	98.3 ± 8.1	80.1 *8.7	91.7 * 5.2	97.7 ± 6.6	92.6 ± 7.5
4	M9	20 July-23 Aug.	110-230 → 890-1,090	114.5± 9.1	95.8	Control, 100	96.1	99.3	108.4	108.8
5		20 July-23 Aug.	120-300 → 880-1,480	108.0	110.8 ± 7.1		99.5	Control, 100	102.9	105.2

TABLE 10. Growth of underyearlings of the experimental females in ponds ("Ropsha," 1961)

Pond	Method of rearing	Male identifi-cation No.	Average weight of underyearlings, g	Average weight of underyearlings as % of control group						
				♀ M1r	♀ M50r	♀ M2	♀ M12	♀ M21	♀ M37	M71
Stock pond 1	All progeny together	K	7.9- 8.7		Control, 100(21)	–	90.1(2)	96.5 (9)	104.5 (13)	95.0 (17)
Stock pond 2	The same	M9	12.0- 14.7	Control, 100(8)	91.2 (21)	–	84.1 (19)	–	81.9 (12)	91.4 (18)
Of fish hatchery 1-6	Jointly, by 2 cross-ings in one pond (general control)	M9	4.4-11.8	Control, 100(8)	101.3 (81)	99.5 (79)	96.7 (80)	82.9 (87)	–	103.1 (91)

Note. Numbers in parentheses denote the number of experimental underyea lings.

Principally, these investigations show that female breeding qualities ma proved by joint raising and evaluating their young.

Because the small experiments carried out in 1962 to check testing of males added nothing new to the conclusions drawn in 1957 and 1958, we shall not analyze them here.

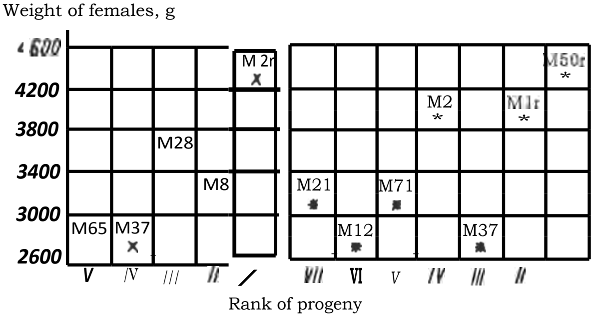

FIGURE 3. Correlation between weight of females and the rank of their progeny by growth rate ("Ropsha," 1960 (left) and 1961 (right)).

Testing carp spawners for heterozygosity

Sparse-scale carp of the Galician strain, with genotype ssnn were used in the late 30's as initial brood stock for crossing of carp with "eastern carp." Later, this same Galician strain was used also to create hybrid "Ropsha" carp. Because it is known (Kirpichnikov, 1937) that the wild carp used in these hybridizations are homozygous in factor S, the 2nd generation of hybrids showed segregation by scales, i. e., $^3/_4$ of the 2nd generation were scaly and $^1/_4$ were sparse-scaled. Subsequently, owing to the dominance of gene S among the scaly hybrids selected for breeding, a fairly large number of spawners were heterozygous (Ss). Thorough laboratory and field investigations established the fact that sparse-scale hybrids lag behind scaly ones in viability, growth rate, and body build (Kirpichnikov, 1959, 1960; Kirpitshnikow, 1961). To avoid the appearance of recessive genes in future generations all the heterozygous spawners had to found and culled. This work began in 1956 and was completed on 3rd generation hybrids in 1961. Some hybrids of the 4th generation back-crossed in 1962-1964. This checking will be completed soon. Hybrids obtained in 1960 and later do not require checking as their parents are previously tested homozygous spawners.

Third generation hybrids belonged to 2 groups of which 1 was about 42% and the other over 90% homozygous (Table 11), these figures being very close to the expected values.

Two strains, M and MB, also produced a different number of homozygous spawners; among 4th generation hybrids somewhat fewer homozygous specimens were found among males of strain MB than had been predicted, 54% instead of 66%. These hybrids were obtained in 1959 from crossings of 3 females (including2 heterozygous). Most probably, this deviation was caused by the lower fertility of a smaller homozygous female, the weight of which was 2880 g in spring 1960, when the weights of the 2 heterozygous females were 3830 g and 3840 g respectively.

TABLE 11. Testing 3rd and 4th generation spawners of "Ropsha" hybrids for heterozygosity in factor S ("Ropsha," 1956-1964)

Breed group	Year of testing	Sex	Number of specimens		
			homozygous	heterozygous	total
Interlinear hybrids of 3rd generation	1956-1958 1960, 1961 1958-1962	♂♂ ♀♀	64 (41.0%) 43 (42.6%)	92 58	156 101
		Total	107 (41.6%)	150	257
Recurrent hybrids of 3rd generation	1956-1958 1958-1961	♂♂ ♀	40 (88.9%) 9 (100%)	5 0	45 9
		Total	49 (90.8%)	5	54
Hybrids of 4th generation, strain M	1962-1963 1963-1964	♂♂	30 (83.3%) 3 (75.0%)	6 1	36 4
		Total	33 (82.5%)	7	40
Hybrids of 4th generation, strains MB and BM	1962-1964	♂♂	47 (50.5%)	46	73
	Total		236	208	414

In all, over 400 spawners were tested for heterozygosity in a 9-year period. At that time we crossed tested hybrids with either sparse-scale or frame-scale carp (S(s?) X ss), or with previously tested heterozygous hybrids (S(s?) X Ss). Procedures were the same in all cases. After receiving a pituitary extract injection, the spawners were stocked in live-tanks: some of the mature eggs (4-5 thousand) were mixed with previously collected milts and placed on frames covered with gauze. No more than 24 hours later, the eggs were removed from the gauze with a scalpel and placed in crystallizers for incubation. About 100 larvae of each crossing were reared in aquariums until scale cover appeared.

Heterozygous parents had about 50% recessive sparse-scaled larvae when crossed with homozygous sparse-scaled carp, and 25% when crossed with heterozygous hybrids. These relations are very evident where mortality was low and over 50 larvae survived until scale cover appeared. When embryonic and postembryonic mortality was high and only a few larvae lived until the time of observation, the ratio of genotypes shifted toward a predominance of scaly carp (Table 12). At the early stages, sparse-scale hybrids are substantially less viable than are scaly hybrids. They also lag in growth rate; in some years (1957 and 1958) this lag was marked and statistically significant.

TABLE 12. Segregation in progeny testing of spawners for heterozygosity by gene S

Number of fish in aquarium	Year	Expected segregation	Total number of fry			Average weight of fry	
			scaly		sparse-scale	scaly, mg	sparse-scale, mg
			specimens	%			
Under 40-50	1957-1958	1:1	757	56.1	591	391±9	340 ± 12
	1959	1:1	102	57.3	76	—	—
	1960	1:1	142	54.0	121	—	—
	1961	1:1	79	59.8	53	—	—
	Total		1080	56.2	841	—	—
Over 40-50	1956	1:1	958	50.2	949	—	—
	1959	1:1	567	52.3	517	—	—
	1960	1:1	921	50.1	919	276 ± 17	266±16
	1960	3:1	367	73.4	133	—	—
	1961	1:1	383	49.8	386	255±8	242 ± 9
Total (in recurrent crossings)			2829	50.5	2771	—	—

Weight of homozygous and heterozygous spawners could be compared only in those few years when the number of tested spawners was sufficiently great and when they had been raised together. Homozygotes grew somewhat slower. This was most evident in 1956 when over 70 males were tested simultaneously. Their weight (by data of spring inventory) was as follows: homozygous 1719 ± 38 g, n= 30; heterozygous 1802 ± 35 g, n= 41.

The differences were reliable only at the 90% confidence level. Reliable values could not be obtained in any of the experiments, but the superiority of heterozygotes can be considered as very probable. The results of recent progeny testing of females also support this view. Thus, in 1959, heterozygous females M26 had the best growing young of 3 strain M females tested. In 1960, of 5 females of the same strain, 2 heterozygous females, M2r and M8, were again the best. Unfortunately our material does not show whether the superiority of heterozygotes is heterozygosity only in gene S or whether it depends on the heterozygosity of a whole section of chromosomes linked with S.

Importance of progeny evaluation of spawners in carp fish farms

Analysis of the 1956-1962 experiments on progeny evaluation of spawners led to some important conclusions. We shall begin with the techniques of such experiments.

There are some essential differences between testing males and testing females. Male testing is simpler and requires less time. Observation of the growth of larvae and young (weight up to 1g) makes it possible to estimate the breeding qualities of the males fairly accurately by growth rate. "Paternal effect" lasts for a short time. Crossings with 2 females are quite sufficient for obtaining objective data: evaluation of 1 female generally agrees with the estimation of the other one.

Thus, aquariums and pools can be utilized for testing males; that is, laboratory experiments are sufficient for this purpose, in principle. However, it would be still better to conduct additional experiments in which the underyearlings of several crossings and uniform weight are stocked jointly in ponds.

The possibility of testing 3 to 4-year-old males is also a great advantage. In the north, females mature 1-2 years later than males. However, difficulties remain, principally the necessity of three- or fourfold replications of each experiment to obtain statistical reliability.

The main difficulty in testing females is the presence of strong and comparatively long-lasting maternal effect. In early development, both the survival rate and the growth rate are closely correlated with weight and, to a lesser degree, diameter of eggs; apparently the amount of yolk accumulated by the oocyte is a factor. Only when the larvae weigh 200-300 mg does this link weaken, and the'actual genetic differences between descendants of various females begin to become apparent. The later they appear, the more distinctly they are expressed.

Evidently the amount of yolk in the egg depends not only on genotype and age of females, but also to a large extent on the environment of the female in the previous summer and during winter spawning. This factor sharply increases the nonheritable variance in size of eggs. "Maternal effect" may have a long-lasting influence, for as long as the first year of life, if foraging conditions are competitive. Therefore testing of females requires a longer period of raising the young, at least to 1 year, preferably to 2 years. The attenuation of food competition is an important condition for joint raising of young from different females. As we noted previously (Kirpichnikov, 1959), creation of "hothouse" conditions is not permissible, but starvation is no less dangerous. "Maternal effect" gives advantage to one sib-group already at the start, and this advantage is maintained for a long time under conditions of intense food competition.

There are also some general patterns in estimating the qualities of males and females. Primarily, genetic differences become evident only when larvae attain a weight of 200-300 mg. Growth and survival rate at earlier larval stages are mainly controlled either by "maternal effect" or by characteristic "paternal influence." The latter is expressed in the fact that spermatozoids of large males are more potent, and survival rate of embryos and larvae obtained from these males is somewhat higher. Later on "paternal influence" ceases and purely genetic differences become of primary significance.

The recurrence of results of testing in crossing males with different females and females with several males should be considered the second important general phenomenon. Theoretically, it means the predominance of additive genetic variability by growth rate; epistasis and dominance are obviously insignificant. The practical significance of coincidence of data and consequently of additivity of differences is equally important. The testing methods are simplified. Males to be tested can be crossed with one female instead of 2 or 3, and the same is true for females. Furthermore the additive character of variability increases the effectiveness of selection. All this is favorable for individual and mass selection in carp breeding.

Before discussing the effectiveness of individual selection, 3 more important problems should be analyzed. The first problem concerns the correlation between the weight of spawners and growth rate of progeny, which was found while testing both males and females; data for 1960 and 1961 are presented in Figure 3 as an illustration. Progeny growth was estimated mainly at one year.

The correlation between the weight of a female and that of its progeny is quite revealing. Firstly, we may assert that genetic differences in growth rate are similar in the first year of life and in subsequent years. Schaperclaus (1961) reported a very weak correlation between the growth rate of young of the year and of fish aged 2 and 3 years. According to our data, group genetic differences in carp are sufficiently stable over several years. The correlation indicated here is also important because it is a substantial argument in favor of application of mass selection in carp breeding.

The second problem is more complex. We have already pointed out that the record-breaking specimens were frequently found to be heterozygotes. It is apparently not a random effect; it can be assumed that hybrids heterozygous in factor s receive a slight advantage in their fight for existence and grow faster on the average than homozygotes. This complicates selection work and should be taken into consideration in elaborating plans for commercial crossings in carp breeding.

Finally, the third problem concerns the choice of a method of raising fish, and the choice of indexes in evaluating progeny. At larval stages, separate and joint raising generally yielded similar results. Experiments on keeping underyearlings and yearlings separately were impracticable in our conditions as the number of similar experimental ponds was insufficient. Based on aquarium experiments, we assume that in raising ponds as well as in joint raising of several sib-groups, the "aggressiveness" of underyearlings to which some investigators attribute great importance (Moav and Wohlfarth, 1963) is not very significant. It is possible that in group testings, differences in aggressiveness become less important, and genetic differences in the efficiency of food assimilation become more apparent than differences in the ability to take food from neighbors.

As to the choice of indexes, we can discuss only one, so far: the growth rate. Theoretically the advantages of individual selection are nil for habitus, where heritability is somewhat higher, and the main method of selection will remain the usually high intensity mass selection. The significance of individual selection will certainly be greater in selection by several physiological and biochemical indexes which can be measured on live fish or cannot be determined en masse, but experiments of this kind have not been conducted so far.

In conclusion, we shall attempt to evaluate progeny testing of spawners as a method of selection. The defect of this method (in carp breeding) is that it is exceptionally time-consuming. First, pituitary extract injection of spawners must be made and then artificial fertilization of eggs must be

CONCLUSIONS

experiment and in controls. Methodological difficulties arising in work with general control make it less valuable.

3. In 1957, 1958, and 1962, we progeny-tested males of "Ropsha" hybrid carp. In 1959, 1960, and 1961 we tested females.

It was established in testing the males that the so-called "paternal effect" is distinct in early development: in large males, sperm is physiologically more potent, and survival rate of embryos higher. Later on, paternal effect gradually diminishes.

In female testing, the maternal effect is much stronger: survival rate in embryonic and larval stages, as well as size of eggs, are correlated with weight of eggs.

Maternal and paternal effects disappear when male progeny larvae attain a weight of 100 —150mg, and those of female progeny reach 200-300 mg. Then, the genotypic qualities of spawners become of main importance. Unfavorably reared underyearlings continue to reflect maternal effect throughout the first year.

4. Progeny evaluation of males may be done in aquariums for fingerlings (weight up to 1-2 g) and in ponds for underyearlings.

Females should be evaluated by quality of young of the year and yearlings, and thus, female evaluation is more time consuming.

5. Results of crossing tested spawners with either of 2 females or males are usually quite similar. This shows the additive character of weight variability and simplified testing.

6. Testing males, and particularly females, enabled us to establish the presence of definite correlation between weight of spawners and growth of their young to one year. Heritability of weight in "Ropsha" carp proved to be higher than was expected: 0.3-0.5 instead of 0.1-0.2.

7. In most cases, spawners heterozygous in factor S had faster growing.

8. Theoretical analysis of the efficacy of mass and individual selection in carp breeding showed that individual selection is not always most efficient.

With low heritability (0.1–0.2), mass selection is preferable, if selection differential in such selection is 5-10 times the differential in individual selection.

With higher heritability (0.3-0.5) a double or triple advantage is sufficient. The very high fertility of carp can produce very great values of selection differential in mass selection. On the other hand, technical difficulties in individual selection do not allow the simultaneous testing of more than 10-12 spawners; thus, selection differential is insignificant.

Combined selection should be considered the best solution of this problem; mass selection should be used in the first and second years of life with subsequent testing of males by progeny. Individual selection of females is possible only if there is a sufficient number of well prepared experimental ponds. As shown by the data correlating between the weight of females and growth rate of progeny, mass selection among spawners may also be significant.

9. Experience in backcrossing spawners to test for heterozygosity in factor S led us to the following conclusions:

a) The proportion of heterozygous spawners usually corresponds to that predicted theoretically for a given group.

b) In early development, sparse-scale hybrids lag behind scaly hybrids in viability and growth rate.

c) On the average, heterozygous spawners are generally larger than homozygous ones, but this conclusion requires further study.

Bibliography

Publications in Russian

K ir pi chnik ov, V. S. Osnovnye geny cheshui u karpa (Major Genes of Scale in Carp). —Biologicheskii Zhurnal, Vol. 6, No. 3. 1937.

K ir pi c hn ik ov, V. S. Geneticheskie metody selektsii ryb (Genetic Methods of Fish Selection). —Byulleten' Moskovskogo Obshchestva Ispytatelei Prirody, Vol. 64, No. 1. 1959.

K ir pi chnik ov, V. S. Geneticheskie metody selektsii gibridov ryb (Genetic Methods of Selection of Fish Hybrids). —Trudy soveshchaniya po otdalennoi gibridizatsii rastenii i zhivotnykh, Moskva. 1960.

Ku z' oma, 0.I. Do pytannya perevirky plidnykiv za yakistyu yikh potomstva u koropivnytstvi (Progeny Testing of Spawners in Carp Breeding). —Naukovi Pratsi Ukrayins'koho Naukovo-Doslidcheho Instytutu Rybnoho Hospodarstva, Vol. 13. 1961. [In Ukrainian. I

Kuz ' oma, 0.I. Perevirka plidnykiv koropa za yakistyu potomstva (Progeny Testing of Carp Spawners). —Naukovi Pratsi Ukrayins'koho Naukovo-Doslidcheho Instytutu Rybnoho Hospodarstva, Vol. 14. 1962.

Publications in Other Languages

Falconer, D. S. Introduction to Quantitative Genetics. Edinburgh and London. 1960.

Kir pit s c hnik ow, V. S. Die genetischen Methoden der Selektion in der Karpfenzucht. —Z. Fisch., Vol. 10, (N. F.), Nos. 1-3. 1961.

M oa v, Rom and G.W. Wohlfarth . Breeding Schemes for the Genetics Improvement of Edible Fish. —Prog. Rep., 1962, Jerusalem. 1963.

Schäper claus , W. Die Bewertung des Karpfens bei der Zuchtauslese. —Z. Fisch., Vol. 4 (N. F.), Nos. 7-8. 1955.

Schaper claus , W. Stand der Leistungsprüfungsverfahren in der Karpfenteichwirtschaft. —Dt. Fisch Ztg., Vol. 5, No. 2. 1958.

SchA. per claus , W. Lehrbuch der Teichwirtschaft. 2nd edition. Berlin. 1961.

Wohlfarth, G.,R om Moav, and M. Lahman. Genetics Improvement of Carp.III. Progeny Tests for Differences in Growth Rate, 1959-1960. —Bamidgeh, Vol. 13, No. 2. 1961.

HETEROSIS IN INTRASPECIFIC CROSSINGS OF CARP

M. A. A

favorable effect; it explains heterosis as a result of the overriding of recessive genes by dominant ones present in homologous chromosomes.* The second hypothesis, that of overdominance, was first suggested by Schell and East in 1908 and definitively formulated by Hull (1945, cited in Kheis, 1955). It assumes that heterozygosity in itself contributes to the vigor of development. Genetically, this means that there are alleles which are much more active in the heterozygous state than they are in the homozygous (Aa> AA> aa). Wallace's experiments (1958) with small mutations obtained as a result of X-raying *Drosophila melanogaster* are some of the most convincing evidence of the presence of a heterosis mechanism based on this principle. Specimens that were heterozygous in the newly created small mutations were generally more stable than others.

By now, most investigators have acknowledged the existence of both these mechanisms of heterosis (Karp, 1940; Crow, 1952; Kheis, 1955; Mather, 1955; Kirpichnikov, 1959a; and others). Crow (1952) analyzed in detail the relative significance of dominance and overdominance and concluded that their relative importance depends on the size and genetic structure of the population, intensity of selection, and many other factors. Variations in the manifestation of heterosis in crossing various inbred lines among themselves, and also incrossing various natural (not inbred) organisms, indicate that the proportionate influence of each of the hypothetical mechanisms does not remain constant. These fluctuations in the proportionate influence of the two mechanisms and the universality of heterosis are evidence that "the phenomenon of heterosis evolved as an adaptive property of a progressive nature" (Borisenko, Al'tshuler, and Polyakov, 1935).

Recently, Haldane (1945; cited in Kheis, 1955) has proposed a biochemical hypothesis of heterosis, which suggests that hybrids have greater biochemical resources ("versatility"). According to Kirpichnikov (1960), biochemical enrichment of hybrids is characteristic of heterosis regardless of the underlying genetic mechanism.

Comparative study of heterosis in various species of plants and animals, particularly if it is associated with cytochemical and biochemical investigations, will help determine the common basis of heterosis.

The present investigation concerns intraspecific cultured carp hybrids which are now important in Soviet pisciculture. Some characteristics of the reproduction and development of hybrid carp (as of carp in general) make these convenient subjects for investigation of heterosis.

Carp heterosis was first found on crossing carp with Volga-Caspian and Taparavan wild carp (Kirpichnikov and Balkashina, 1935; Savel'ev, 1939). The hybrids displayed a higher growth rate and increased resistance; compared to carp, the number of hereditary viability-reducing deformities in the hybrids was insignificant.

One of the best hybrids proved to be a cross between European cultured carp and wild carp of the Amur River. These are 2 subspecies of *Cyprinus carpio* L. —European (*C. carpio carpio*) and East Asiatic (*C. carpio haematopterus*; Berg, 1949). In this crossing, Kirpichnikov (1959b) observed a distinct heterosis in growth rate and viability during the first month of life. Later the difference between

* This hypothesis was later supplemented by concepts of evolution of dominance as developed by Fisher (1932). In the course of evolution, the dominance of genes in diploid animals and plants increases, thus assuring them better protection from harmful mutations.

hybrids and parents decreases,i. e., heterosis "attenuates" (Kirpichnikov, 1938, 1959b). However, the superiority of the hybrids in the first months causes them to remain larger than carp and "eastern carp" for the first 2 years of their life. Kirpichnikov's main experiments involved a small sample; they were of a preliminary nature and require further confirmation. We repeated these crossings in 1959.

Another crossing chosen for investigation was that of 2 strains obtained after prolonged selection of carp-"eastern carp" hybrids. Third generation back-cross and 4-way hybrids were crossed (Kirpichnikov, 1959a). In the course of selection, heterosis of almost the same magnitude as that in 1st generation hybrids was found in 3rd generation hybrids of the Kursk and Novgorod strains. Identification of the presence of heterosis also in 4th generation descendants of males and females of the various strains was of great interest.

"Ropsha" hybrid carp is the main item of breeding in fish pond farms of the northwestern RSFSR. Utilization of hybrids made carp breeding possible further north, up to 60°N lat.

Investigation of the occurrence of heterosis in various crossings of hybrid carp, and the peculiarities of its manifestation are essential to the future development of carp breeding in the north (Kirpichnikov, this collection).

Procedure

The experiments were conducted in fish ponds at "Ropsha" near Leningrad, in the summer of 1959. Heterosis as expressed in the growth and survival rate of 1st and 4th generation hybrids of "eastern carp" (*Cyprinus carpio haematopterus*) and carp was studied. Concurrently the influence of various environmental conditions on the different hybrids was investigated.

First generation hybrids of "eastern carp" and Ukrainian frame-scale carp were obtained according to the following scheme:

9 "eastern carp"	9 frame-scale carp
δδ "eastern carps"	δδ frame-scale carps

There were thus. 4 simultaneous crossings. "Eastern carp" is characterized by high growth rate in the first year of life, good viability, and general resistance. Frame-scale carp is a distinct breed, distinguished by its rapid growth, but it is not very viable under existing conditions.

Fourth generation hybrids were obtained according to a similar scheme:

♀ 3rd generation backross hybrid	♀ 4-way 3rd generation hybrid
M 3rd generation backcross hybrids	dd 4-way 3rd generation hybrids

In one of the parental forms of 3rd generation 4-way hybrids, vigorous heterosis in growth and survival rate was found earlier as noted above.

Artificial fertilization of eggs was used in the crossings; to avoid the influence of 1 male on the progeny, a mixture of milts (in equal amounts) from 3 males was employed in each crossing. The main requirement in all the experiments was maximum uniformity of environmental conditions for the progeny and their parents from the moment of fertilization to the end of the experiment.

The following experiments were conducted:

A. Investigation of the survival rate during the embryonic and early post-embryonic development. Percent of fertilization was established from samples of 100 eggs taken 6-8 hours after fertilization. The mortality rate of the eggs was counted daily, and dead eggs were removed. After hatching, the larvae were counted; later the number of larvae that reached the stage of transition to active feeding was established.

Combinations under study were compared in pairs,* each of which constituted 1 variant of the experiment and was raised in triple replication. For 1st generation hybrids the pairs were: CX C and C X F; FX F and F X C; C X C and C XS; for hybrids of 4th generation: M M and MX B; B X B and BX M, (C —"eastern carp," S—sparse-scaled carp, F —frame-scale carp, M —4-way and B-3rd generation backcross hybrid; strain of female is indicated first.

B. Investigation of the fingerlings after transition to active feeding. These experiments were done in large (100 1) and small (20 1) aquariums, pools, and small ponds. The combinations were raised separately (with double and triple replications) and jointly. In joint raising, we tagged the fingerlings with radioactive calcium isotope (fish were placed for 90 minutes in a solution of $Ca^{45}Cl_2$ with activity of 1.5 millicurie/l) and also by mutilation (in grown fingerlings, 1 lobe of the caudal fin was cut off).

The weight at stocking and number of fingerlings for every combination were uniform. All the fingerlings were removed from the aquariums every 10-12 days for counting and weighing; we recorded average weight gain since the previous determination. At this time, the number of fingerlings in each variant of the experiment was made uniform by removing the extra specimens unselectively. At the end of the experiments, fingerlings were counted again and weighed individually. In the experiments in which Ca^{45} was used, the fish were dried for determination of radioactivity.

C. Investigation of resistance and variability of 1st generation hybrids under various environmental conditions. These experiments investigated the effects of temperature, mineral composition of water, pH, and diet on growth and survival rate of hybrid fingerlings and of the parent breeds.

Fingerlings obtained from the following crossing were used in the investigation of temperature influence:

99	♂♂ frame-scale carp
frame-scale carp	
	♂♂ "eastern carp"

* Simultaneous comparison of all 4 combinations was technically impracticable in our conditions.

Water was maintained at 12-15°C for the experimental group, with double replication and at temperatures fluctuating from 15 to 27-30° for the controls, which initially were a single group, and later were divided into 2 groups.

Fingerlings from all 4 combinations of the "eastern carp" —frame-scale carp crossings were placed in 10 aquariums to investigate the significance of the mineral composition of the water. In4 control aquariums, the calcium content of the water was from 52 to 58-60 mg/l, while in the experiment aquariums, the water had a low calcium content: 10-13 mg/l. The Ca content in a sample of water taken from each aquarium was determined by titration with Trilon B before weekly refilling.

Owing to technical reasons, experiments on changes of pH had to be interrupted before any results were obtained.

To study the differential effect of starvation on "eastern carp" fingerlings and "eastern carp" —frame-scale carp hybrids, fingerlings of uniform weight were stocked in 2 concrete pools with $7m^3$ volume each. Hybrids were tagged with Ca". Stocking density in one pool was almost 10 times that of the other pool. The same amounts of food were placed in both pools to establish any sharp differences in food supply to the fingerlings.

Radioactive material was processed by burning the fingerlings. Ash radioactivity was determined by counting the number of impulses per time unit on a B-2 device with an MST- 17 pulse counter, then by comparing the results with natural background radioactivity.

Survival rate of 1st generation "eastern carp"-carp hybrids

We studied the survival rate of hybrids and parental forms in the embryonic period, during hatching, and at the larval stage until transition to active feeding (Table 1).

Differences in survival rate were observed in the embryonic period, but their reliability was low. The difference between the number of hybrid and nonhybrid larvae that hatched proved to be minimal (in 1 experiment, there were even fewer hybrids than "eastern carp" specimens). The most distinct, highly reliable difference was established in the larval period (from the moment of hatching to transition to active feeding); total differences for all 3 periods were also reliably significant. It can be concluded that heterosis is manifested at least as early as the second half of embryogenesis.

At later stages of development, the survival rate of the same hybrids was studied in small aquariums. For this, 175 fingerlings of uniform weight were placed into each of 4 aquariums. Mortality during the experiment, from 28 June to 12 July 1959, was:

Frame-scale carp F x F	52.5%
Frame-scale carp × "eastern carp" F × C hybrids	10.2%
"Eastern carp" X frame carp C x F hybrids	10.6%
C × C "Eastern carp"	10.6%

TABLE 1. Survival rate of 1st generation "eastern carp"-carp hybrids at early stages of development (C – "eastern carp," F - frame-scale carp, S - sparse-scale carp; "Ropsha," 1959)

Type of crossing	Initial number of eggs*	Number of replications	Mortality, %			
			embryonic period**	hatching stage	larvae before transition to active feeding	throughout experiment
C x C	2,838	3	16.3 ± 0.69	16.1	27.6	60.0 ± 0.89
C X F	2,815		14.1 ± 0.64	11.7	15.4	41.2± 0.89
F X F	3,340	4	19.3 ± 0.68	19.7	41.8	80.8 ± 0.70
F X C	3,302		18.5 ± 0.68	19.3	29.0	66.8 ± 0.82
C x C	2,000	2	16.8± 0.83	11.7	28.6	57.1 ± 1.18
C × S	2,000		14.8± 0.77	17.9	18.1	50.8 ± 1.08

* Eggs were counted at the b astula and gastrula stage; in all experiments there could be a small admixture of unfertilized, but live eggs (that did not turn white).

** Actual mortality is somewhat higher because of the admixture of unfertilized eggs.

Similar data on survival rate were obtained in spring 1960 upon removing fish from a wintering pond where fingerlings of almost equal weight from 3 sib-groups had been stocked:

	Initial number of fish	Mortality, %
Frame-scale carp	29	69.0%
F × C hybrids	26	15.4%
C X F hybrids	46	21.6%

Hybrids endured hibernation much better than frame-scale carp. Unfortunately there were no data on "eastern carp."

We shall see later on that the same differences in survival rate were found in special experiments on the effects of different environmental factors on larvae.

Growth of 1st generation hybrids

The growth of larvae was studied with separate raising in aquariums. Results of these experiments are presented in Table 2. The reliability of the differences could not be determined because there were no data on individual weight. The superior growth rate of hybrids, however, is beyond doubt, with the exception of group CX S, which had the same weight gain as "eastern carp." The superiority of the hybrids was also manifested in fingerlings of the same ancestry in intermediate pond No. 8 (Table 3), and through conducting special experiments.

TABLE 2. Growth of larvae of 1st generation hybrids of "eastern carp" and frame-scale or sparse-scale carp* ("Ropsha," 28 June –30 July 1959)

Index	Crossing				
	F × F	F × C	C × F	C × S	C × C
Final average weight, mg	330.0	409.6	430.0	394.0	397.0
Total weight gain,	9.09	12.01	12.69	11.59	11.65
Final number of fish	28	30	30	30	30

* See designations in Table 1.

TABLE 3. Growth of the underyearlings of 1st generation hybrids* ("Ropsha," 7 August –31 October 1959)

Type of crossing	Number of fish		Average final weight, g
	initial	final	
F X F	15	14	7.01
F × C	19	17	7.88
C × F	19	14	9.37
C × S	18	16	7.85
C × C	19	17	6.33

* Average initial weight at stocking, 0.38 g; see designations in Table 1.

Survival rate, growth, and variability of hybrids under various environmental conditions

"Eastern carp" -frame-scale carp hybrids were studied again in these experiments.

Experiment 1. Influence of temperature. Survival rate of frame-scale carp-"eastern carp" F X C hybrids both in the experiment (at lower temperatures) and in the control was higher than that of carp (Table 4).

TABLE 4. Influence o temperature on survival rate of hybrids and carp* ("Ropsha,"June -August 1959)

Index	Control (15–30°)		Experiment 12-15°	
	F × C	F × F	F X C	F × F
Initial number of fish	120	120	240	240
Mortality in period I,	0.8±2.34	11.2* 2.61	14.6± 1.24	43.1 ± 4.25
Mortality in period II,		15.2 ± 3.59	7.3 ± 2.28	15.8 ± 3.42
Total mortality, %	0.8± 2.34	26.4 ± 4.44	21.9 ± 2.59	58.9± 5.45

* See designations in Table 1.

At lowered temperatures, only about 41% of the carp larvae survived, while 78.1% of the hybrids lived.

The high mortality of carp lowered the population density in the carp aquariums. Although differences in density were ameliorated by periodic removal of fish, these could not be eliminated completely. As the feeding conditions of carp were more favorable at 15—30°, they grew even somewhat larger than the hybrids; however, the total weight gain of the hybrids was slightly higher (Table 5). Lowered temperatures (12—15°) affected carp more: by the end of the experiment, they were smaller than hybrids and their total gain was also less (Figure 1). The differences between hybrids and carp are quite reliable in this part of the experiment both in average weight and in total gain.

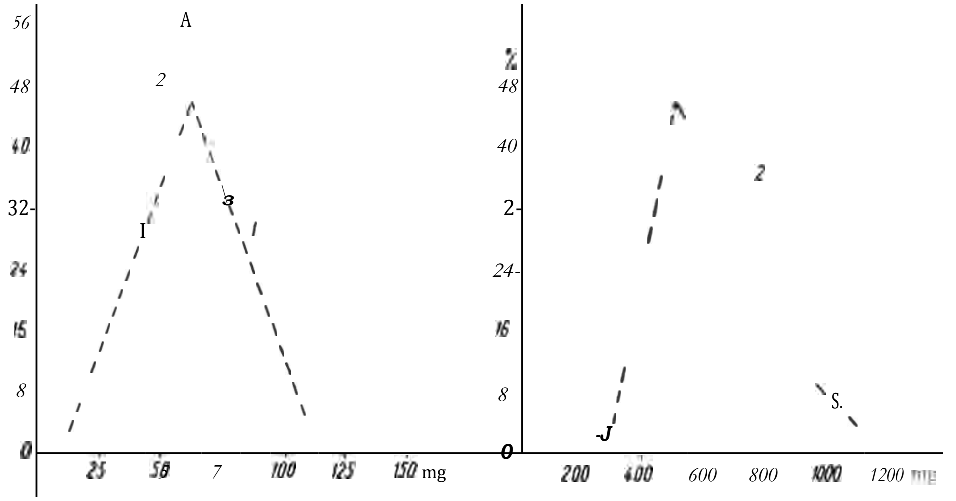

FIGURE 1. Effect of lowered temperature on growth and variability of weight in fingerlings: A – experimental variant (12- 15°); B- control variant (15-30°); 1-F × C hybrids; 2-F × F frame-scale carp.

Experiment 2. Effect of lowered calcium content in the water. Survival rate of FX C hybrids in these experiments was reliably higher than that of frame-scale carp. No such difference was found between C × F hybrids and "eastern carp" (Table 6). The superiority of F × C hybrids was equally evident in both experimental and control conditions.

In only 1 case in the control were the FX C hybrids superior in average weight, but this difference is not very reliable. The difference in total weight gain between F X C hybrids and carp in aquariums with calcium deficiency is more marked. On the whole, the experiments with calcium did not give very clear results although we found that hybrids were somewhat better able to withstand calcium deficiency.

Experiment 3. Effect of insufficient food. Hybrids (tagged with Ca^{45}) and "eastern carp" were raised jointly. Observation of survival rate

TAB 5. [illegible]

	Control(15–30')				Experiment(12–15')				
	First replication		Second replication**		First replication		Second replication**		
		F							
Average final weight ± g	469.4 ± 24.1	510.8 ± 27.4	616.6 ± 24.6	646.3 ± 26.1	6 8 8	7.6 8	.9 :	9	. 6
V, %	36.3	3	29.8	27.1	?.	4 .	7 9	2	8.
Total gain, g	21.92	9	23.35	22.24	.	2	2.3	2 2	2 2
Total relative gain, % †	110.0	0	104.9	100	0.	0	6	3i	0
Final number of fish	49	40	49	45	51	4		48	50

* Initial number and weight of fish are uniform in the crossings compared.

** Individual weighing was carried out on fixed fish.

† Carp gain is taken as 100 %.

was hampered by the fact that radioactive calcium tagging did not allow us to observe mortality during the experiment. Final data show somewhat lower mortality in hybrids compared with that in "eastern carp," in both the experimental and the control groups. Unfortunately, as radioactive tagging of fingerlings proved inadequate, this conclusion is uncertain.

In hybrids kept in the densely stocked pool No. 5, heterosis as manifested by growth rate was more evident than in hybrids in the control pool (Table 7).

Variability of hybrids. In 2 experiments with lowered temperature and decreased mineral content of water, the coefficients of weight variability were lower in FX C hybrids than in carp (see Tables 5 and 6).

The unfavorable action of low temperature undoubtedly influenced the variability of carp; the variability of their indexes increased while those of hybrids did not change (see Figure 1).

Lowered Ca content also increased carp variability. In this experiment, the difference between "eastern carp" and CX F hybrids also became apparent; hybrids are less variable than are "eastern carp" in water with Ca deficiency.

In the starvation experiment, variability increased considerably in both experimental groups (see Table 7). In hybrids the increase was even somewhat greater. The frequency distribution of weight of the starved fingerlings and the controls (Figure 2) shows a great difference between the experiment and control.

TABLE 6. Effect of lowered calcium content in water on growth and survival rates of "eastern carp" – frame-scale carp hybrids ("Ropsha," 1959)

Condition	Type of crossing	Index				
		average weight at removal(M ± m), mg	V, %	total gain, g	total relative gain,* %	mortality, %
Control (>50 mg Ca/l)	C X C	298.2 ± 10.39	36.6	20.69	100.0	7.2 ± 2.6
	CXF	294.5 *11.06	36.0	21.77	105.2	4.1 ± 2.0
	FXC	384.7 ± 16.90	36.2	21.05	105.0	29.6 5.5
	F × F	359.4 ± 14.10	29.5	19.98	100.0	45.8* 6.7
Experiment (10-12 mg Ca/l)	C × C	307.9 15.22	45.3	23.01	100.0	14. 9 ± 3.5
	CXF	311.0 ± 10.56	31.2	24.56	106.4	12.4± 3.8
	C X F	312.8 ± 10.76	31.8	20.84	90.3	18.3 ± 3.9
	F X C	367.8 ± 14.44	31.2	24.34	111.9	18.8 ± 4.3
	FXC	357.6± 16.50	42.3	23.06	110.6	18.6± 3.9
	F X F	389.2 ± 20. 01	39.1	20.84	100.0	31.1 ± 6.0

* Gains by "eastern carp" (in comparison with C X F hybrids) and carp (in comparison with F X C) are taken as 100%.

TABLE 7. Effect of insufficient food on growth and survival rate of 1st generation hybrids ("Ropsha," 12 June – 15 August 1959)

No. of pool	Type of crossing	Final number of fish	Final average weight		
			M ± m, mg	%	
5 (experimental)	C X C	140	148 ± 8.3	100	63.5
	C X F (Ca)	158	187 ± 10.0	126	67.4
6 (control)	C X C	23	502.6 ± 51.9	100	48.9
	C × F (Ca)	29	572.8 ± 49.8	114	43.5

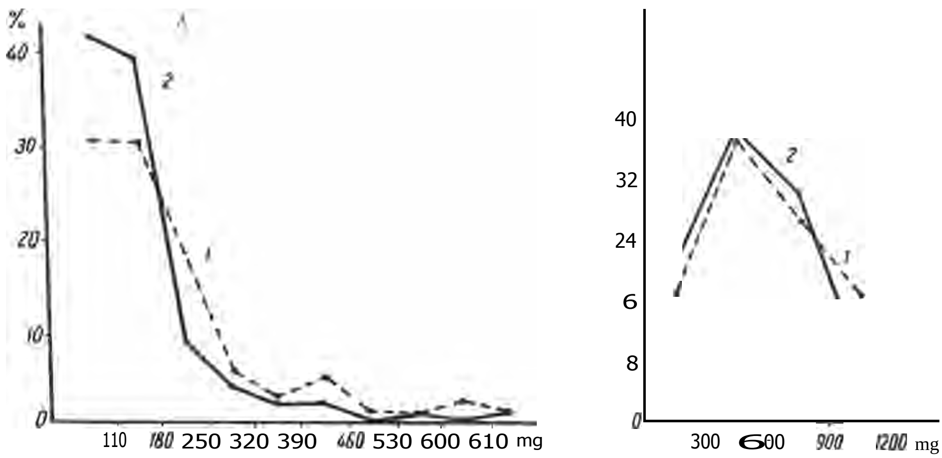

FIGURE 2. Effect of starvation feeding on growth and variability of weight of fingerlings:

A -experimental variant (higher stocking density); B -control variant (lower stocking density); 1 -hybrids (C X F); 2- "eastern carp" (C X C).

Survival rate and growth of 4th generation hybrids at early stages of development

We found no differences between hybrids and parental forms in survival rate in the embryonic period and during hatching. The eggs of the backcross female proved to be more viable than those of the 4-way hybrid. A distinct superiority of MX B hybrids over the initial MX M form became apparent in the transition to the active feeding period. No differences between descendants of BX M and BX B were noted at this stage (Table 8).

TABLE 8. Survival rate of 4th generation hybrids at early stages of development (M and B are respectively 4-way and recurrent backcrosses of 2nd generation hybrid spawners; "Ropsha," 1959)

Crossing	Initial number of eggs*	Mortality, %			
		embryonic period	hatching stage	larvae before transition to active feeding	throughout the experiment
M x M	2,970	20.5 ± 0.74	28.3	27.5	76.3
M × B	2,960	22.1 ± 0.76	30.0	18.8	70.9
B x B	2,522	8.2 ± 0.51	22.5	11.7	42.4
B X M	2,532	8.0 ± 0.50	23.6	10.4	42.0

• All the experiments had triple replication.

Subsequently, survival rate was observed in hybrids raised up to age 2 months in large aquariums. Separate raising enabled us to establish the fairly clear advantage of BX M hybrids over the BX B form. In aquarium No. 5, an outbreak of ichthyophthiriasis made it impossible to obtain reliable data for crossings MX B and MX M (Table 9).

TABLE 9. Survival rate of 4th generation larvae* ("Ropsha," 26 June–24 August 1959)

Crossing	Aquarium No.	Initial number of fish	Mortality, %
M X B	5	120	46.6**
	8	120	10.0
M X M	7	120	14.1
B X M	3	150	15.4
	6	150	17.8
BXB	4	150	23.3

* Initial weight is 2.1 mg see designations in Table 8).
** Infected with ichthyophthiriasis.

In addition, data on survival rate of 4th generation MX B and MX M hybrids were obtained in separate raising in 2 small aquariums from 5 to 28 July, with a uniform initial weight. Mortality for this period was 6.2% in MX B hybrids, and 23.1% in normal hybrids. After these fingerlings were transferred for joint raising, there was no mortality in MX B hybrids while the form MX M showed 6.6%.

TABLE 10. Growth rate of 4th generation hybrids ("Ropsha," 25 June — 12 August 1959)

Aquarium No.	Type of crossing	Final number of fish specimens	Final average weight (M ± m), mg	p	VA
1	M × M M × B (Ca)	57 57	660.1 ± 46.4 670.7 ± 46.2	–	53.2 53.0
2	B x B B × M (Ca^{45})	80 74	406.0 ± 26.6 433.2±26.9	–	59.4 53.7
3	M x M M × B	30 59	1131.3 ± 77.5 1362.7 ± 61.8	<0.05	35.2 33.7
5	B x B B X M	30 58	1033.6 ± 47.7 1092.4 ± 28.2	> 0.05	25.2 19.6
6	B × B B x M	30 57	945.0 ±50.3 994.0 ± 29.8	> 0.05	29.2 22,6
7	B X B B × M	31 58	904.0 ± 54.1 977.0 ± 27.6	> 0.05	33.3 21.3

The growth of 4th generation hybrids was compared in 6 large aquariums, 2 forms being raised jointly in each of them (Table 10). The advantages of heterosis were evident in all the aquariums.

The weight advantage of MX B hybrids is reliable in one aquarium, No. 3. Differences in growth between hybrids B× M and parental form (BX B) become reliable when p values obtained in each of the replications are multiplied (aquariums Nos. 5,6,7; $p< 0.022$).

TABLE 11. Growth of 4th generation hybrids ("Ropsha," 28 July-30 August 1959)

Index	Experiment and combination No.									
	1	2	3		4		5		6	
	M x M	M X B	M X M	M × B	M x M	M × B	M X M	M x B	M × M	M x B
Final average weight, mg	277.4	310.8	1,610	1, 953	1,488	1,877	1,411	1,848	1,414	1,574
Individual gain,mg	273.4	305.3	1,288	1,633	1,190	1,578	1,188	1,622	1,188	1,350
Final number of fish	39	39	5	10	5	10	10	5	10	5

In all the experiments except in aquarium No. 1, hybrids had a lower variability.

Data on growth of 4th generation MX B hybrids were also obtained from additional experiments in which fingerlings were first raised separately from 5 July to 28 July, and were then raised jointly from 28 July to 30 August. The initial weight of the fingerlings was uniform. The data obtained are presented in Table 11. In all cases, MX B hybrids grew faster. The absence of data on individual weight makes it impossible for us to establish the reliability of this difference.

Discussion

Our experiments on the survival rate and growth of 1st generation "eastern carp" —carp hybrids enabled us to establish the presence of heterosis in all cases. The effect is most evident in early development. Thus, the superior survival rate of hybrids in embryogenesis was established in all the experiments. Later, at 1-2 months, the distinct superiority of hybrids became mainly apparent only under adverse conditions.

These data agree with those of all the investigators who studied the manifestation of heterosis in crossing carp with "eastern carp."

Interestingly, peculiarities of parental forms influenced the degree of manifestation of heterosis in reciprocal hybrids at later stages of development (1-2 months). Heterosis, as manifested in survival rate of F X C hybrids as compared with frame-scale carp, which has a low viability, is rather marked. It is more difficult to establish this advantage in reciprocal form CX F in comparison with "eastern carp," as the latter is very viable. Similar results were obtained in all the other comparisons.

Because both frame-scale carp and "eastern carp" grow rapidly in their first year of life, their hybrids should not differ very much in this respect from the parents. This is precisely what was revealed in our experiments.

We note that inbreeding affected survival and growth rates of frame-scale carp as their spawners were related to each other. Inbreeding depression could increase the relative value of heterosis in F X C hybrids somewhat. Because the eastern carp were not related, the advantages of CX F hybrids are due completely to heterosis.

Raising hybrids and parental forms at lowered temperature and with food deficiency clearly revealed the superiority of hybrids. Heterosis was much more evident in all experimental groups (except in the experiment on starvation); the variability of hybrids was generally lower than that of the parent breed.

Inadequate food increased the variability of CX F hybrids more than that of "eastern carp." This exception can be easily explained. High population density creates stronger food competition. This competition is best withstood by the largest specimens, which thus increase their weight continuously. The rapid weight gain of several exceptional specimens increases the variability of the entire population (Kryazheva, this collection). Heterosis of hybrids increases their ability to withstand competition and, therefore, it is not surprising that in the experiment their variability coefficients increased more than those of "eastern carp." Because of a few exceptional fish, the weight distribution curve of the hybrids is skewed and wider than that of "eastern carp" (Figure 2).

On the other hand, low temperature increased the variability of weight of hybrids less than it did that of "eastern carp." In this case, there was no competition as food was abundant. In this particular experiment, heterosis of hybrids became apparent not only in weight but also in ability to withstand adverse environment. The distribution curves (see Figure 1) illustrate this assumption well.

As mentioned earlier, growth heterosis was not apparent in the study of the effect of lowered calcium content in water. Nevertheless, in the experimental aquariums, the variability of hybrids was lower than that of their original breed.

In our view, this is indirect evidence of the unfavorable action of lowered mineral content of water on the growth rate of fingerlings.

Data on the growth and survival rate of 4th generation hybrids enable us to assert that BX M and MX B hybrids have a small but obvious advantage over parental forms in both growth and survival rate.

We have found no evidence of superiority in survival of eggs for hybrids of MX M and MX B. This. does not mean, however, that there is no heterosis at that developmental stage. The greater viability of hybrid *eggs* might show itself later, when the larvae hatch, and particularly upon transition to the stage of active feeding. At that point, we did indeed observe a reliable difference in survival rate between MX B hybrids and the parental M X M form.

Heterotic superiority in survival rate is less clearly expressed in BX M hybrids as compared with the BX B form. This is not surprising because descendants of BX B matings inherit about $^3/_4$ of their chromosomes from "eastern carp," and are distinguished by their very high viability. If the descendants of the 4-way hybrid female (MX M and MX B) are compared with those, of the backcross female (B X B and B X M), the backcross-4 -way hybrids and backcross descendants prove more viable at early stages than those of the 4-way hybrid female.

Experiments on growth show that hybrids of MX B and BX M have some advantage over parental MX B and BX M hybrid forms. The reliability of this advantage is higher in 4-way-backcross hybrids. In experiments with joint raising of 4th generation hybrids and initial forms (food deficiency) the hybrids were less dependent on environment. In all the experiments, we observed less increase in the weight variability of hybrids than in that of initial forms.

It was noted earlier that the initial forms, 4 -way and backcross hybrids of the 3rd generation, were obtained by isolated breeding of 1st generation hybrids by strains and subsequent crossings between them, crossing the northern strain and the Kursk strain yielded 3rd generation 4 -way hybrids, and crossing the northern strain with "eastern carp" produced 3rd generation backcross hybrids. Inbreeding by strains helps create genetic systems in hybrids; crossing these systems produces heterosis. Kirpichnikov (1957) established the fact that the heterotic effect in 3rd generation hybrids was even more marked than that of 1st generation hybrids. Our experiments showed that crossing such highly heterotic lines among themselves produces some heterosis, but considerably less than in the original hybrids.

This decrease in the effect of heterosis can be explained, in our view, by the fact that 3rd generation 4-way and backcross hybrids are a direct result of crossing between strains. The "attenuation" of heterosis in our experiments is similar to a decrease in heterotic effect in inbreeding 1st generation hybrids. However, we did not observe a complete disappearance of heterosis, probably owing to the high heterozygosity of carp (Kirpichnikov, 1958).

The study of heterosis in 1st and 4th generation fingerlings, and also the study of the effect of unfavorable living conditions on the variability of these hybrids, established 2 major peculiarities in the manifestation of heterosis in intraspecific crossings of carp:

1. Heterosis becomes apparent in growth and survival rates of hybrids at early stages of development.

A stronger manifestation of heterosis at early stages of development was noted by many authors (Kirpichnikov, 1938, 1943, 1959a; Kirpichnikov and Balkashina, 1936; and others). It was also confirmed in our experiments. We think that this peculiarity is indirect evidence for the biochemical concept of the basis of heterosis. We shall attempt to present some arguments for this assumption.

In general, the survival rate, growth, and development of a living organism depend on the degree of its adaptation to the environment. Adaptation is a result of the coordinated action of various functional systems of the organism. These systems form and develop as the animal grows and develops. At the earliest stages of development, when the functional systems are just beginning to emerge, survival rate and growth must depend, in many respects, on biochemical peculiarities of the cells of the developing organism. The zygote that possesses the greater biochemical resources will have the advantages. In the opinion of many authors, hybrid zygotes possess this quality. If this is correct, then at early stages of development, hybrids will be distinguished by high viability and faster growth. This would also explain the relative increase of the effect of heterosis in hybrids under unfavorable conditions.

The same assumption may also help explain the well known phenomenon of "attenuation" of heterosis with age. As the organism grows and develops, the coordination of various functional systems acquires still greater importance for it. Advantages resulting from the higher biochemical resources of heterotic cells will gradually disappear with growth.

2. The second peculiarity we found in manifestation of heterosis in carp is that hybrids are better able to withstand unfavorable environment, and their development is less dependent on the conditions of existence.

This peculiarity of the hybrids that were examined agrees with many published data on the low proportion of variability due to environment in very different hybrid forms (Balsunov, 1936; Kusakina, 1959; Dobzhansky, 1952; Dobzhansky and Levene, 1948; Lerner, 1954; Lewis, 1955;Lewontin, 1958; and others).

Evidently, the increased ability of hybrids to withstand adverse environment is an essential manifestation of heterosis. There is another reason that the disclosure of great hardiness in the 1st generation carp — "eastern carp" hybrids is of particular interest. These 2 forms originate from different subspecies of C. carpi o, the European and the Far Eastern ones, that have been isolated populations since the beginning of the Quaternary period (Berg, 1949). Establishment of obvious heterosis in their crossings contradicts the assertions of Dobzhansky (1956) that only hybrids of ecologically close forms can exhibit heterosis.

We shall note in conclusion that the appearance of heterosis in crossing various strains of carp among themselves, in particular of 4-way and backcross hybrids, leads us to expect successful utilization of heterosis in commercial carp breeding.

CONCLUSIONS

1. In 1st generation hybrids of Ukrainian frame-scale carp and "eastern carp" we found a considerable heterosis in growth rate and viability. Heterosis in the same features was also found upon crossing 3rd generation, 4-way, and backcross hybrids with each other. The heterosis of 4th generation hybrids was small.
2. Heterosis is most vigorous in early development in both 1st and 4th generation hybrids.
3. Under unfavorable conditions (lowered temperature, starvation, decreased calcium content in water) 1st generation hybrids were more hardy and less dependent on environment than were descendants of the initial strains, as shown by the decrease of variability of weight in 1st generation hybrids in the experimental groups. Fourth generation hybrids raised jointly with descendants of the original strains were also less variable. Apparently, general resistance to unfavorable environmental conditions is an essential manifestation of heterosis in fish.
4. Heterosis as evidenced in the growth and viability of hybrids of various strains, in particular in 4th generation hybrids, suggests the advantage of large-scale 4-way crossing in commercial carp breeding, primarily in the northern USSR.

Bibliography

Publications in Russian

Balsunov, I.I. K izucheniyu geterozisa u Nicotiana rustica. 1. Vliyanie vneshnikh uslovii (Studying Heterosis in Nicotiana rustica. 1. The Effect of Environment). —Sbornik rabot po selektsii, genetike i semenovodstvu tabaka i makhorki, Vol. 2, Sel'khozizdat. 1936.

Berg, L. S. Ryby presnykh vod SSSR i sopredel'nykh stran (Freshwater Fishes of the USSR and Adjacent Countries). Vol. 3. Moskva-Leningrad. 1949.

Borisenko, E.Ya., V.E. Al'tshuler, and A.N.Polyakov. Geneticheskii analiz geterozisa. Soobshchenie 1. (Genetic Analysis of Heterosis. Communication 1.). —Biologicheskii Zhurnal, Vol. 4, No. 4. 1935.

Darwin, C. Deistvie perekrestnogo opyleniya i samoopyleniya v rastitel'nom mire (The Effects of Cross- and Self-Fertilization in the Vegetable Kingdom). — Sochineniya, Vol. 6, Izdatel'stvo AN SSSR. 1950.

Karp, M. L. Intsukht i geterozis (Inbreeding and Heterosis). —Izvestiya AN SSSR, Seriya Biologicheskaya, No. 2. 1940.

K[illegible]dz[illegible]nov, M. I. Geterozis. Teoreticheskie osnovy selektsii (Heterosis. Theoretical Bases for Selection). Vol. 1. Moscow-Leningrad. 1935.

Khe[illegible], B. Razvitie predstavlenii o geterozise ([illegible] Heterosis). —In Sbornik: "Gibridnaya kukuruza," Moscow. 1955.

Kirpichnikov, V. S. Gibridizatsiya ryb i problema geterozisa (Fish Hybridization and the Problem of Heterosis). —Izvestiya AN SSSR, Seriya Biologicheskaya, No. 4. 1938.

Kirpichnikov, V. S. Eksperimental'naya sistematika sazana (Experimental Taxonomy of Wild Carp). I. —Izvestiya AN SSSR, Seriya Biologicheskaya, No. 4. 1943.

Kirpichnikov, V. S. Sozdanie novoi severnoi gibridnoi porody karpa (Creation of a New Northern Hybrid Breed of Carp). —Trudy soveshchanii po rybovodstvu, Moscow. 1957.

Kirpichnikov, V. S. Stepen' geterogennosti populyatsii sazana i gibridov sazana s karpom (The Degree of Heterogeneity of Populations of Wild Carp and Hybrids of Wild Carp with Carp). — DAN SSSR, Vol. 122, No.4. 1958.

Kirpichnikov, V. S. Geneticheskie metody selektsii ryb (Genetic Methods of Fish Selection). —Byulleten' Moskovskogo Obshchestva Ispytatelei Prirody, Seriya Biologicheskaya, Vol. 64, No. 1. 1959a.

Kirpichnikov, V. S. Gibridizatpiya karpa s amurskim sazanom primenitel'no k zapadnym oblastyam (Hybridization of the Carp with "Eastern Carp" as Applied to Western Regions of the USSR). —Trudy 5-i nauchnoi konferentsii po izucheniyu vnutrennikh vodoemov Pribaltiki, Minsk. 1959b.

Kirpichnikov, V. S. Geneticheskie osnovy geterozisa i ikh ispol'zovanie v rybovodstve (Genetic Basis of Heterosis and its Application in Fish Breeding). —Sbornik pamyati N. I. Vavilova, Izdatel' stvo AN SSSR. 1960.

Kirpichnikov, V. S. Tseli i metody selektsii karpa (Goals and Methods of Carp Selection). In the Collection.

Kirpichnikov, V.S. and E.I. Balkashina. O khozyaistvennom ispol'zovanii gibridov kul'turnogo karpa i volzhskogo sazana (Concerning the Utilization of Hybrids of Cultured Carp and Volga Wild Carp). — Rybnoe Khozyaistvo SSSR, No. 3. 1935.

Kirpichnikov,V.S. and E.I. Balkashina. Materialy po genetike i selektsii karpa (Materials on the Genetics and Selection of Carp). — Biologicheskii Zhurnal, Vol. 5, No. 2. 1936.

Kryzheva, K. V. Vliyanie plotnosti posadki na rost, izmenchivost' i vyzhivaemost' molodi gibridnykyh karpov (The Influence of Stocking Density on the Growth, Variability, and Survival Rate of Young Hybrid Carp). In the Collection.

K[illegible], A. A. Tsitofiziologicheskoe issledovanie myshechnoi tkani pri geterozise u nekotorykh mezhvidovykh gibridov ryb (Cytophysiological Investigation of Muscular Tissue in Heterosis of Some Interspecific Fish Hybrids). —Tsitologiya, Vol. 1, No. 1. 1959.

Savel'ev, V.I. Ogibridizatsiitaparavanskogo sazana i kul'turnogo karpa (The Hybridization of Taparavan Wild Carp with Cultured Carp). — Izvestiya VNIORKh, Vol. 22. 1939.

Publications in Other Languages

Dobzhansky, Th. Nature and Origin of Heterosis. —Heterosis, New York. 1952.

Dobzhansky, Th. Genetics of Natural Populations, XXV. Genetic Changes in Populations of Drosophila pseudoobscura and Drosophila persimilis in Some Localities in California. —Evolution, Vol. 10, No. 1. 1956.

Dobzhansky, Th. and H. Levene. Genetics of Natural Populations, XVII. Proof of Operation of Natural Selection in Wild Populations of Drosophila melanogaster.— J. Genet., Vol.33. 1948.

Fisher, R. A. The Genetical Theory of Natural Selection. Oxford. 1932.

Grow, I.E. Dominance and Overdominance. —Heterosis, New York. 1952.

Haldane, I. B. S. On the Biochemistry of Heterosis and the Stabilization of Polymorphism. —Proc. R. Soc., Ser. B., Vol. 144, No. 915. 1955.

Lerner, M. I. Genetic Homeostasis. Edinburgh. 1954.

Lewis, F. R. S. Gene Interaction, Environment and Hybrid Vigor. —Proc. R. Soc., Vol. 144, No. 915. 1955.

Lewontin, R. C. Studies on Heterozygosity and Homeostasis. IL Loss of Heterosis in a Constant Environment. —Evolution, Vol. 12, No. 4. 1958.

Mather, K. The Genetical Basis of Heterosis. —Proc. R. Soc. London, Vol. 144, No. 915. 1955.

Wallace, B. The Average Effect of Radiation-Induced Mutations on Viability in Drosophila melanogaster. —Evolution, Vol. 12, No.4. 1958.

THE INFLUENCE OF STOCKING DENSITY ON THE GROWTH, VARIABILITY, AND SURVIVAL RATE OF YOUNG HYBRID CARP

K. V. Kryazheva

The relation between the density of population and variability of body weight and length in fish has several aspects.

Some investigators believe that this variability is an important adaptive property of fish, promoting the maintenance of high population. Increased variability increases the range of food requirements; thus, fish can more fully utilize the food resources of the water body.

Other investigators believe that increased variability means there is additional material for natural selection, and thus contributes to the evolutionary transformation of the population and of the species.

Our experiments studied the effects of different densities and, consequently, different degrees of abundance of food supply on growth and variability of the young of northern hybrid carp. We shall try to establish the effect of these changes on survival rate in an effort to resolve the contradiction mentioned above. The experimental data may be of essential significance, as they allow a fresh look at the complex problem of intraspecific competition in plants and animals, its role in species formation. It is very important to evaluate the evolutionary significance of environment and food competition correctly. Resolution of this problem will also help us devise the most effective selecting method for fish.

Growth rate varies widely, depending on environment and, primarily, on the quantity and quality of food available. The better the diet, the better the growth rate. Experience of pond fish farms has shown that underyearling carp that have been densely stocked in poor forage ponds, without additional feeding, have an average weight not exceeding 10-15 g. In some cases, the average autumn weight of such young was only lg (Kirpichnikov, 1945, 1948). Conversely, young carp stocked at low density in ponds abundant in food, were of marketable size after only one growth period. At the Zagorsk experimental fish farm (VNIIPRKh), in 1954, Golovinskaya and Musselius (1956) obtained carp underyearlings with an average weight of 275 g. Carp weighing over 1 kg were raised in one summer in the Moldavian SSR (Yaroshenko, 1955) and in the Ukraine (Movchan, 1941, 1960). In Israel, carp reached a weight of 1500 g in a year (Sklower, 1949).

Differences in population density, but primarily in food supply, affect weight gain more than body length. Bekker (1959) showed on C. carassius (L.)that after density was lowered to 1/7.5 its former value, females grew 4.2 times as long and gained 16.6 as much weight.

Poor feeding conditions not only lower average size and weight, but also raise the variability of these measurements. Variation coefficients of body length and weight are 1.5-2 and 2-3 times as great, respectively, as are the same indexes for fish raised under good forage conditions (Polyakov, 1958, 1959: Bekker, 1959).

If feeding conditions of carp fingerlings are particularly poor, not only the relative but also the absolute variability increases (Polyakov, 1958). Under extremely poor feeding conditions, the distribution curves not only extend but also become skewed, greatly to the right (Nakaroku and Kasahara, 1955,1956,1957; Moav and Wohlfarth, 1963).

Insufficient food supply aggravates trophic relations among the water-body inhabitants and intensifies intraspecific competition. Formozov (1948), proving the presence of intraspecific competition for existence, gives an example from a fish pond farm: "If too many carp are released into a pond, they will grow worse, slower, and less evenly (individual carp stand out, leaving others behind) than if a smaller number of carp are released into a similar pond with similar food supply. One can easily estimate the intensity of the competition for food among species and age groups by the gain in length and in weight.

"Often in "wild" water bodies where there was no fishing, the growth rate of some fish species was low, but it improved markedly after fishing began there, and the number of specimens decreased and the intraspecific competition for food also became correspondingly less intense" (p. 28).

The increase of variability in poorer feeding conditions and higher stocking density (with overpopulation) promotes selection for adaptation to the new conditions of existence, according to Bekker (1959). After some time, selection will inevitably narrow the range of variation, and the population will reach a new equilibrium.

The significance of intraspecific competition in species formation and evolution of fish is disputed by Nikol'skii (1953) and Polyakov (1958). According to Nikol'skii, intraspecific variability is not the basis of competition and natural selection, but it is, rather, a peculiar adaptation, a form of normal species existence. Variability is advantageous for the species, according to Nikol'skii (1955), Nikol'skii and Pikuleva (1958) and Polyakov (1958, 1960, 1961, 1962); it guarantees better utilization of the food resources of the water body by members of the given species. At the same time, Nikol'skii completely denies the existence of intraspecific competition.

Procedure

Experiments were conducted at "Ropsha" near Leningrad in 1961 and 1962. Several experiments in aquariums and ponds studied the growth and variability rates of larvae and fingerlings with different food supplies.

Larvae of 4th generation carp-"eastern carp" hybrids of various crossings were the subjects of the aquarium experiments. Average weight of larvae was 0.85-44.6 mg. At the beginning of each experiment, each of the 100-200 larvae was weighed and measured. Altogether, there were 8 experiments. Each included 3 aquariums with different population density, as listed in Table 1.

TABLE 1. Stocking density of larvae in aquariums

Year	Experiment No.	Volume of aquarium, liters	Aquarium No. and population					
			1	2	3	1	2	3
			density: fish/l			density: fish/aquarium		
1961	I	15	2.0	6.7	20.0	30	100	300
	II	15	2.0	6.7	20.0	30	100	300
1962	III	15	3.3	13.3	53.3	50	200	800
	IV	30	1.7	6.7	26.7	50	200	800
	V	30	3.3	10.0	60.0	50	300	1,800
	VI	100	0.5	2.0	8.0	50	200	800
1961	VII	100	0.5	2.5	12.5	50	250	1,250
	VIII	100	1.0	4.0	16.0	100	400	1,600

During the first 10-15 days, the daily food ration was uniform in all the aquariums of each series. Later on, the quantity of daily ration was determined according to the average weight of fish in each aquarium, to maintain the initial difference in food supply. At the lowest density, the daily ration usually amounted to 30-40% and sometimes even 50% of the fish weight. At the highest density, the ration constituted 1.2-5%, and in experiment 5, each fish received only 0.9-1.4% of its weight in food, daily. Every 10-15 days all the fingerlings were weighed and counted. At the end of the experiments, the survivors were counted, measured, and weighed, with the exception of those in 2 aquariums of experiments VII and VIII, in which over 1,000 fingerlings were raised. From these, a random sample of 300 specimens from each aquarium was weighed and measured.

The experiments in spawning ponds began in 1962. Two ponds with an area of 0.25 ha each were allotted for this purpose. Spawning occurred on 17 June. Final population density of pond No. 4 was 2.5 times that of pond No.2 and amounted to 205 specimens/m^3. Despite the large number of larvae removed from pond No. 4, conditions in this pond were relatively favorable, judging from their growth rate (see Figure 7). This was due to the abundant food supply of pond No. 4.

Experiments in growing ponds were conducted in 1961 and 1962. Fourth generation hybrid fingerlings were also the subjects of these experiments. The fingerlings were raised in 1961 in 3 intermediate ponds (Nos. 5,6 and 7), and in 1962 in ponds Nos. 5 and 6. Concurrently, we studied both utilization of the pond's food resources at different population densities and the influence of diet on biochemical indexes and winterhardiness of fish. The conditions of the carp underyearlings in ponds Nos. 5 and 6 (depths, bottoms, vegetation, food reserves) were identical according to Maksimova (1961) and Sergeeva (this collection): in the intermediate pond No. 7, they were somewhat worse. This is indicated particularly, by the data on fish productivity for 1960. Fish productivity for ponds No.5 and No.6 exceeded 350 kg/ha; for pond No. 7 it was 320 kg/ha. The number of fingerlings stocked in each pond is listed in Table 2.

TABLE 2. Population density of hybrid fingerlings in ponds

Pond No.	Pond area, ha	Population density, thousands/ha		
		initial (planting)	after division of ponds	final (autumn) catch
		1961		
5	0.073	27.4	10.7	16.7
6	0.043	30.2	21.8	19.4
7	0.018	66.7		58.4
		1962		
5	0.073	27.4		17.0
6	0.043	81.4		60.2

The conditions of the 1961 and 1962 experiments were different.

In 1961, the fingerlings were reared on only natural food for the first 5 weeks. Early in August, all fish were removed from ponds No. 5 and No. 6, and each pond was divided, with a wooden partitition, into 2 approximately equal halves. The original population was divided at random into 2 equal groups of fish of uniform average weight and were stocked in each section. Subsequently, the fingerlings in the upper halves of the ponds received a supplement to the natural food.

In 1962, the ponds were divided with partitions at the beginning of the experiments. Again, an equal number of fish were stocked in each half of each pond. The initial density in pond No. 5 was the same as in 1961; in pond No. 6, it was about 2.7 times as high. Unfortunately, many fingerlings passed from the upper half of pond No. 5 into the lower half at the very beginning of the experiment so that by autumn, the population density in the latter was the same as that in the sections of pond No. 6. Therefore, only the fish from the upper half of pond No. 6 and lower half of pond No. 5 were examined in the autumn. The fingerlings were not given supplementary food for the entire period of that year' s investigations because of low temperatures.

The data were processed according to standard statistical methods. Fulton's condition factor (F) and 1/H index were taken as characterization of the condition factor and body build of the carp. In several cases, we determined the reliability of the differences between experiments at various population densities (t).

To establish differences in variability of a characteristic, the correlation coefficient (r) was calculated and the reliability of differences in variability were assessed. In individual cases, in comparing groups with greatly differing means, all the deviations were calculated as percentages of the mean.

It should be noted that in 1962 the water temperatures in aquariums and ponds were lower than in 1961 (Figure 1); temperatures in 1961 were more favorable to carp growth.

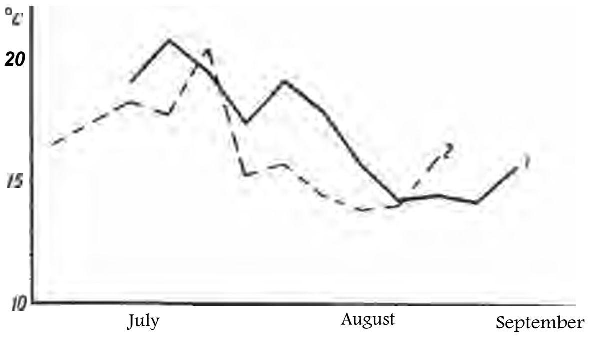

FIGURE 1. Fluctuations of average daily temperature of water in ponds:
1 — 1961; 2 — 1962.

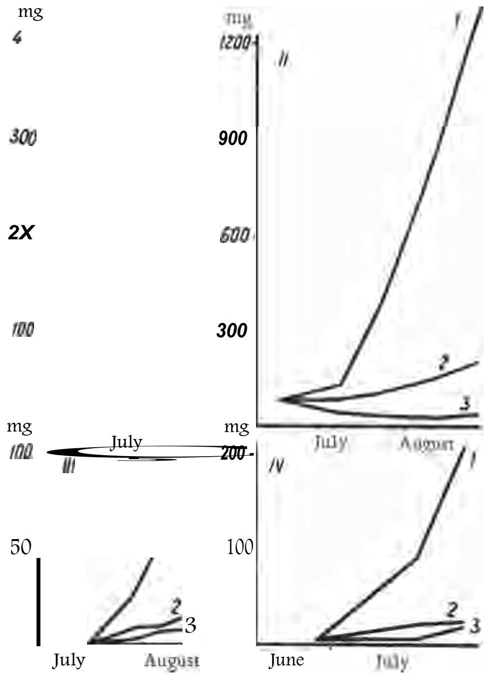

FIGURE 2. Distribution of growth of larvae in experiments I, II, III and IV:
1, 2, 3 — lowest, intermediate, and highest density.

Results

1. Growth and variability of larvae and fingerlings in aquariums.

In experiments I and II, the ratio of densities in aquariums was 1:3.3:10.

These experiments, which lasted 22 and 42 days respectively show that increased population density retards the growth of fingerlings sharply. In series I, in the aquarium where density was highest, the average weight per fingerling was only 1.5 times the initial weight at the end of the experiment, while fingerlings from the aquarium where density was lowest had a final weight 13 times the initial weight; in series II, these figures were 1.7 and 52, respectively. Still greater differences were observed in growth rate (Table 3, Figure 2).

TABLE 3. Weight gain and changes in habitus indexes in experimental larvae

Experiment No. and the ratio of densities in the aquariums	Time of observation	No. of aquarium	Weight, mg	Length, cm	Condition factor (F)	1/H
I	Initially	–	25.2 ± 0.05	–	–	–
			333.7±13.2	2.37±0.02	2.49±0.03	3.36±0.03
1:3.3:10	Finally	2	107.5±2A	1.72 ± 0.01	2.09±0.02	3.87±0.03
		3	35.3±0.6	1.36±0.005	1.41 ± 0.01	4.79±0.02
H	Initially	–	25.2±0.05	–	–	–
		1	1310.0±50.0	3.50 ± 0.04	2.82 ± 0.04	2.83 ± 0.02
1:3.3:10	Finally	2	210.0±6.6	2.03 ± 0.02	2.44 ± 0.02	3.37±0.02
		3	42.2±1.2	1.41 ± 0.01	1.44±0.02	4.39±0.03
III	Initially	–	0.85	–	–	–
			85.8±4.6	1.54±0.02	2.22 ± 0.04	3.58±0.04
1:4:16	Finally	2	12.0±0.4	0.98 ± 0.007	1.24 ± 0.15	5.20±0.04
		3	9.0 ± 0.8	0.92±0.01	1.06 ± 0.04	5.00±0.08
IV	Initially	–	4.1±0.1	0.81±0.006	0.77±0.01	6.67±0.11
		1	209.2 ± 9.2	2.04±0.02	2.38 ± 0.04	3.41±0.05
1:4:16	Finally	2	24.5 ± 1.0	1.25±0.01	1.11±0.02	5.18±0.05
		3	20.4±1.7	1.25±0.02	1.11±0.03	4.96±0.08
V	Initially	–	0.85	–	–	–
		1	105.1±8.7	1.59 ± 0.04	2.34 ± 0.05	3.78±0.04
1:6:36	Finally	2	13.6 ± 0.6	0.99 ± 0.01	1.21±0.02	5.17±0.05
		3	8.5±0.8	0.86 ± 0.01	1.18 ± 0.04	5.24±0.10

Note. 1, 2,3 stand for aquariums with lowest, intermediate, and highest densities.

In the aquariums with the lowest and highest density, the differences in body length gain were 200-250% at the end of the experiment. Different stocking density and the resulting different growth rate were sharply reflected in the condition factor and the 1/H ratio; the former decreases with increased density, and the latter increases. The different food quantities were also sharply reflected in the variability of all 4 investigated indexes (Table 4). Increased density increases the variability of weight and exterior body build; the variations in experiment II were particularly large. The greatest variability of length was observed at intermediate density.

E[illegible] III [illegible] IV [illegible] (IV [illegible]). T[illegible] 1:4:16, [illegible] III [illegible] 1.7 [illegible]. T[illegible] 40 [illegible].

TABLE 4. Coefficients of variability of investigated indexes in experiments with different densities

Experiment No. and ratio of densities	Time of observation	Aquarium No.	Weight, mg	Length, cm	F	1/H
I	Initially	–	18.8± 1.3	–	–	–
1:3.3:10	Finally	1	19.9 ± 2.6	5.5 ± 0.7	5.6 ± 0.7	4.3 ± 0.05
		2	22.7 ± 1.6	8.1 ± 0.6	9.9 ± 0.7	8.0 ± 0.6
		3	26.8 ± 1.1	6.2 ± 0.2	12.0 ± 0.8	8.6 ± 0.4
II	Initially	–	18.8± 1.3	–	–	–
1:3.3:10	Finally	1	18.8±2A	5.8 ± 0.7	6.8* 0.9	3.6±0.5
		2	31.4±2.2	9.2±0.6	7.1±0.5	5.6±0 A
			45.8±1.9	8.2±0.3	20.0±0.8	11.7±0.5
III	Initially	–	–	–	–	–
1:4:16	Finally	1	34.7 ± 3.7	10.2 ± 1.1	12.3* 1.3	6.4 ± 0.7
		2	42.9 ± 2.4	8.6* 0.5	15.9 ± 0.9	10.3 ± 0.6
		3	61.8 ± 6.5	10.1 ± 1.1	23.1 ± 2.4	10.8 ± 1.1
IV	Initially	–	30.7 ± 1.8	6.9 ± 0.5	19.7 ± 1.4	16.4± 1.2
1:4:16	Finally	1	29.4 ± 3.1	7.7 ± 0.8	10.6 ± 1.1	9.0 ± 0.9
		2	51.1 ± 2.8	10.2* 0.6	20.7 ± 1.1	12.8 ± 0.7
		3	89.4* 7.3	11.1 ± 0.9	25.3± 2.1	13.8* 1.1
V	Initially	–	–	–	–	–
1:6:36	Finally	1	47.0 ± 5.7	15.6 ± 1.9	12.0 ± 1.5	5.4 ± 0.7
		2	52.7 ± 3.4	9.9 ± 0.6	18.1 ± 1.2	11.1 *0.7
		3	73.0* 7.0	13 .1 *1.3	21.7* 2.1	13.6 ± 1.6

Note. See note in Table 3 for numerical des'gnations.

D[illegible], [illegible] 10 [illegible], [illegible] 100 [illegible] III; [illegible], [illegible] 5 [illegible] 50 [illegible] IV (T[illegible] 3 [illegible] F[illegible] 2). I[illegible]. V[illegible], [illegible], [illegible].

S[illegible]; [illegible] 62% [illegible] 89%. T[illegible], [illegible] 90% [illegible]. I[illegible], [illegible]. F[illegible], [illegible] IV [illegible], the variation of weight and habitus had even considerably decreased (that of habitus was nearly halved) by the end of the experiment. Evidently in this aquarium the fish had abundant food.

In experiment V, still sharper gradations of densities were observed (1:6:36). The experiment lasted 41 days. Despite the extreme increase in the range of densities, the results were similar to those of experiments III and IV (see Tables 3 and 4, and Figure 3). We feel that this is because many larvae died even at the beginning of the experiment at high densities. The true densities in the aquariums of experiment V were close to those of series III after only 15 days.

TABLE 5. Changes of weight, length, and habitus indexes in experimental larvae

Experiment No. and ratio of densities	Time of observation	Aquarium No.	Weight, mg	Length, cm	F	1/H
VI 1:4:16	Initially	–	44.6 ± 1.5	1.46 ± 0.01	1.38 ± 0.02	3.74 ± 0.04
			335.0 ± 19.4	2.36 ± 0.04	2.42 ± 0. 03	3.40 ± 0.05
	Finally	2	118.3 ± 7.1	1.85 ± 0.02	1.79 ± 0.04	4.18 ± 0.07
		3	66.0 ± 2.5	1.62 ± 0.01	1.53 ± 0.01	4.43 ± 0.04
VII 1:5:21	Initially	–	7.8 ± 0.2	–	–	–
		1	672.5 ± 31.4	2.8 ± 0.04	2.93 ± 0.03	2.96 ± 0.02
	Finally	2	106.6 ± 4.2	1.5 ± 0.01	2.70 ± 0.03	3.48 ± 0.02
		3	17.1 ± 0.2	–	–	–
VIII 1:4:16	Initially	–	3.35 ± 0.05	–	–	–
		1	1279.0 a 4.0	3.5 ± 0.03	2.87 ± 0.02	2.80 ± 0.01
	Finally	2	131.1 ± 3.6	1.8 ± 0.01	2.20 ± 0.02	3.75 ± 0.02
		3	26.0 ± .O	–	–	–

TABLE 6. Coefficient of variability of investigated indexes in experiments with different densities

Experiment No. and ratio of densities	Time of observation	Aquarium No.	Weight, mg	Length, cm	F	1/H
VI 1:4:16	Initially	–	38.3 ± 2.4	8.3 ± 0.5	15.7 ± 1.0	8.8 ± 0.5
		1	39.1 ± 4.03	12.1 ± 1.2	8.35 ± 0.9	9.4 ± 1.0
	Finally	3	47.8* 4.2	10.3 ± 0.9	18.0 ± 1.6	13.2 ± 1.2
			52.4* 2.7	10.0 ± 0.5	21.6 ± 1.1	13.3 ± 0.7
VII 1:5:25	Initially	–	31.0 ± 2.2	–	–	–
		1	32.7 ± 3.3	9.6 ± 1.0	6.8 ± 0.7	5.4 ± 0.5
	Finally		58.5 ± 2.6	13.7 ± 0.6	14.0 ± 0.6	7.5 ± 0.3
		:	68.4 ± 1.4	–	–	–
VIII 1:4:16	Initially	–	19.7 ± 1.4	–	–	–
		1	27.3 ± 1.9	9.1 ± 0.6	7.0 ± 0.5	4.1 ± 0.3
	Finally	2	50.4 ± 2.5	14.8 ± 0.7	12.7 ± 0.6	9.8 ± 0.5
			66.1 ± 1.4	–	–	–

The last three experiments (VI, VII, and VIII) used large, 100-liter aquariums. The initial density ratios were close in all these experiments; the experiments lasted respectively 29, 32, and 55 days. In all three experiments, the same effects as in the first five were observed: as population density increased, the weight and length gains of larvae dropped sharply, condition factor deteriorated, variability of all the indexes, except the body length, increased. The variability of body length in experiment VI, where food supply was best, even decreased somewhat as density rose, and in the others it increased only slightly (Tables 5 and 6, Figure 3).

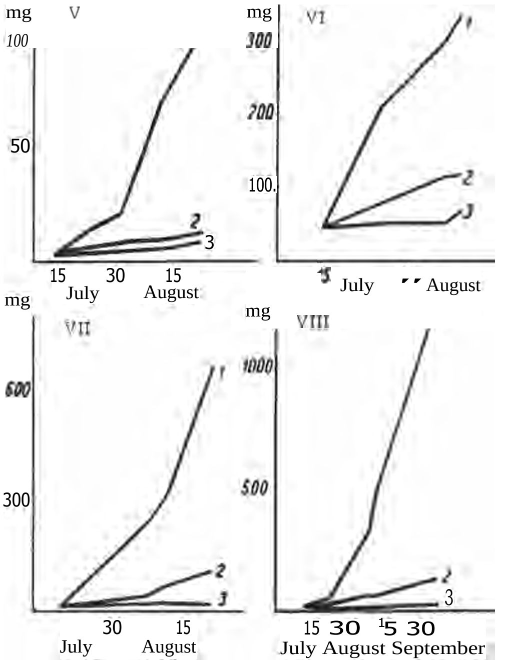

FIGURE 3. Distribution of weight gains of larvae in experiments V, VI, VII, and VIII:

1, 2, 3 — lowest, intermediate, and highest density.

In experiments VI, VII and VIII the difference in the variability of weight of the fingerlings from the aquariums with intermediate and highest densities was not as great as in the other experiments (see Figure 5). The greatest increase of weight variability and of the condition factor is observed upon transfer from low to medium 'density.

The effect of changing the density on the variability of larvae weight is quite evident on comparative graphs (Figure 4). A particularly great increase in variability was observed in experiments IV, VII, and VIII, with densities in the ratio of 1:4:16 and 1:5:25. In all these three experiments, the coefficients of variability increased 2-3 times over their initial values by the end of the experiments. The overwhelming majority of the differences were statistically significant both between the lowest and the intermediate density and between the lowest and highest density. The differences in variability of body length and habitus were also reliable. As an example, we give indexes of reliability for experiment II:

	Aquarium	t		Aquarium	t
Weight	1-2	3.88	F	1 - 2	0.30
	1-3	8.82		1 - 3	11.33
Body length	1-2	3.58	1/H	1 - 2	3.13
	1-3	3.12		1-3	11.41

Combining all the experiments with more or less uniform initial density of larvae, we find, in Table 7, that transfer to densities of the order of 2.5-8 specimens/l retards growth at least 500%, decreases condition factor slightly, and increases variability very considerably. Further increase of density almost halts growth and causes extreme exhaustion, but raises the indexes of variability only comparatively slightly. Variability of body length increases only at the highest stocking densities.

We attempted to make the same calculations in considering the aquariums by final density, but doing so gave us a much less clear picture. Evidently the density of fingerlings in the initial part of the experiment, before they began to die, affected all the indexes including variability.

In many of the aquarium experiments, we, as well as other investigators (Nakaroku and Kasahara, 1956, 1957; Moav and Wohlfarth, 1963), observed that at very high density, a few specimens maintained their high growth rate despite the food shortage, and they considerably surpassed their sibs. This small group of rather exceptional specimens greatly increased the variability of weight and of habitus in high density aquariums (Figure 5). Most of the other fish were fairly uniform in these characteristics; within the aquarium their variability did not increase and sometimes even decreased. To compare data for different average weight we plotted graphs of the deviations calculated as percentages of the arithmetic mean. The figures show clear asymmetry of distribution even at intermediate densities but the exceptional group appears only at highest density.

TABLE 7. Relationship between weight, condition, and variability of fish at the beginning and the end of aquarium experiments with different population densities

Density, fish/l	Aquarium No.	Final indexes						
		average weight, mg	average gain, mg	Fulton's condition factor	variability coefficient			
					weight	1	Fulton's condition factor	1/H
0.5-2	8	545	526	2.51	32.7	9.4	9.4	6.8
2.5-8	7	105	89	2.04	51.4	9.4	14.0	9.0
10.0-30	7	26	14	1.28	56.0	8.8	18.3	11.1
50.0-60	2	9	8	1.12	67.4	11.6	22.4	12.2

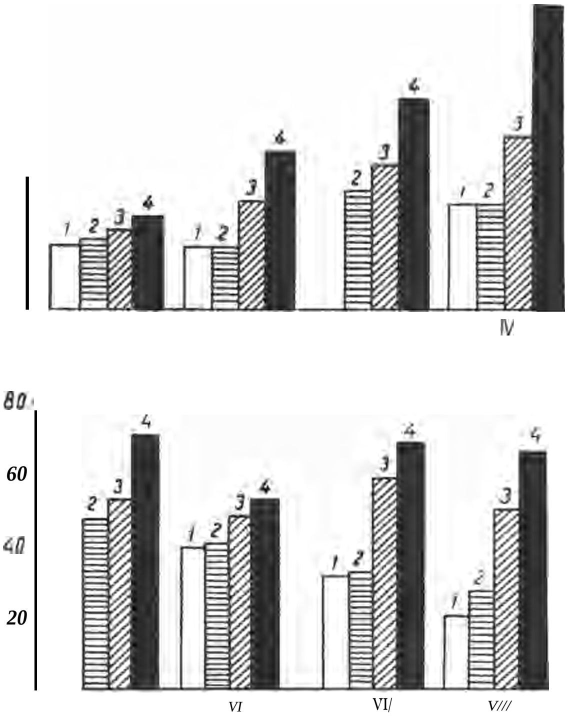

FIGURE 4. Variability of weight of hybrid larvae at different population densities in aquariums. The ordinates indicate the coefficient of variation, the abscissas,the experiment No.:

1— initial value; 2,3,4, the final variation at lowest, intermediate, and highest density.

2. Survival rate of larvae and fingerlings in aquariums.

In the first experiments, where the density ratio was 1:3,3:10, the fingerling mortality for the experimental period was negligible, even at the highest densities. It amounted to 0.3%; in the second experiment, to 3%. The increase of mortality in the second experiment is related to the longer duration of the experiment.

The more sharply graded densities of the other experiments decreased survival rate considerably. Thus in experiments III, IV, and V, the mortality of aquariums with the highest density was over 90% (Table 8). In two experiments, V and VI, mortality was high even at intermediate density. Experiment VII was an exception. Here, mortality at highest density was only 20.7% at the end of the larval period. Mortality was somewhat higher at low density, when larvae that had not yet begun active feeding were placed in the aquariums (experiments III and V). The considerable mortality where food shortage was most acute was caused by exhaustion, lowered resistance to diseases, and greater probability of infection at the higher density. Indeed, it was in the most overcrowded aquariums that epidemic chilodonelliasis occurred.

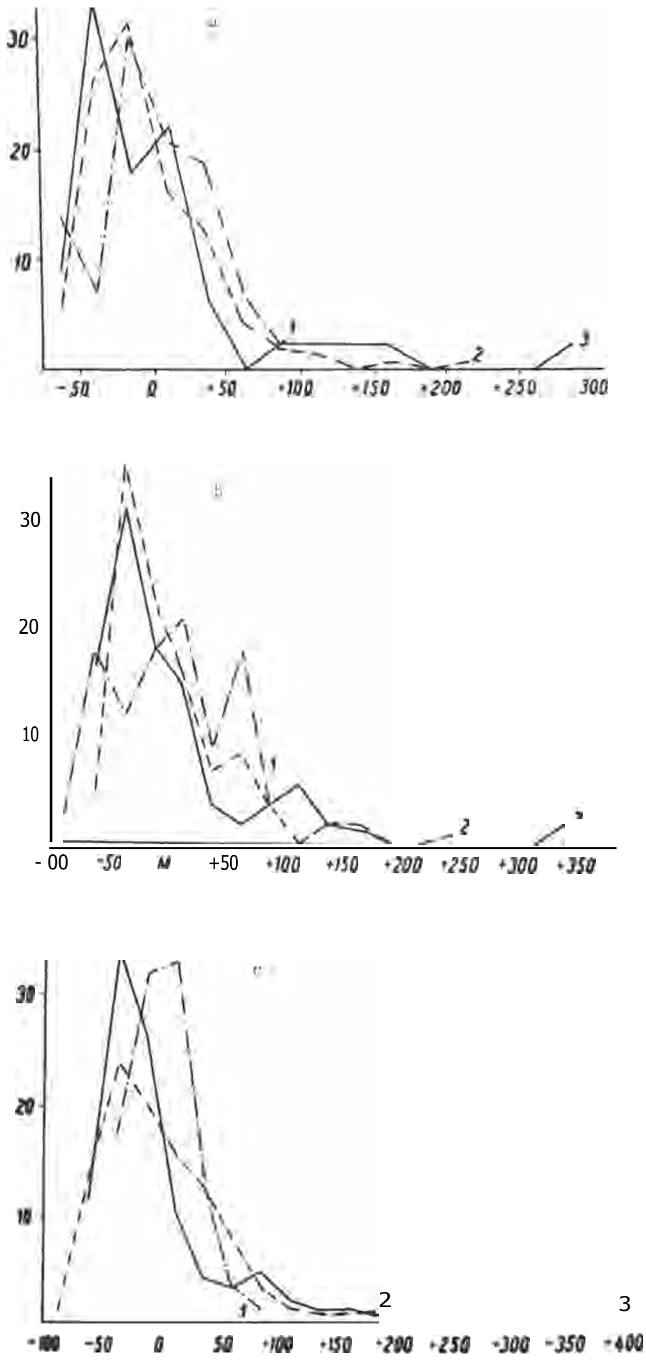

FIGURE 5. Distribution curves of weight:

a—III, b —V, arid c — VIII experiments. The ordinates indicate the frequency, the abscissas the deviation from the mean in %.

TABLE 8. Mortality of fingerling during experiment

Experiment No.	Aquarium No.	Initial number	Mortality		
			first half of experiment	second half of experiment	entire period, %
III	1	50	4	3	14.0
	2	200	22	14	18.0
	3	800	186	569	94.4
IV	1	50	1	3	8.0
	2	200	11	22	16.5
	3	800	246	477	90.3
V	1	50	9	7	32.0
	2	300	88	91	59.7
	3	1,800	1,223	522	96.9
VI	1	50	0	3	6.0
	2	200	8	128	68.0
	3	800	120	486	75.8
VII	1	50	0	0	0
	2	250	7	22	11.6
	3	1,250	42	217	20.7
VIII	1	100	7	2	9.0
	2	400	41	27	17.0
	3	1,600	406	779	74.1

3. Growth and variability of larvae and fingerlings in ponds.

Spawning ponds (1962 experiments). The carp grew slower in pond No.2 than in pond No. 4; there were particularly sharp differences in the second part of the experiment (Figure 6; Table 9).

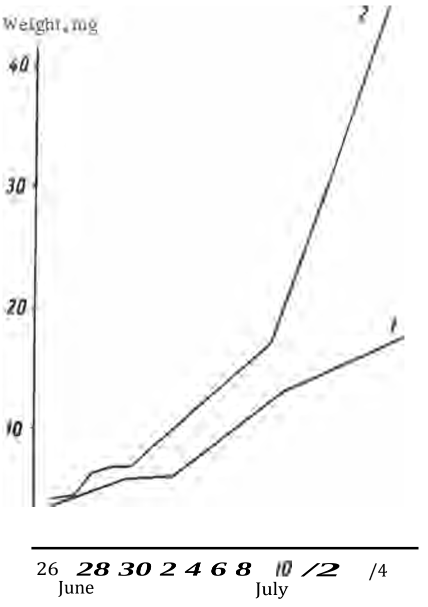

FIGURE 6. Weight gains of larvae in spawning ponds ("Ropsha,"1962):

1—pond No.2; 2— pond No. 4.

Poor feeding conditions in pond No. 2 also affected variability of weight, body length, and habitus. The variability of weight nearly doubled, reaching almost 80% in pond No.2 for the period from 5-14 July, while in pond No.4 it increased less than 3% to only 38.8% in that period. In pond No. 4, density was gradually lowered by removing fingerlings. Interestingly, under these conditions, body length and habitus became still less variable. In pond No.2, where density also decreased somewhat, the ratio of the quantity of food to the number of fish remained very low due to the small amount of edible plankton. The acute food competition in this pond considerably increased the variability of body length and habitus.

Raising ponds (1961 and 1962). The experiments in raising ponds gave us additional data on the relation between growth rate and variability of weight (Table 10).

TABLE 9. Growth and variability of larvae in spawning ponds ("Ropsha," 1962)

Absolute and % variation	Pond No. 2		Pond No. 4		
	5 July (N = 150)	14 July (N = 150)	27 June (N = 100)	5 July (N = 150)	14 July (N = 150)
			Weight, mg		
	9.38 ± 0.31	17.7* 1.15	4.14± 0.104	14.0 ± 0.41	44.6 ± 1.49
V (%)	40.9* 2.37	79.6 ± 4.60	30.7 ± 1.78	35.9 * 2.07	38.8± 2.36
			Body length, cm		
	1.03 ± 0.007	10.6 ± 0.011	0.81 ± 0.006	1.06 ± 0.007	1.46 ± 0.01
V (%)	8.25 ± 0.48	13.3 ± 0.77	6.91 ± 0.49	8.58 ± 0.49	8.30 ± 0.51
			Fulton's condition factor		
	08.0 ± 0.014	1.30± 0.027	0.77 ± 0.015	1.10 ± 0.015	1.38± 0.019
V (	21.1 ± 1.22	25.5± 1.48	19.7 ± 1.40	16.6 ± 0.96	15.6 ± 0.96
			1/H index		
	7.27 ± 0.99	5.46 0.085	6.67 * 0.110	6.34 ± 0.078	4.74± 0.036
V (%)	16.7 ± 0.96	19.0± 1.10	16.4± 1.17	15.2 ± 0.88	8.78 ± 0.53

Right after stocking in 1961, the fingerlings grew rapidly, but even at that time, those in pond No.7 had somewhat retarded growth.

In the 2nd period (until the beginning of August) the growth rate remained high in ponds No.5 and No. 6, while in pond No. 7, it slowed down considerably. By early August, the underyearlings in No.7 weighed nearly ⅔ less than those in ponds No.5 and No. 6.

In the 3rd period (August-September) growth rate decreased in all ponds. Only fish in the upper sections, which received additional food, gained substantial amounts (about 7 g).

The variability of weight also changed in accordance with these patterns. Initial variability was very high (40%), but it decreased sharply (to 20%) during rapid growth in ponds No.5 and No. 6. In the autumn, as a result of food shortage in sections without food supplements, and in pond No. 7, there was again some increase in variability; the greatest increase occurred in pond No.7, where density was highest. Interestingly, supplementary feeding increased variability still more.

The 1962 experiments took place at low temperatures and at still higher densities. Here, growth was extremely retarded, and the variability coefficients remained high throughout the period.

4. Correlation between weight and habitus in larvae and fingerlings.

The change of indexes of habitus in the experiments and the increase of variability of habitus may be a result of age and size differences in larvae. In order to determine whether such relationships are in evidence, we tried to establish the correlation between weight and indexes of habitus in our

TABLE 10. Growth and variability of fingerlings in raising ponds ("Ropsha" intermediate ponds, 1961 -1962)

No. of pond	1961				1962			
	Date	No. in sample	M, g	V, %	Date	No. in sample	M, g	V, %
5	23 June	100	0.11 ± 0.004	40.9± 2.9	17 July	150	0.058 ± 0.002	53.3±3.1
	10 July	85	2.04± 0.09	39.8 ± 3.1	20 Aug.	258	2.57	—
	3 Aug.*	99	15.54±0.32	20.5± 1.5	10 Sept.	120	4.00	—
	3 Oct.	134	22.7 ± 0.60	30.1± 1.9	4 Oct.	150	4.18±0.18	53.5 ±3.1
	(supp. feed.)	145	20.3 ±0.40	21.5 ± 1.3				
6	23 June	100	0.11 ±0.004	40.9± 2.9	17 July	150	0.058 ± 0.002	53.3±3.1
	2 Aug.*	100	14.35 ± 0.28	19.6± 1.4	20 Aug.	327	2.64	—
	2 Oct.	150	21.2± 0.53	30.2± 1.7	3 Oct.	150	2.91±0.12	49.1 ± 2.8
	(supp. feed.)	150	18.7± 0.36	23. 4s 1.4				
7	23 June	100	0.11 ± 0.004	40.9 ± 2.9	No observations			
	8 July	71	1.20 ± 0.05	32.8 ± 2.8				
	4 Aug.	100	5.83± 0.14	23.3± 1.7				
	30 Sept.	200	7.48± 0.14	27.0 ± 1.4				

Data on weight and variabili y in control removal are presented for a sample of chosen fish that later were raised separately.

data. For example, we present the weight-habitus correlation for 2 of the aquarium experiments (Table 11), and 2 spawning pond experiments (Table 12). The correlation in all the experiments proved to be high Correlation coefficients reach 0.8-0.9, and in most cases are fairly reliable. The correlation of weight with condition factor was somewhat higher than the correlation of weight with 1/H index. As expected, the latter correlation was negative in all cases.

TABLE 11. Correlation of weight with habitus in larvae and fingerlings of hybrid carp in aquarium experiments I and IV

Aquarium No.	No. in sample	Variations in weight, mg	Weight - Fulton's factor		Weight – 1/H	
				t	r	t
Experiment I						
1	29	221- 520	+ 0.406 ± 0.155	2.6	– 0.462± 0.146	3.2
2	95	58- 176	+0.488 ± 0.078	6.2	- 0.285 ± 0.094	3.0
3	298	17-76	+ 0.594 ± 0.037	16.0	– 0.319 ± 0.052	6.1
Experiment IV						
1	46	58- 357	+ 0.888 ± 0.031	28.7	– 0.602 ± 0.094	6.4
2	166	7.5 - 97	+ 0.871 ± 0.019	45.8	- 0.653 ± 0.044	14.8
3	74	7.5- 177	+ 0.729 ± 0.054	13.5	- 0.431 ± 0.094	4.6

TABLE 12. Correlation of weight with habitus of larvae in spawning ponds ("Ropsha," 1962)

Date of con-trol removal	Pond No.	No. n sample	Variations in weight, mg	Weight - Fulton's factor		Weight – 1	
				r	t	r	t
27 June	4	100	1.0- 6.5	+ 0.508 ± 0.074	6.8	– 0.330 ± 0.089	3.7
	2	150	1.0- 23.5	+ 0.906 ± 0.015	60.4	- 0.810 ± 0.028	29.0
5 July	4	150	3.5- 25.5	+ 0.874 ± 0.019	46.0	- 0.782 ± 0.032	24.4
	2	150	4.0- 113.5	+ 0.803 ± 0.029	27.7	– 0.584± 0.054	10.8
14 July	4	135	17.0- 106.5	+ 0,793 ± 0.032	24.8	- 0.738 ± 0.039	19.0

The correlation of weight with habitus for hybrid larvae is curvilinear (Figure 7). In all the cases we calculated the correlation coefficient [r] and not the correlation ratio. The correlation is higher if we consider the curvilinear nature of the relationship. To determine whether the deterioration of condition factor and habitus and the increase of variability in these indexes with increased density lies in age variability only (or size), we calculatedcondition factors for fish of uniform weight, which had been raised under different feeding conditions. It seemed impossible to explain all the differences on the basis of age changes only. Both in aquariums and in ponds with acute food competition, the condition factors in fingerlings of identical weight were markedly lower (Table 13). Correspondingly, the variability indexes were increased in these cases.

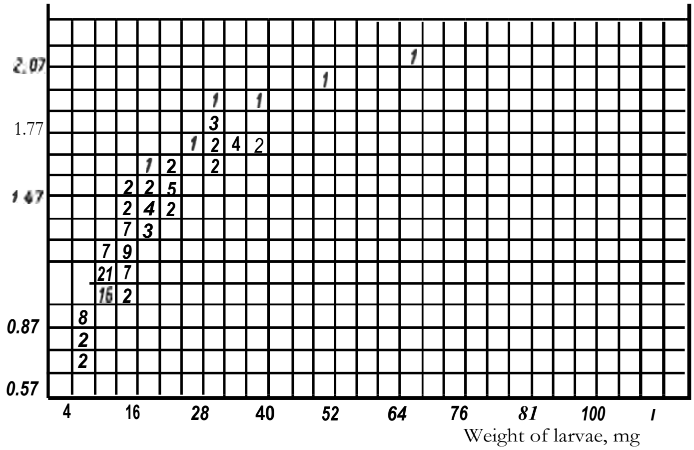

FIGURE 7. Correlation grid for weight and condition in 150 larvae removed from spawning pond No. 2 on 14 July 1962.

TABLE 13. Variation of condition factors with different food supply ho ding weight constant

Type of environment	Aquarium or pond No.	Average weight, mg	No. in sample	Condition factor (F)	
				M	V
Aquariums, Exp. IV	2	11.5	44	0.94	12.0*1.3
	3	11.5	35	0.91	13.8 ± 1.6
Spawning ponds, 5 July 1962	4	6.0	23	0.85	12.9± 1.9
		14.0	44	1.11	7.2± 0.8
	2	6.0	61	0.69	15.0±1.4
		14.0	28	0.96	8.4± 1.1

5. Food conversion ratios of zooplankton and Oligochaeta for larvae raised in aquariums.

An incidental result of our study of the influence of density on growth and variability of hybrid larvae was that we could determine the approximate conversion ratios of larvae of different weight (Table 14).

Owing to great mortality in some aquariums, the conversion ratio could not be determined in all cases. Neither could it be calculated for those periods when a population was so dense that food was used entirely for energy needs. Even with these limitations however, we obtained interesting results. Conversion ratios proved to be very low (from 1.02 to 2-3) for larvae weighing 25-100 mg, sometimes 200 to 300 mg. For smaller larvae, as well as for large fingerlings, the ratios were from 2.5-6.

The lowering of conversion ratios (calculated by the ratio of wet weight of food to the live weight of fingerlings at certain stages of growth) is of great interest and will be considered later.

TABLE 14. Conversion ratios (K) at different population densities of larvae (principal food is plankton)

Experiment No.	Date	Population density			
		low		intermediate	
		weight of larvae, mg	K	weight of larvae, mg	K
I	5 – 17 July	25.2-135	1.98	25.2- 83.6	1.12
	18 - 25 July	135 -334	1.59†	83.6-107.5	2.46**
II	5-17 July	25.2-141	1.94	25.2- 88.6	1.02
	18 - 25 Aug.	141 -366	1.79"	86.6-112	3.18"
	26 July- 5 Aug.	366 - 869	2.85†	112 -155	3.388
	6 – 14 Aug.	869 -1313	6.16†	155 -210	5.78"
III	13 July – 1 Aug.	0.85- 26	3.82	0.85-10.3	2.56
	1-12 Aug.	26 - 53	3.25		–
	13 - 21 Aug.	53 - 86	3.91	10.3-12	3.33
IV	27 June - 17 July	4.1- 89	4.00	4.1-21.6	3.27
	18-28 July	89 -209	6.21	–	–
V	14- 25 July	44.6 – 211	2.98"	44.6- 77	6.35"
	26 July - 12 Aug.	211 -319	6.30	–	–
VI	22 July-10 Aug.	36.2- 508	2.77*	18.4- 66	4.51
	11 Aug. -4 Sept.	508 -1279	4.02†	66 -131	2.52†
VII	20 July - 10 Aug.	7.8-316	3.76*	7.8- 62	3.48*
	10-20 Aug.	316 -673	3.08†	62 -107	2.80†
VIII	13-31 July	0.85- 20	4.90	0.85- 7.3	2.56
	1-12 Aug.	20 - 73	1.97	7.3 – 9.5	5.05
	13 - 22 Aug.	73 -105	6.50	9.5 -12.6	2.59

* Plankton 75%, Oligochaeta 25%.
Plankton 25%, Oligochaeta 75%.
† Oligochaeta were the principal food.

Discussion

Laboratory experiments on raising hybrid larvae and fingerlings in different population densities, and consequently with different food supplies, showed primarily that much higher density leads to a considerable slowing of weight gain. At the highest density, the proportion of food used for energy and that used for growth change greatly. In some experiments larvae stopped growing in the most densely populated aquariums, and showed only a negligible increase in weight when mortality was high in the last period of living in that aquarium. In experiments I and VII, weight had even decreased by the end of the raising period.

Under these conditions of food shortage, the fish rapidly became exhausted, the condition factor decreased, and the 1/H index increased. The intensive acute exhaustion led to decreased resistance to various diseases.

I[illegible], [illegible] C[illegible].

T[illegible] (V%) [illegible]. V[illegible] ([illegible] 2 — 8/1). T[illegible]. T[illegible]; [illegible], [illegible]. T[illegible], [illegible] 2 [illegible] 3 [illegible] VIII [illegible] experiment [illegible] 332 [illegible] 425 [illegible]. I[illegible] III, IV, [illegible] V, [illegible].

W[illegible] J[illegible] N[illegible] K[illegible] (1956, 1957) [illegible]. W[illegible], [illegible].

I[illegible], [illegible] 0.1-0.2 (K[illegible], 1958; M[illegible] W[illegible], 1963). A[illegible], [illegible]. W[illegible], [illegible] J[illegible]; [illegible] (N[illegible] K[illegible], 1957). C[illegible], [illegible] possibility [illegible], [illegible]. I[illegible], [illegible]. T[illegible] -[illegible]. W[illegible], [illegible]. M[illegible]; [illegible], [illegible], [illegible].

I[illegible], [illegible]; [illegible], [illegible]. P[illegible]. M[illegible], [illegible], [illegible], [illegible].

T[illegible]: [illegible]. E[illegible]. A[illegible], [illegible].

• C[illegible].

Improvement of feeding conditions does not always decrease variability. For example, in those sections of the raising ponds where supplementary feed was given, the presence of various kinds of foods (natural and artificial) may have caused the increased variability. Presumably, this is because some underyearlings did, and others did not, eat the artificial food.

Finally, the data on conversion ratios suggest that larvae which weighed about 25 mg assimilate the food most fully. Comparatively large organisms present in plankton become available to them. The low conversion ratios in some of our experiments (which sometimes dropped to 1-2) can be explained in various ways. One factor could be the assimilation of nutritive substances, especially phosphorus and calcium salts. This phenomenon was established by several researchers in their experiments with radioactive isotopes of phosphorus and calcium (Kirpichnikov, Svetovidov, and Troshin, 1956). Another possibility was that the fish ate the growths on the aquarium walls, a factor which we could not take into account in our experiments.

CONCLUSIONS

1. The 1961 and 1962 experiments on young northern hybrid carp in aquariums and ponds showed once more that a decreased food supply sharply retards growth and adversely affects the condition factor. At high population densities, growth completely or almost completely ceases, and the food is utilized mainly for energy. At the highest densities in our experiments there was mass mortality among the greatly exhausted, stunted fish. Chilodonelliasis was usually the direct cause of this mortality.
2. In all the aquarium experiments and in several cases in ponds, weight variability increased with population density. Variability was particularly high at densities of 27-60 specimens/1 (800 and 1,800 carplarvae per 30-liter aquarium). In these aquariums, the variability was 70-90% of the mean. High variability was noted in densely populated ponds. With supplementary feeding, the yearlings' variability of weight also increased somewhat, apparently owing to differential consumption of artificial foods.
3. Increase of the variability of weight of larvae and fingerlings is due mainly to the differentiation of a small group of exceptional specimens from the total population. These grow far more rapidly than the other fish, the variability of which does not in fact increase, and may even decrease a little.
4. In several experiments, variability of body length was highest at intermediate density in aquariums.
5. A reduced food supply also increases variability of habitus. One reason for this phenomenon is that habitus indexes reflect size changes of larvae. However, the increase in variability of habitus cannot be explained entirely by size differences: it is also directly connected with food scarcity.
6. In aquariums where food was scarce, the mass mortality of stunted exhausted fish, and the concurrent emergence of a group of exceptional fingerlings with considerable superiority in growth rate, suggest that where food competition becomes acute, intraspecific competition intensifies and the natural selection gradient increases.

7. The conversion ratios of larvae and fingerlings fed live food appear to be small, particularly low values being obtained for larvae weighing from 25 to 100-200 mg. The low conversion ratios (up to 1–2) are readily explained by increased assimilation of food. The unusually small value of the ratio may also be due to the absorption by larvae of some mineral phosphates or calcium salts directly from the water or by eating the growths on the aquarium walls.

8. The increase in variability and intensified food competition when food is scarce should be considered when developing carp selection methods. Testing genetic qualities of exceptional fish that distinguish themselves during food shortage is of particularly great importance for the selection theory.

Bibliography

Publications in Russian

Bekker, V. E. O vliyaniiplotnostinaseleniya ryb na ikh rost i vosproizvoditel'nuyu sposobnost' (na primere zolotogo karasya) (The Effect of Population Density of Fish on their Growth and Replenishment (e. g. among Goldfish —Car ass ius aura tu s)). — Trudy Moskovskogo Tekhnicheskogo Instituta Rybnoi Promyshlennosti i Khozyaistva, No. 10. 1959.

Formozov, A. N. Nablyudeniya nad vnutrividovoi bor'boi za sushchestvovanie u pozvonochnykh (Observations on the Intraspecific Struggle for Existence in Vertebrates). —In Sbornik: "Vnutrividovaya bor'ba u rastenii i zhivotnykh," Moskva, Izdatel'stvo MGU. 1948.

Golovinskaya, K.A. and V.A. Musselius. Opyt vyrashchivaniya segoletok karpa pri razrezhennoi posadke s kormleniem (Experiment in Raising Underyearlings of Carp with Sparse Stocking and Supplementary Feeding). —Rybnoe Khozyaistvo, No. 4. 1956.

Kirpichnikov, V. S. Vliyanie uslovii vyrashchivaniya na zhiznesposobnost', skorost' rosta i morfologiyu karpov razlichnogo genotipa (The Effect of Raising Conditions on Viability, Growth Rate, and Morphology of Carp of Different Genotypes). —Doklady AN SSSR, Vol. 47, No. 7. 1945.

Kirpichnikov, V. S. Sravniteltnaya kharakteristika chetyrekh osnovnykh form kul'turnogo karpa pri ikh vyrashchivanii na Severe SSSR (Comparative Characteristics of 4 Main Forms of Cultivated Carp Raised in the Northern USSR).— Izvestiya VNIORKh, Vol. 26, No. 2. 1948.

Kirpichnikov, V. S. Stepen' geterogennosti populyatsii sazana i gibridov sazana s karpom (The Degree of Heterogeneity of Wild Carp Population and of Hybrids of Wild Carp with Carp). —Doklady AN SSSR, Vol. 122, No. 4. 1958.

Kirpichnikov, V.S., A.N. Svetovidov, and A.S. Troshin. Mechenie karpa radioaktivnymi izotopami fosfora i kal'tsiya (Tagging Carp with Radioactive Isotopes of Phosphorus and Calcium). —Doklady AN SSSR, Vol. 3, No. 1. 1956.

Mak simova, L.P. Pitanie istepen' ispol'zovaniya estestvennykh i is-kusstvennykh kormov gibridami karpa s amurskim sazanom (The Utilization of Natural and Artificial Food by Hybrids of Carp with "Eastern Carp"). —Izvestiya GosNIORKh, Vol. 51. 1961.

Movchan, V.A. Vyrashchivanie stolovogo karpa za odno leto v prudakh i na risovykh polyakh USSR (Breeding of Table Carp for One Summer in Ponds and on Paddy Fields in the Ukrainian SSR). —Rybnoe Khozyaistvo, No. 5. 1941.

Movchan, V.A. Tovarnyi karp za odno leto (Marketable Carp for the First Summer). —Rybovodstvo i Rybolovstvo, No. 3. 1960.

Nikol'ski i, G. V. 0 zakonomernostyakh pishchevykh otnoshenii u presnovodnykh ryb (Patterns of Food Relations in Freshwater Fishes). — In Sbornik: "Ocherki po obshchim voprosam ikhtiologii," Moskva. 1953.

N ikol's k ii, G. V. Ob izmenchivosti organizmov (On the Variability of Organisms). —Zoologicheskii Zhurnal, Vol. 34, No. 4. 1955.

Nikol' sk ii, G. V. and V.A. Pikule va. O prisposobitePnom znachenii vidovykh priznakov i svoistv organizmov (On the Adaptive Importance of Species Characteristics and Properties of Organisms).- Zoologicheskii Zhurnal, Vol. 37, No. 7. 1958.

P olyak ov, G. D. 0 prisposobitel'nom znachenii izmenchivosti vesa segoletkov karpa (The Adaptive Importance of Variability of Weight of Carp Underyearlings). —Zoologicheskii Zhurnal, Vol. 37, No. 3. 1958.

P olyakov, G.D. Vzaimosvyaz' lineinogo rosta, uvelicheniya vesa, nakopleniya veshchestv i energii v tele segoletkov karpa vyrashchivae-mykh v raznykh usloviyakh (Interrelationship of Growth in Length, Weight Gain, and Accumulation of Substances and Energy Exchange in the Body of Carp Underyearlings Raised in Different Conditions). — Trudy Vsesoyuznogo soveshchaniya po biologicheskim osnovam rybnogo khozyaistva, Moskva, Izdatel' stvo AN SSSR. 1959.

Polyak o v, G. D. Prisposobitel'nye izmeneniya razmerno-vesovoi struk-tury odnovozrastnoi populyatsii ryb v svyazi s usloviyami pitaniya (Adaptive Variations of the Weight-Dimensional Structure of Fish Populations of the Same Age in Connection with Forage Conditions). — Voprosy Ikhtiologii, No. 16. 1960.

P olyak ov, G.D. Prisposobitel'noe znachenie izmenchivosti priznakov i svoistv populyatsii ryb (Adaptive Importance of the Variability of Characteristics and Properties in Fish Populations). —Trudy soveshchanii po dinamike chislennosti ryb, Moskva, Izdatel'stvo AN SSSR. 1961.

P olyakov, G. D. Prisposobitel'naya vzaimosvyaz' izmenchivosti populyatsii ryb s usloviyami pitaniya (Adaptive Interrelationship between Variability of Fish Populations and Food Conditions). —In Sbornik : "Materialy po izmenchivosti i ekologii ryb," Moskva, Izdatel' stvo AN SSSR. 1962.

Sergeeva, M. N. Opitanii segoletok severnykh (ropshinskikh) gibridnykh karpa pri razlichnoi plotnosti zaseleniya prudov i razlichnom temperaturnom rezhime (Nutrition of Northern (Ropsha) Carp Hybrid Fingerlings at Various Densities and Temperatures in Ponds). In this Collection.

Yaroshenko, M. F. 0 vozmozhnostyakh proizvodstvennogo vyrashchivaniya tovarnykh segoletok karpa v prudakh Moldavii (P P R M C Underyearlings P M). —Izdatel' stvo Moldavskogo filiala AN SSSR, N . 4(24). 1955.

P O L

Moav, R G.W. Wohlf rth. B S G I E F . —Prog. R ., 1962, J . 1963.
Nak r oku, N. S.K s r . O E S W S C A .—B J S S F , V . 21, N . 2. 1955.
Nak r oku, N. S. K s ahar . O E P S Q F . — B J S S F , V . 21, N . 9. 1956.
Nak r oku, N. S. Kasa r . O R C M G G C F R I . — B J S S F , V . 22, N . 11. 1957.
Sklower, A. Karpfenzucht Palastina,praktische und wissenschaftliche Untersuchungen. —Verhandl. . Verein theoret. und angew. Limnologie, V . 10. 1949.

EVOLUTION OF SCALE COVER IN CULTIVATED CARP

G. I. Shpet

(UkrNIIRKh)

Reduced scale cover is characteristic of many breeds of cultivated carp. This is the basis for distinguishing various genetic groups of carp: scaly, mirror (sparse-scale, linear and frame-scale) and bare. Pisciculturists know that very different degrees of denuding can be found among carp with few scales (mirror and bare). Study of these forms shows that scale reduction is not a disorderly process, but rather, follows regular patterns which result from the partial domestication of cultivated carp.

Procedure

In this investigation, 708 carp with reduced scale cover were taken at random from various fish farms of the Kiev Region ("Sovki," "Rotok," "Pushcha-Voditsa"), and of the Vinnitsa ("Vishnya") and Khmel'nitsk ("Antoniny") districts. The carp were sparse-scale, frame-scale, linear and bare (Kirpichnikov, 1937), but we purposely ignored their genetic nature in order that we might be more objective in reporting the general patterns of scale cover reduction.

A template with the outline of a carp was made; then for every fish a drawing of its scale disposition and its bare spots was plotted separately. The right side was usually depicted, but both the right and the left sides were sometimes outlined, to study and depict the degree of asymmetry in scale arrangement. These outlines were the basis for final comparison and processing of data.

Results

Among the thousands of carp with complete scale cover, we found specimens with disrupted arrangement of scale cover and differing sizes of scales. Usually these differences encompassed several scales and areas, or spots, so that there were irregular rows of, and unusual or larger scales.

Such disruptions are probably phylogenetic precursors of the so-called mirror carp, that is, reduced scale cover, in that the first small bare spots are often visible among the areas with disrupted rows of scales. Conversely, there are no natural "mirrors" to be found among normal rows of scales.

We find a definite pattern in the development of bare spots based on the increase in area occupied by these sections, independent of the genotypic structure.

The smallest mirrors were found along the lateral line, on the sides of the body, in the middle of it, or closer to the head (Figures 1-5).

These spots grow and fuse to form 2 continuous bands (Figures 6-10), the lower band frequently being wider and more distinct than the upper one.

As the bands develop, the upper and lower band on each side of the body begin to fuse anteriorly (Figure 11), posteriorly (Figure 12), or in the middle (Figure 13). The fusion area of the back and belly expands (Figures 14, 15, 16) until the fusion is complete (Figures 17, 18, 19).

The complete frame of scales, which is still present on each side of the fish as depicted in Figure 17, breaks in various areas, at first between the fins ventrally (Figure 18), then at the gill cover (Figure 19).

Eventually, as the reduction of scale cover continues, the denuded dorsal area on one side fuses with the denuded area of the other side, either posterior to the dorsal fin (Figure 20) or anterior to it, but most frequently both anteriorly and posteriorly to it (Figures 21-24).

T[illegible], [illegible] the scales at the base of the pectoral fins (Figures 20, 22, 24) disappear. Fish with absolutely no scales at the caudal fin (Figure 23) or behind the head were rare (Figure 24). Specimens with completely bare spots that joined on at least 2 of these sections (Figure 24—behind the head and at the base of pectoral fins) were even rarer. Areas that were mostly scaleless generally still had single or groups of scales.

We found no fish that did not have at least one scale at the base of the pelvic and anal fins, or a band of small scales at the base of the dorsal fin.

Although one group of carp is called "bare," completely scaleless carp apparently are not encountered. Among the several thousand "bare" carp we examined, not one was completely scaleless.

According to the frequency of the various types of scale cover, the 708 fish in this investigation are distributed as follows:

Figure No	1	2	3	4	5	6	7	8	9	10	11	12
Number of specimens	1	3	2	2	12	3	12	80	20	8	37	35
Figure No	13	14	15	16	17	18	19	20	21	22	23	24
Number of specimens	30	59	88	97	45	27	33	19	46	39	7	3

The [illegible] distribution represents the presence of different genotypes, especially linear and bare carp. The extreme members of the groups were observed more rarely than the others. As the patterns varied widely, it was impossible to find two similar specimens; all the transitions between the depicted patterns were present.

Because only the right side of most specimens has been pictured, comparison of the right and the left sides may be of some interest.

A visual survey of all 708 sketched specimens, and of a greater number of which no drawings had been made, convinced us that the arrangement of scaly and scaleless parts of both sides is fairly, although not completely, symmetrical.

Only 42 carp were depicted from both sides. Some of these drawings are presented to illustrate typical cases.

Asymmetry usually affects only the details of the drawing (Figures 27-28, 29-30, 31-32), although sometimes it is somewhat stronger (Figures 33-34,

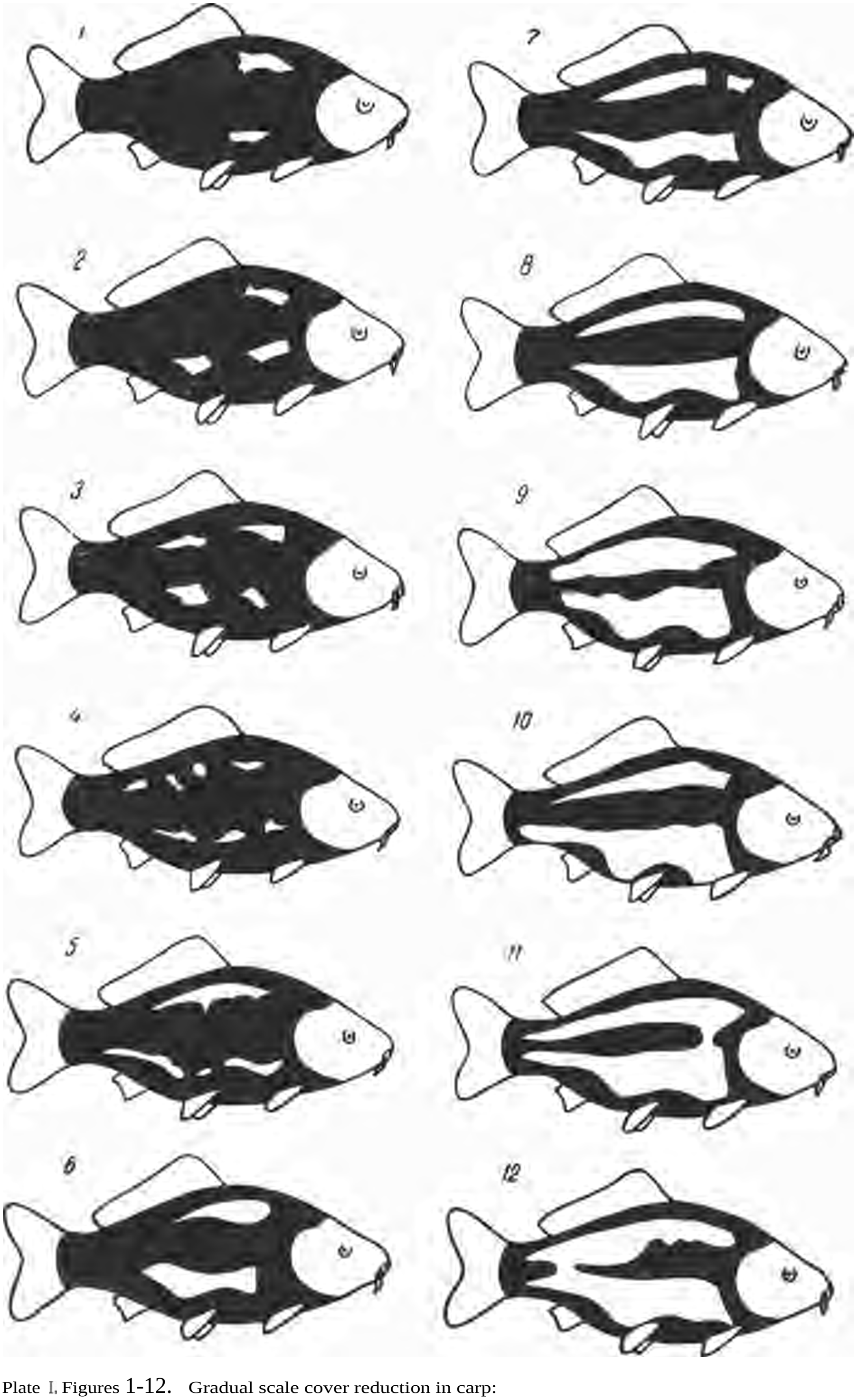

Plate I, Figures 1-12. Gradual scale cover reduction in carp: black areas indicate scaly surfaces; white areas, bare of scales.

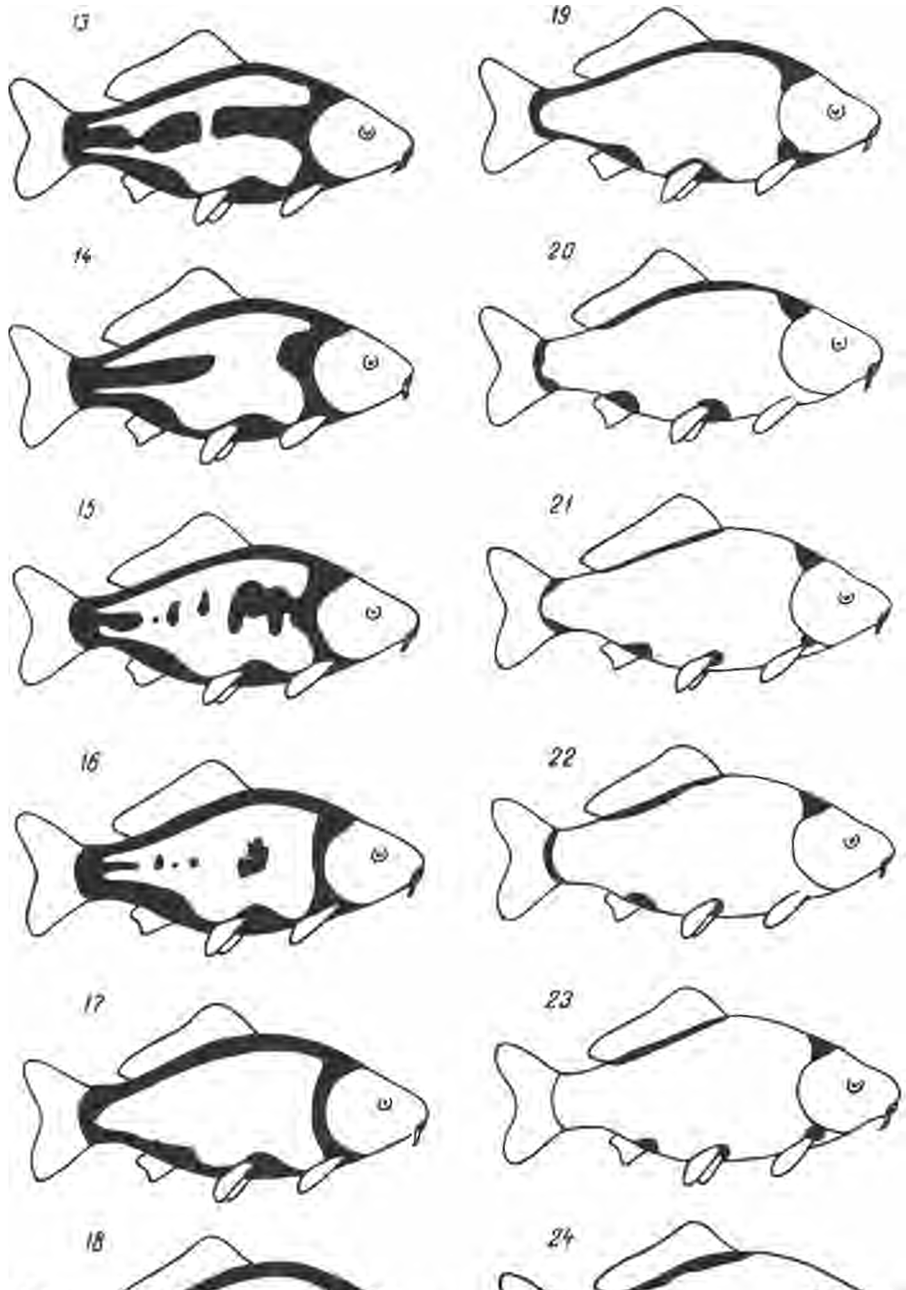

Plate I continued, Figures 13–24.

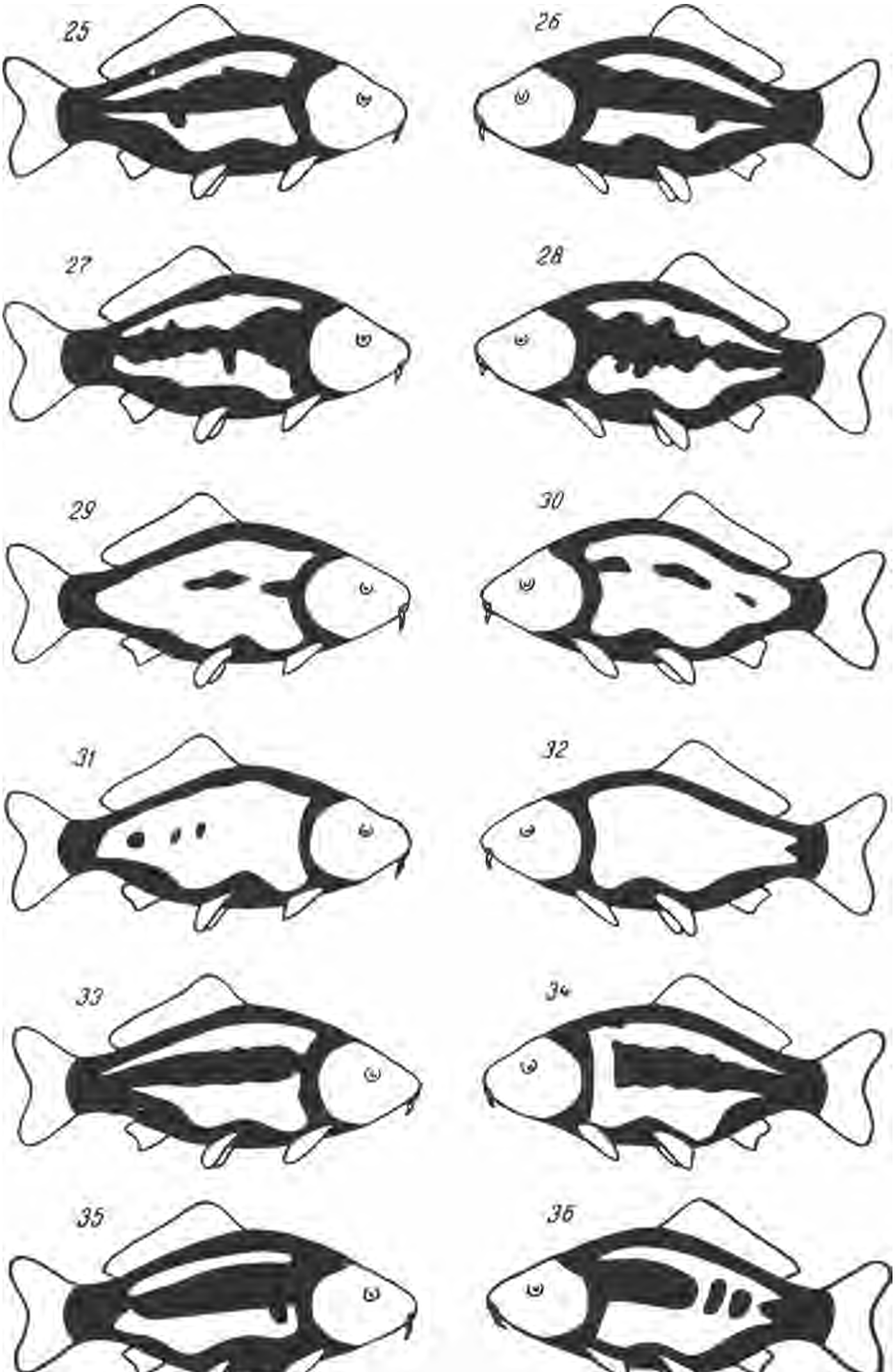

Plate II, Figures 25–36. Asymmetry in the development of scale cover of the right and left side.

35-36). Sometimes, on the contrary, a curious repetition of details is observed. For example, Figures 25-26 show a forward directed projection of scale behind the lower scaleless band.

In any case, in the specimens studied, the left and the right sides were always of the same pattern or very close to it, and were thus symmetrical.

Discussion of data

The foregoing description and drawings indicate a definite tendency toward scale cover reduction.

Scale cover reduction does not begin at any special part of the body, that is, the first mirrors do not appear, for instance, on the spine, at the tail, or near the fins. Rather, they appear at points having the least contact with surrounding objects: vegetation, other fish, bottom. These are the points that become scaleless bands up and down the median line.

Scales forming a regular (linear carp) or irregular row appear to have been detained at the median line. These forms are fairly frequent (Figures 8-13), and are, to a certain extent, genetically determined. We may assume that the delay in scale reduction in linear forms is connected with adaptive needs. The median line is the most extreme point of the body sides, and is therefore most subject to contact and friction with outside objects.

In typically linear carp (Kirpichnikov, 1937) and in some other fish, as sturgeon, for example, the scale row along the median line has become a stable genetic character.

In further scale reduction, this process is not haphazard. Reduction does not spread over the spine or the area of the fins, where scales protect these most vitally important external organs, i. e., no linear carp is found with naked spine and mirrors next to the fins.

The subsequent spreading of scaleless surfaces occurs by breaks in, and then disappearance of, the median line of scales, resulting in a typical scale cover known as frame-scale (Figures 16-19). The frame-scale carp is also a rather stable breed group (Kuzema, 1950).

A frame of scales protects both the most protruding and the most important parts of the fish body such as the fins.

Eventually, the frame becomes thinner and breaks, forming the typical pattern of bare carp which pisciculturists also classify as a genetically stable breed group.

But even the bare carp still have a few scales. More frequently than in other groups (61 specimens) they had no scales at all at the base of the pectoral fins and, rarely, a few fish had no scales at the base of the caudal fin (7 specimens) and behind the head (3 specimens). Here, too, the scales disappear completely at the base of the pectoral fins first, in inverse relation to their protective function. It may be assumed that this area is somewhat protected by the slightly protruding gill covers, while the other fins and the area behind the head have no protection at all.

Not a single specimen was observed without scales at the base of the pelvic, anal, and dorsal fins. Apparently the bases of fins are particularly important and vulnerable parts of the body. Thus, interestingly, where scale cover reduction occurs in the area below the median line of the body, it adheres tenaciously above and in front of the anal, pelvic, and pectoral fins, forming characteristic elevations at these points, and depressions between the fins as evident in all the drawings (Figures 5-19,25-36), where scaleless spaces begin to approach the ventral line.

On the other hand, even at the greatest reduction of the number of small scales in front of the pelvic and anal fins, there were always at least isolated scales, as apparent from the numerical data which follow:

No. of specimen	Anal fin	Pelvic fin	Pectoral fin
1	2 scales	2 scales	2 scales
2	2 "	1 scale	
3	2	2 scales	no scales
4	2 "	2 "	
5	4 "	1 scale	
6	3 "	1 "	
7	2 "	1 "	
8	2 "	1 "	
9	1 scale	1	
10	1 "	1	

Observing the gradual scale cover reduction, its "sliding off" the body, one becomes convinced of the adaptive nature of this reduction. It is as though the organism fights for every change, surrendering the position of each scale with great discrimination, in the order of their vital importance, watching closely and analyzing which can be relinquished earlier and which later. This strict choice can, of course, be made only by natural selection, which is active both in the creation of new properties and characteristics and also in the abandonment of old ones.

Scale cover which is generally normal, but has several breaks, is not exclusive to carp, being found in crucian carp and other Cyprinidae as well. These patterns are not common in nature, however (we shall not go into the more general problem of the origin of scaleless species of fish).

The spread and genetic consolidation of carp with reduced scale cover is due to the interaction of several basic factors. First, scale reduction is a result of the partial domestication of carp. Man protects carp from predators, feeds it, and removes the rigid forms of vegetation in ponds. There is progressively less need for the carp to make jerky movements, rushing into vegetation, hitting against plant stems, bumping over the bottom and into mollusk shells and other fish, while searching for food or escaping predators. The chances of damaging the cover become fewer in conditions of cultivation. Selection for preservation of the continuous scale cover ceases, leading to scale reduction: "the organ begins to atrophy when it ceases to be biologically useful to the animal" (Severtsov, 1939).

On the other hand, man certainly accelerated scale reduction by artificial selection of carp with scaleless areas in response to commercial requirements.

Experiments confirm that preservation of scale in carp in the most vitally important parts is adaptive. Strong irritation of the skin at the "mirrors" causes the growth of scales in those areas (Merla, 1959; Shpet, 1961) even in a carp yearling.

Experimental studies of the genetic foundation of carp breed groups by Kirpichnikov and Balkashina (1935, 1936), Kirpichnikov (1937, 1960), Golovinskaya (1940, 1946) and others have proved that sparse-scale, linear, and bare carp are sufficiently stable hereditary forms, although their phenotypes may overlap.

From both the evolutionary and practical selection aspects it is significant that one or several centuries of "semi-wild" carp cultivation were apparently needed (Spitschakow, 1935) to form a number of new hereditary forms within the species. The relatively rapid alteration of carp heredity under "semi-wild" maintenance indicates the possibility of altering carp genetics within decades using purposeful selection and modern methods of individual selection and progeny testing.

CONCLUSIONS

1. Reduction of scale cover is characteristic of cultured carp. This is evident from study of the location of scaly and bare areas in 708 carp specimens with various degrees of scale reduction. The fish used in the study were taken at random from many fish farms; sparse-scale,linear, and bare carp were examined.
2. We found a definite pattern in the mode of scale reduction with the increase of scaleless body areas. Beginning with the smallest "mirrors" and reaching almost scaleless forms, scale reduction always occurs first at those places which require the least mechanical protection (in the median part of the body, above and below the lateral line), then spreads to more vulnerable places (the most protruding parts of the body, crests) and reaches the most vitally important parts on the body surface (the bases of fins) last. In other words, the adaptive character of changes in scale cover is maintained throughout reduction.
3. These changes are a result of natural selection, which is aided and partly directed by artificial selection. Scale cover reduction is caused by changes in the environment of carp, primarily changes in feeding resulting from the partial domestication of carp.
4. The general tendency to scale reduction in carp under conditions of cultivation indicates that incomplete scale cover patterns are favorable characters for selection along with habitus, physiology and other characteristics.

Bibliography

Publications in Russian

Golovinskaya, K.A. Pleiotropnoe deistvie genov cheshui u karpa (Pleiotropic Effect on Genes of the Scale in Carp). —Doklady AN SSSR, Vol. 28, No. 6. 1940.

Golovinskaya, K.A. O lineinoi forme kul'turnogo karpa (The Linear Form of Cultured Carp). —Doklady AN SSSR, Vol. 54, No. 7. 1946.

Kirpichnikov, V. S. Osnovnye geny cheshui u karpa (Major Genes of the Scale in Carp). —Biologicheskii Zhurnal, Vol. 6, No. 3. 1937.

Kirpichnikov, V.S. Geneticheskie metody selektsii gibridov ryb (Genetic Methods of Selection of Fish Hybrids). —In Sbornik: "Otdalennaya gibridizatsiya rastenii i zhivotnykh," Moskva, Izdatel'stvo AN SSSR. 1960.

Kirpichnikov, V. S. and E.I. Balkashina. Materialy po genetike i selektsii karpa. I (Data on the Genetics and Selection of Carp.I). —Zoologicheskii Zhurnal, Vol. 14, No. 1. 1935.
Kirpichnikov,V.S. and E.I. Balkashina. Materialy po genetike i selektsii karpa. II (Data on the Genetics and Selection of Carp.II). —Biologicheskii Zhurnal, Vol. 5, No. 2. 1936.
Ku z em a, A. I. Organizatsionnye osnovy porodnogo uluchsheniya karpa v rybkhozakh Ukrainskoi SSR (Management Principles of Improvement of Carp Breeds in Fisheries of the Ukrainian SSR). — Trudy Ukrainskogo NIIRKh, Vol. 7. 1950.
S eve rtso v, A. N. Morfologicheskie zakonomernosti evolyutsii (Morphological Patterns of Evolution). —Moskva, Izdatel'stvo AN SSSR. 1939.
Shp et, G. I. Novoobrazovanie cheshui u dvukhletnego zerkal'nogo karpa pod vliyaniem razdrazheniya (New Formation of Scale in 2-Year-Old Mirror Carp under the Influence of Stimulation). — Voprosy Ikhtiologii, Vol. 1, No. 3. 1961.

Publications in Other Languages

r, W. Untersuchungen tiber die verschiedene Gestalt der Schuppen beimKarpfen, Cyprinus carpio L. —Z. Fisch., N. F., Vol. 5, No. 6. 1957.
M e r la, G. Karpfen—Brandmarkierung und sekundare Schuppenbildung. — Dt. Fisch Ztg., Vol. 6, No. 4. 1959.
Spits chakow, T. Zum Problem der Rasse und des Exterieurs beim Karpfen. —Z. Fisch., Vol. 33, No. 3. 1935.

THE ECOLOGICAL PHYSIOLOGY AND BIOCHEMISTRY OF CARP, "EASTERN CARP," AND THEIR HYBRIDS

G. L. Shkorbatov

(Kharkov State University)

Study of the physiological and biochemical ecology of fish is of great interest in elaborating theoretical problems of, and practical recommendations for, acclimatization and hybridization of fish, as well as for studying their intraspecific differentiation.

Carp, the chief item of pond pisciculture, is of great interest in this respect, particularly in connection with the breeding of "eastern carp" and its hybrids with carp in the north. We studied some physiological and biochemical statistics which characterize the reactions of these fish to temperature and oxygen concentration, which are the main abiotic limits on raising and breeding many fish species. The following statistics were chosen:

1) maximum tolerable temperature at different oxygen concentrations in water; 2) minimum oxygen needs (asphyxia point) at various temperatures; 3) activity of blood catalase, hemoglobin content, and erythrocyte count; 4) temperature dependence of dehydrogenase activity in the liver; 5) cold resistance of muscular tissue (time of disappearance of excitability at 1.5°).

The experiments were conducted on the following fish, aged 6-16 months: 1) carp of northern population (the 1st generation progeny of Ukrainian frame-scale spawners brought to "Ropsha" in 1955); 2) carp of southern population (scaly and mirror) from the Rakityansk fish nursery of the Kharkov Region; 3) "eastern carp" (C. c. haematopteru s) (progeny of spawners brought to "Ropsha" in 1945); 4) 1st generation hybrids of female "eastern carp" X male frame-scale carp (hereafter designated as F1 C X K hybrid); 5) 1st generation: female frame-scale carp X male "eastern carp" hybrids, hereafter F1 K X C hybrid; 6) 4th generation backcross hybrids (F4 B X B) which have about 75% of the genes of "eastern carp" (1st crossing: female carp X male "eastern carp," 2nd crossing: female "eastern carp" X male 2nd generation hybrid).

All the fish, except the carp of the southern population, were raised to the age of 5 months at "Ropsha" in 1960 and 1961. The fish were then delivered to the laboratory of the hydrobiology department of Kharkov University where they were kept in uniform conditions (diet, temperature, oxygen) in aquariums for not less than a month before being used in experiments.

The experiments were done at the department of hydrobiology of Kharkov University with the participation of senior laboratory assistant Kudryavtseva and graduate students Radchenko, Kolybaeva, and Petrova. Kirpichnikov, under whose guidance at the fish farm "Ropsha" all the experimental fish were raised, was very helpful.

We express our sincere thanks to all those persons who aided these investigations.

Maximum tolerable temperatures

Studies on the acclimatization and hybridization of carp in northern regions of the USSR primarily investigated tolerance of cold, and this problem has been studied fairly extensively (Kirpichnikov, 1944; Kirpichnikov and Berg,1952; Kirpichnikov and Lebedeva,1953; Kirpichnikov, 1958; and others).

We investigated ability to withstand heat as a distinguishing feature of fish from various habitats; this may also be utilized as an index of intraspecific differentiation and degree of eurythermicity of the various breeds. We also investigated the flexibility of this characteristic, and whether increased tolerance of cold is accompanied by decreased tolerance of heat in carp bred in northern waters.

Maximum tolerable temperatures were investigated at different oxygen concentrations, ranging from 1-7 mg/l, where temperatures were raised 1° every 10 minutes. The water was warmed with a Wobser universal thermostat; the necessary oxygen content was provided by aeration. Heat shock was taken as the point at which respiratory movements ceased. In each experiment 4-8 specimens were tested and the temperature was recorded when the first fish went into shock, and when 50 and 100% of the experimental specimens went into shock.

Temperatures in the experiments certainly rose faster than in nature. However, our data were similar to those obtained at slower rates of temperature rise, since the temperature limits established by us are close to the natural ones. This is apparently explained by the inherent adaptability of most fish to relatively sharp changes in temperature. As active swimmers, fish must frequently endure fluctuations of temperature resulting from temperature stratification and uneven warming of water bodies.

In June 1960 the first determinations were made of the temperature of heat shock for carp and F_4 B X B hybrid yearlings. The experiments were conducted on a small sample (3 experiments with 4 specimens in each). The results were more or less uniform: 50% of the carp went into shock at an average of 33.8° (oxygen content 4.2 mg/l), while the figure was 33.6° (oxygen content 5.3 mg/l) for the hybrids.

In 1961 a comprehensive and diverse sample was investigated. The determinations were made on 6- and 7-month-old underyearlings of the following groups: carp from the northern population, carp of the southern population, "eastern carp" and 1st generation C X K and K X C hybrids. Before the experiments began, all the fish were maintained for one month at 15-17° in generally uniform conditions. The experiments were conducted at 3 different oxygen concentrations (2-3, 3-5, and 5-7 mg/l). In each experiment, the temperature at which 50 and 100% of the experimental specimens went into heat shock was recorded.

Type of carp	n	5–7 mg O_2/1		3-5mg 02/1		2–3 mg O_2/1	
		I	II	I	II	I	II
Carp of northern population	16	**34.0** 0.07	**34.2 0.05**	**33.0 0.09**	33 3 ± 0. 2	31.9 ± 0.15	**32.5 0.13**
"Eastern carp"	16	33.8 ± 0.10	34.2 ± 0.07	33.0 ± 0.08	3M [illegible] 0	32.0 ± 0.08**	32.6 ± 0.15**
F_1 K × C hybrid	20	34.4 ± 0.20	34.7 ± 0.10	33.7 ± 0.22	34 [illegible] 7	33.0 ± 0.24	33.4 ± 0.17
F_1 C × K hybrid	20	34.3 ± 0.04	34.1 ± 0.04	33.5 ± 0.15	[illegible]	32.4 ± 0.17	32.8 ± 0.11
Carp of southern population	24	35.4 ± 0.20	36.1 ± 0.06	34.2 ± 0.21	35 1 ± [illegible] 0	34.1 ± 0.22	35.4 ± 0.22

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As evident from Table 1, the heat shock temperature of all the fish fell 1.5-2.0° with decrease of oxygen concentration from 5-7 to 2-3 mg/l. The interaction of temperature and oxygen factors on fish is well illustrated by this relation. Oxygen requirements increase with rising temperature but oxygen concentration usually decreases as the solubility of gases in water diminishes. Consequently, there is also an oxygen deficiency at sublethal temperatures. Similar ability to withstand heat found in the different types of carp leads to the following conclusions:

1. The heat tolerance of young carp from the northern population and "eastern carp" proved to be the same or nearly the same at all three oxygen concentrations in the experiment.
2. Heat tolerance of the young 1st generation hybrids is somewhat higher than that of the parental forms,but these differences do not exceed 1° and are statistically unreliable in most cases. Consequently, there are no grounds for the assumption that the fish we examined displayed heterosis in this characteristic.
3. The temperature at which the carp of the southern population had heat shock is 0.7-2.9° higher than that of northern forms and their hybrids. It is as yet difficult to determine whether this is a result of hereditary physiological differences or, as is more probable, reflects the differences in temperature conditions of the individual development in carp from the southern and northern populations; this requires special experiments. In any case, the established differences are statistically significant and relatively stable. Moreover, they go beyond the usual limits of regulatory reactions because maintenance in uniform temperature conditions for over a month, which usually suffices for altering shock temperatures in fish, did not eliminate the differences.

Cold tolerance of muscular tissue

As an indicator of ability to withstand cold at the tissue level, we tried to apply the index widely employed to indicate heat tolerance of muscles in various cold-blooded animals (Ushakov,1956,1958,1959; Ushakov and Kusakina,1960; Kusakina,1962; and others). This is the time at which cooled muscles no longer respond to electric current.

The experiments involved a limited sample to test the method, but the results proved to be sufficiently significant to be mentioned here. Procedure was as follows: preparations of muscles about 1 X 1.5 cm were cut out together with ribs from the lateral areas of the fish body, placed in Ringer's solution and cooled to -1.5°. Every 3-5 min the preparations were removed from the solution, placed on a small cooled table, and stimulated for 1-2 sec with 9 volts at 50 cycles A. C. For 3-4 fish of each experimental group that had been maintained for 6 months in uniform conditions at 10-15°, the following results were obtained:

Type of fish	Time of disappearance of muscle excitability (sec) at — 1.5 °C
Carp of northern population	15-20
K × C hybrid	18-23
"Eastern carp"	30-33
F1 C X K hybrid	30-35

These results indicate that tissue of "eastern carp" F1 C X K hybrid has much more ability to withstand cold than that of carp and the F1 K X C hybrid. These data indirectly confirm the results of investigations of the ability of "eastern carp" and carp to withstand zero temperature (Kirpichnikov,1958). Kirpichnikov's statement that differences in the reaction of "eastern carp" and carp to temperature changes are due to differences in reactivity of their nervous system should perhaps be supplemented by indications of differences in the cold tolerance of tissue. In addition, comparison of the cold tolerance of muscles of hybrids enables us to assume matrilinear inheritance of cold tolerance of tissue. However, as the number of determinations was very small, these data should be considered as only preliminary, requiring further testing and more exact definition. The method of determining the ability of muscle to withstand cold is in itself simple and convenient, and may be applied to estimate the cold tolerance of fish in both hybridization and selection.

Oxygen threshold

The value of oxygen threshold — asphyxia point (in mg O_2/1) — was established as the point of cessation of respiratory movements at 15° for fish placed in a respirator where the oxygen concentration was gradually and constantly reduced by gradual replacement of oxygen-rich water with deoxygenated water, using the method described by Shkorbatov (1957).

Before the experiment, the fish were kept in aquariums for at least a month (and in several cases much longer) at 13-16° and oxygen concentrations of 6-8 mg/l. From 2 to 6 determinations were made on 4-6 specimens of each group (Table 2).

TABLE 2. Oxygen threshold of carp, "eastern carp," and their hybrids at 15 (oxygen concentration at which 50% of the fish were asphyxiated)

Type of fish	Age, months	Average weight, g	No. of determinations	Total No. of specimens	Oxygen threshold, mg O_2/1	
					average	fluctuations
Carp of northern population	10	8	3	14	0.40	0.3 — 0.6
"Eastern carp"	10	8	5	20	0.36	0.3 — 0.4
F_1 C × K hybrid	10	8	2	8	0.28	0.25-0.30
F_1 K × C hybrid	10	8	3	12	0.34	0.3 —0.4
F_4 B × B hybrid	13	28	5	30	0.56	0.4-0.8
Carp of southern population	15	78	3	12	0.20	–
	6	12	8	32	0.38	0.3 — 0.4

The data show that all the investigated groups had similar values of oxygen threshold — below 0.5 mg 02/1 with most fluctuations in the 0.3 to 0.4 mg 02/1 range. The threshold was lowest in yearlings from the southern population (0.2 mg 02/1) and highest in F4 B X B hybrid yearlings (0.56 mg O_2/1), possibly due to a higher metabolic rate in those hybrids. The data below on dehydrase activity in the liver partly confirm this assumption.

On the whole, all the types of fish investigated had a high tolerance to oxygen deficiency. The "eastern carp" and its hybrids with carp practically did not differ from carp in this respect. Carp is known as a freshwater fish which is most tolerant of oxygen deficiency, a decisive factor in the success of pond carp breeding. It should be noted that our data on the oxygen threshold of carp are very close to results of similar investigations by Privol'nev (1956) and others.

Catalase activity and respiratory properties of blood

Investigation of the activity of enzymes that are directly connected with the tissue respiration process (including catalase) and the respiratory properties of blood in the various types of carp allows us to form a more complete opinion of the nature of the respiratory function of fish and its variation with changes in environment. Moreover, the differences in enzymatic activity in various intraspecific groups of carp, "eastern carp," and their hybrids indicate the extent of the functional shifts occurring in intraspecific differentiation and hybridization.

In comparing vital temperature and oxygen limits, we study the reactions of the whole organism, but in considering temperature dependence of enzyme activity, we find differences at the protein level, i. e., much more profound structural and functional changes.

Table 3 compares the hemoglobin content (after Sali), erythrocyte count in mm^3 of blood, and activity of blood catalase in carp of the southern population and F4 B X B hybrids. Catalase activity was determined according to Bakh and Zubkova (Zbarskii et al., 1954), wherein catalase activity

TABLE 3. Hemoglobin content, erythrocyte count, and activity of blood catalase in carp and hybrids

Type of fish	No. of specimens	Average weight, g	g no hs	Erythrocyte count, millions/mm^3	Hb, HO	Catalase activity at various temperatures (°C)*				
						2	10	20	35	50
n hybrid	17	63	16	2.15± 0.068	10.0 41 0 12	0.62 ± 023 / 0.28	1.06 5 / 0.49	1.34± 0.061 / 0.62	0.61 ± 0.033 / 0. 0	0.44 ± 0.018 / 0.20
Carp of southern population	18	2	16	1.86 ± 0 057	9.7 ± 11	1.82 ± 0 06 / 0.98	2 17 ± 0.065 / 1.16	3.05± 0.140 / 1.64	2.04 096 / 1.10	1.59 ± 0.067 / 0.86
Carp of northern population	5	15	5	1.90 0.050	8.6 41 0.23	0.48 33 / 0.25	0.84 0.082 / 0.44	1.15 ± 0.123 / 0.61	0.76 ± 0.031 / 0.41	0.40 ± 0.029 / 0.21

is expressed in mg of hydrogen peroxide decomposed by the enzyme in mm^3 of blood in 30 minutes.

The data show that hybrids having a somewhat higher erythrocyte count and a hemoglobin content almost equal to that of carp of the same age evidence lower activity of blood catalase than do the carp.

Even the considerable retardation of weight of hybrids, resulting from prolonged maintenance in aquariums, did not decrease their hemoglobin content and erythrocyte count as compared to carp. Thus, the observed differences in catalase activity indicate a different saturation of erythrocytes with this enzyme in the 2 types of fish, in that blood catalase is concentrated in the erythrocytes, and its effective concentration as given here is the ratio of catalase activity to the number of erythrocytes. This is also confirmed by comparison of data on carp yearlings (16 months) and underyearlings (5 months) in which we find great differences in the catalase activity at almost uniform content of erythrocytes. Apparently the content of catalase in erythrocytes changes with age and other physiological shifts in the organism.

From examining the temperature dependence of catalase activity, we find that in all the fish investigated, maximum activity occurred at 20°, above and below which temperature the enzyme activity gradually declines. The differences in the rate of decline of activity with rise and fall of temperature point to some qualitative differences of catalase between southern carp and its hybrid. Thus, if catalase activity at the optimum temperature (20°) is taken as 100%, a very characteristic picture is obtained (Table 4).

While in the southern carp the decline of enzyme activity with rise and fall of temperature is relatively symmetrical, catalase activity declines much less with falling than with rising temperature in the cold-tolerant F_4 B X B hybrid. It should also be emphasized that at 35°, the level of catalase activity is 20% higher in the southern fish than in the hybrid.

TABLE 4. Activity of blood catalase in % of its activity at 20°

Type of fish	Catalase activity.%	
	10°	35°
F_4 hybrid, 16 months	79	47
Carp of southern population 16 months	71	67
5 months	72	66

The temperature coefficient of enzymatic reaction (Q_{10}) is also characteristic, particularly between 10-20°, e., the ratio of catalase activity at 20° to the activity at 10°:

	Q_{10}
F_4 B X B hybrid, 16 months	1.26
Carp of southern population, 16 months	1.42
" 5 "	1.39

Consequently, with the rise of temperature within these limits, the activity of blood catalase in hybrids increases less intensively than in carp; the reaction is slower and calmer. It should be noted that the level of enzyme activity at the given temperature is not an objective indicator of its quality. Thus, it is not always correct to assume that heterosis will be manifested in hybrids in the higher rate of enzymatic or metabolic activity as a whole because the greater enzymatic activity, and particularly the increase of Q_{10}, rather indicates greater than optimal energy expenditure for a given biological reaction. Nevertheless, changes in catalase or other enzymatic activity with temperature are of interest as indicators of heat or cold tolerance, and Privol'nev (1953) believes that they can be of great practical significance in solving problems of acclimatization.

Dehydrogenase activity in the liver

Catalase,which decomposes hydrogen peroxide, participates in the final stage of tissue respiration while dehydrogenase functions in the initial links of this process. Both in studying the catalase activity and in this case, we are primarily interested in the change of enzymatic activity with temperature.

The activity of dehydrogenase in the liver was determined according to Tunberg's method whereby the total activity of dehydrogenase is established by the length of time methylene blue solution discolors under oxygen-free conditions (Ferdman and Sopin,1957). For every determination in our experiments, 100 mg of homogenized tissue of liver on phosphate buffer with pH 6.8, and 0.25mg of 0.01% of methylene blue solution were introduced into each Tunberg test tube. Dehydrogenase activity was determined at temperatures from 10 to 50° in 10° intervals.

		ge e gh g	hs	Time ofdiscol tionof methylene blue (sec.) at different temperatures (CC)					
								4	5
Carp of northern pop	22	o	6	—	226 8	9 ± 8.	5 ± 0.	0 9.6	40 ± 0.
"Eastern carp"	20	o	6	—	8 2	26 ± 1.9	1 2 ± 9.	3 2.5	44) ± 3.3
F1 K × C hybrid	3	0	6	—	2 2 5	1 4 ± 0.2	33 41 6	01 3 4	1:7 ± 0.7
F1 C × K hybrid	2	ta	6	—	252 ± 0	1 ± 5.5	6 41 5.	2 6	4(004 ± 0.6
F4 B × B hybrid	13	6	1	0 ±	1	5 41 1.8	68 ± 3.	5Z 8 9	3 CO 41 3
Carp of southern pop	Z6	2		—	38 +	6 ± 2.8	60 ± 8.	I07 7	6 CO 44 1 3
" " "	20	20		49 ±	1	212 ± 6 2	34 ± 6 4	96 5 3	41 0

Table 5 summarizes the mean data of dehydrogenase activity in the liver of the fish studied. Because the activity of dehydrogenase is expressed by the time of discoloration of methylene blue, a higher enzymatic activity is indicated by a shorter time in Table 5.

Firstly, attention is drawn to the fact that the temperature dependence of dehydrogenase activity is completely different from that of catalase. Activity of catalase in fish declines markedly at temperatures above 20 , but dehydrogenase activity increases at temperatures up to 50° and higher. Dehydrogenase becomes less active only at temperatures above 70° (these data are not given in the table).

Very negligible, statistically insignificant differences in dehydrogenase activity were found between the underyearlings of carp from the northern USSR and F1 K X C hybrids.

The differences between the yearlings and underyearlings of the southern carp were also insignificant. The differences between the underyearlings of both groups of F1 hybrids become significant at temperatures above 30°.

The greatest difference in dehydrogenase activity occurred between F4 B X B hybrid yearlings and other fish at temperatures above 30°.

All these peculiarities of dehydrogenase activity become considerably more apparent if they are depicted graphically, by replacing the time of methylene blue discoloration with a reciprocal value—the .rate of discoloration which is. $\frac{1}{\text{time of discoloration, in min}}$

These data are presented graphically in Figures 1 and 2. Figure 1 depicts how dehydrogenase activity in the liver changes with temperature rise in underyearling northern carp, "eastern carp," and their 1st generation hybrids. Attention is drawn to the fact that there are quite reliable differences between the parental forms in the 15-40° range, but at 50°,these differences completely disappear. The differences in dehydrogenase activity in the liver of the two F1 hybrids are particularly significant. While the temperature dependence of the dehydrogenase activity of F1 K X C hybrids is of similar nature and level to that of carp, F1 C X K hybrids showed a considerably higher level of dehydrogenase activity at temperatures above 20 , and the curve character itself closely resembles the curve of dehydrogenase activity in "eastern carp." As indicated further on, the same dependence appears in the value of the temperature coefficient (Qio) of this enzymatic reaction.

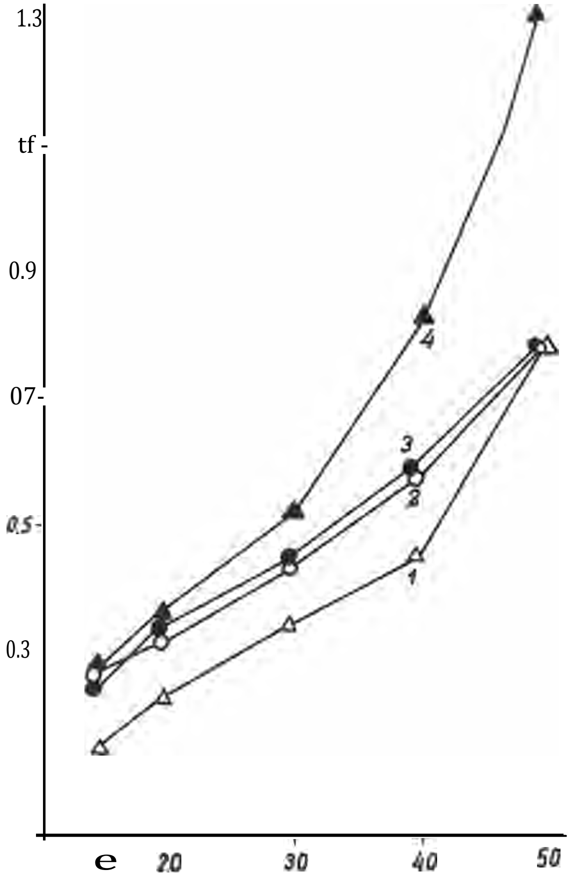

FIGURE 1. Variation of dehydrogenase activity with temperature change:

1 — "eastern carp"; 2 — carp of northern population; 3 — F_1 K)< C hybrid; 4 — F_1 C x K hybrid; the ordinate gives the rate of discoloration of methylene blue, in sec.

The differences in temperature dependence of dehydrogenase activity between carp of the north and those from the south are also important (Figure 2). At relatively low temperatures, dehydrogenase activity is higher in northern carp; as temperatures rise to 50°, dehydrogenase of southern carp becomes more active. This phenomenon reflects the peculiarities of their respective habitats, which apparently determine the differences in temperature "adjustment" of the enzymatic systems of the northern and southern fish. Similar phenomena were found in comparing trypsin activity in Barents Sea cod and in "Black Sea whiting" (Korzhuev, 1936), in comparing catalase activity in northern and southern "Lake Chud whitefish" now being acclimatized in the Ukraine (Shkorbatov and Salo, 1959) and in some other cases.

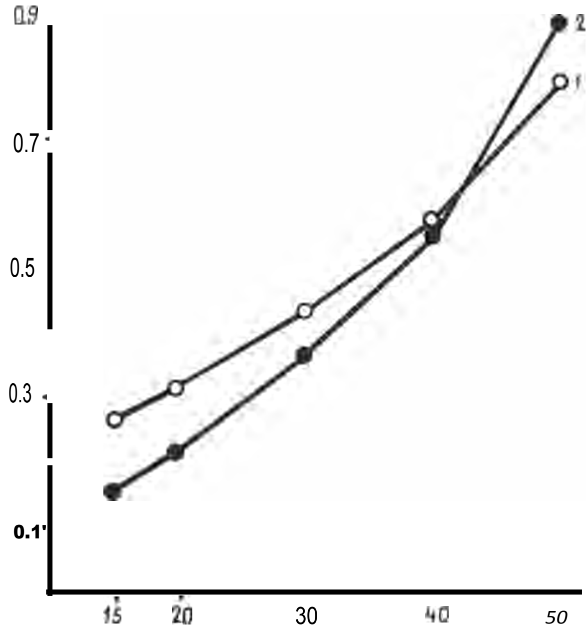

FIGURE 2. Temperature dependence of dehydrogenase activity in carp liver:

1 — carp from the north; 2 — carp from the south; the ordinate gives the rate of discoloration of methylene blue, in sec.

Calculation of the value of temperature coefficient (Q_{10}) of dehydrogenase activity in the liver for various temperature differentials enables us to form an opinion on the nature of the enzymatic activity by the relationship of the rate of reaction at different temperatures, although not by absolute values.

Considering the Q_{10} value at different temperatures (Table 6), we see that it is largest, indicating the highest acceleration of enzymatic reaction with rising temperature, for "eastern carp" and F1 C X K hybrids and smallest for carp and F1 K X C hybrids. This is also indicated by mean Q_{10} values calculated for all the investigated temperature intervals.

These data, and comparison of the character of the curves (Figure 1) point out the fact that although the dehydrogenase activity level in 1st generation hybrids in one case exceeds that in either parental form, and in another case corresponds to the level of one of the parents, the character of temperature dependence of dehydrogenase activity is a matrilinear inheritance. If this assumption is confirmed in the studies of other enzymatic systems, it will be of undoubted practical significance in fish hybridization and may explain the inheritance of several physiological properties in fish.

TABLE 6. Temperature coefficient (Q_{10}) of dehydrogenase activity in the liver of carp, "eastern carp," and their hybrids at age 6 months

Type of fish	Temperature differential (°C)			
	20-30	30-40	40-50	Average for 20–50°
Carp	1.37	1.32	1.36	1.35
F_1 K x C hybrid	1.32	1.31	1.30	1.31
"Eastern carp"	1.52	1.32	1.73	1.52
F_1 C x K hybrid	1.45	1.61	1.59	1.55

The considerable increase of dehydrogenase activity in F1 C x K hybrids and the fact that this property, which originated as manifestation of heterosis in the 1st generation, does not disappear up to the 4th generation (according to the hybridization scheme accepted by Kirpichnikov) are of great interest.

CONCLUSIONS

I. We have found intraspecific differences between "eastern carp" from the northern USSR and those from the southern USSR in ecological-physiological and ecological-biochemical traits. Thus, young southern carp go into heat shock (after prolonged maintenance at uniform conditions) at a higher temperature than do northern carp and "eastern carp." The "eastern carp" displayed a higher cold tolerance of muscles and a lower level of dehydrogenase activity in the liver (within a 15–40 differential) than the northern carp. Dehydrogenase activity in the liver of southern carp is more apt to decline with lower temperatures and to rise with a rise in temperature (50) than that of northern carp.

These differences in the forms under comparison are functional adaptations of apparently different degrees of stability and hereditary fixation, but they all point to intraspecific functional differentiation for the entire organism as well as for processes at lower tissue and protein levels. It should be noted that these results do not agree with the concepts evolved by Ushakov (1956, 1958, 1959, etc.) that the heat tolerance of tissue and protein is a characteristic, specific property of cold-blooded animals which does not vary with differing habitat of the species in various habitation areas of its range.

Our data confirm the idea that habitat of various populations (or subspecies) of a given species can cause temperature adaptations (changes in heat and cold tolerance) not only in the regulatory reactions of the entire organism, but also in protein (enzymes) and tissue reactivity (Shkorbatov, 1961).

II. The following ecological-physiological and ecological-biochemical features of hybrids have been determined.

1. First generation hybrids of the "eastern carp" female and a frame-scale male carp (C × K) have a higher level and a greater value of the temperature coefficient (Q[illegible]) of [illegible] activity, a higher cold tolerance of tissue, and perhaps (this still requires checking) a greater tolerance of oxygen deficiency than the reciprocal (K X C) hybrids.

2. First generation C X K hybrids, and particularly 4[illegible] generation [illegible] (B X B) hybrids considerably exceed both parental forms in the level of [illegible] activity of the liver (particularly at temperatures above 30°), which is one manifestation of [illegible] in these hybrids.

3. Comparison of the indexes of cold tolerance of muscles and the temperature coefficient of [illegible] activity in the liver in the parental forms and in both hybrids suggests that in crossing carp with "eastern carp," such functional features as cold tolerance of tissues and the character of temperature dependence of enzyme activity are inherited [illegible]. This is of direct interest for hybridization of fish, and must be studied also for other characteristics.

III. Although the primary purpose of hybridization of carp with "eastern carp" has been to increase the cold tolerance of hybrids, the latter, as is seen from these experiments, also preserve a high heat tolerance and tolerance of oxygen deficiency.

This capacity for withstanding a wide range of fluctuations of environmental factors, together with other desirable properties of hybrids, make it possible to consider the introduction of hybrids into more southern latitudes, and, in particular, to the continental climate of the central regions of the USSR. It is known that in the middle latitudes, for example, in the Ukraine, approximately up to 50°N, and with the advance to the east and further to the south, the winter frosts frequently damage carp breeding (particularly during the hibernation of the nonstandard young).

Increasing cold tolerance of young fish is an important problem for pond pisciculture in many regions of the USSR. Therefore it is important that hybridization work at G[illegible]NIORK[illegible] be expanded, and that hybrids be introduced in quantity in pond pisciculture not only over the European USSR but also in Siberia, where, despite the need for local, cold- tolerant breeds of carp and the existing possibility of utilizing "eastern carp" for hybridization, no work has yet been done on this problem.

Bibliography

Fe[illegible], D. L. and E. F. S[illegible]pin. P[illegible] po[illegible] [illegible] (Practical Course in Biological Chemistry). Moskva. 1957.

K[illegible], V. S. Zimostoikost [illegible] SSSR (W[illegible] of "Eastern Carp" in Conditions of the Central and Northern Zone of the European USSR).— Doklady AN SSSR, Vol. 43, No. 1. 1944.

K[illegible], V. S. K[illegible], [illegible] (Cold Tolerance and W[illegible] of

Fingerlings of Carp, Wild Carp, and their Hybrids).— Trudy soveshchanii po fiziologii ryb, Moskva, Izdatel'stvo AN SSSR. 1958.

Kirpichnikov, V. S. and R. L. Berg. K probleme povysheniya zimoustoichivosti segoletkov karpa, sazana i ikh gibridov. Soobshchenie 1. (Increasing Winterhardiness in Underyearlings of Carp, Wild Carp, and their Hybrids. Communication 1.). — Zoologicheskii Zhurnal, Vol. 31, No. 4. 1952.

Kirpichnikov, V. S. and L. I. Lebedeva. K probleme povysheniya zimoustoichivosti segoletkov karpa, amurskogo sazana i ikh gibridov. Soobshchenie 3. (Increasing Winterhardiness in Underyearlings of Carp, "Eastern Carp," and their Hybrids. Communication 3.). — Trudy Vsesoyuznogo Gidrobiologicheskogo Obshchestva, Vol. 5. 1953.

Korzhuev, P.A. Vliyanie vysokoi temperatury na tripsin teplokrovnykh i kholodnokrovnykh zhivotnykh (The Influence of High Temperature on Trypsin of Warm- and Cold-Blooded Animals).— Fiziologicheskii Zhurnal SSSR, Vol. 21, No.3. 1936.

Kusakina, A. A. 0 sootvetstvii teploustoichivosti myshts i kholiesterazy temperaturnym usloviyam obitaniya vida u nekotorykh ryb (Conformity between Heat Tolerance of Muscles and Cholinesterase with Temperature Conditions of the Natural Species Environment in Some Fish). — Tsitologiya, Vol. 4, No. 1. 1962.

Privol'nev, T. I. Vliyanie temperatury i solnechnogo sveta na aktivnost' katalazy ryb (The Influence of Temperature and Sunlinght on Fish Catalase Activity).— Izvestiya VNIORKh, Vol. 33. 1953.

Privol'nev, T. I. Perevozka i khranenie zhivoi ryby (Transportation and Preservation of Live Fish). Moskva. 1956.

Razvitie prudovogo rybovodstva v Sibiri (Development of Pond Pisciculture in Siberia).— Materialy VII plenuma Zapadno-Sibirskogo otdeleniya ikhtiologicheskoi komissii Gosplana SSSR, Novosibirsk. 1962.

Shkorbatov, G. L. Ekologo-fiziologicheskie obosnovaniya akklimatizatsii sigov v vodoemakh Ukrainy (Ecological-Physiological Foundations for Whitefish Acclimatization to the Water Bodies of the Ukraine). — Trudy Biologicheskogo Fakul'teta Khar'kovskogo Gosudarstvennogo Universiteta, Vol. 27. 1957.

Shkorbatov, G. L. Vnutrividovaya fiziologicheskaya izmenchivost' u vodnykh poikilotermnykh zhivotnykh (Intraspecific Physiological Variability in Cold-Blooded Aquatic Animals).— Zoologicheskii Zhurnal, Vol. 40, No.10. 1961.

Shkorbatov, G. L. and Z. T. Salo. 0 fiziologicheskoi izmenchivosti populyatsii ryb v svyazi s temperaturoi meat obitaniya (Physiological Variability of Fish Populations in Relation to Environmental Temperature). — Doklady AN SSSR, Vol. 129, No. 3. 1959.

Ushakov, B. P. Teploustoichivost' kletochnykh belkov kholodnokrovnykh zhivotnykh v svyazi s vidovym prisposobleniem k temperaturnym usloviyam sushchestvovaniya (Heat Tolerance of Cell Proteins of Cold-Blooded Animals in Relation to Species Adaptation to Environmental Temperature).— Zhurnal Obshchei Biologii, Vol. 17, No. 2. 1956.

Ushakov, B. P. 0 konservativnosti protoplazmy vida u poikilotermnykh zhivotnykh (The Conservatism of Protoplasm of Species in Cold-Blooded Animals).— Zoologicheskii Zhurnal, Vol. 37, No. 5. 1958.

Ushakov, B. P. Teploustoichivost' tkanei — vidovoi priznak poikilo-termnykh zhivotnykh (Ability of Tissue to Tolerate Heat — a Species Character of Cold-Blooded Animals). — Zoologicheskii Zhurnal, Vol. 37, No. 9. 1959.

Ushakov, B. P. and A. A. Kusakina. 0 labil'nosti i konservativnosti adaptatsii kletok zhivotnykh, obnaruzhivaemoi na belovom urovne (Flexibility and Conservatism in Adaptation of Animal Cells at the Protein Level). — Tsitologiya, Vol. 2, No.4. 1960.

Zbarskii, B.I., I.B.Zbarskii, and L.I.Solntsev. Praktikum po biologicheskoi khimii (A Practical Course in Biochemistry). — Medgiz. 1954.

HERITABILITY OF SOME MORPHOLOGICAL (DIAGNOSTIC) TRAITS IN ROPSHA CARP

G.A. Nenashev

Introduction and review of the literature

Investigation of the patterns of inheritance and variability of economically valuable properties of animals is of great importance for the theory and practice of selection. The knowledge of heritability value of the characters being selected is particularly important for selection. Lately, this value has been included in almost all the formulas used by selective breeders. Wright (1920) was the first to introduce the concept of heritability and to elaborate the methods for determining it.

Lush (1939, 1945, 1949) suggested a distinction between the broad and the narrow sense of the word heritability. Heritability in the broad sense means that share of general phenotypic variability which is determined by the action of the entire genotype. According to Rokitskii (1964b), "heritability is an index of the specific proportion of the genotypic variability in the general variability of the population." Belyaev (1962) gives the following definition: "The value of heritability coefficient reflects the share of variety of genotypes in the overall variety of phenotypes of specimens comprising a population." All these definitions are the same in essence.

Heritability (in the broad sense of the word) is expressed by the following general formula:

$$h^2 = \frac{\sigma_G^2}{\sigma_P^2},$$

where σ_G and σ_P are mean-square deviations of the distribution of genotypic and phenotypic characters.

Heritability in the narrow sense is the portion of overall, phenotypic variability determined by the action of additive genes. Additive genes are identically effective, mutually supplementary hereditary factors, the action of which is summed arithmetically. Here, heritability is expressed by the following formula:

$$h^2 = \frac{\sigma_A^2}{\sigma_P^2},$$

where σ_A is the additive genotypic variability.

Heritability coefficient is usually designated as h^2, and is expressed in fractions or in percent.

Heritability is a quality not only of a character, but also of the population and environmental conditions where the specimens develop. Most significantly, this value determines to what degree variability of the character being studied depends on the influence of parental genotypes, and to what degree it depends on environment.

We can get an idea of the prerequisites of selection methods from knowledge of heritability and, in particular, we can estimate the optimum relationship between mass and individual selection for improving those traits that are commercially valuable (Lush, 1945; Lerner, 1958; Kirpichnikov, 1960, and "Goals and Methods in Carp Selection," the present collection).

Knowing the heritability coefficient, one can predict the results of improved feeding and maintenance, and application of various methods of selection. It has been established that if heritability is low, mass selection is less efficient. In this case, individual selection should be employed. Robertson (1957) concludes that it is not profitable to select animals by characters with a very low heritability as the expense of selection will not be justified by the results.

Mass selection by characters with high heritability yields good results; there is a strong shift of the progeny in the direction given by selection. This is confirmed, in particular, by Lerner's data (1958) on differences in the results of selection by the number of eggs laid by hens in November, and by their average weight.

There are numerous studies on the methods of determining heritability (Wright, 1920; Lush, 1939, 1945; LeRoy and Grühn, 1956; LeRoy and Lortsher, 1955; LeRoy, 1962; Warner, 1952; Plokhinskii, 1962; and others). Many studies give data on heritability in farm and experimental animals (Berge, 1948; Reeve, 1953; Morley, 1956; Mason and Robertson, 1956; Stakan and Soskin, 1962; and others).

There have been few determinations of heritability in fish, however. Kirpichnikov (1958, 1959a) gives the coefficient of heritability of weight in carp as 0.20-0.30. A serious attempt to analyze the main components of phenotypic variation by weight, and to determine its heritability in carp, was made by Moav and Wohlfarth (1963). They determined the value of heritability of differences in carp weight as 0.09-0.18. Moav and Wohlfarth consider this value to be very approximate. Further investigations will make it more precise.

We attempted to determine the heritability of some traits in hybrids of carp with "eastern carp"; the body length and weight, habitus (1/H and H/B) and several morphological (diagnostic) traits (the number of scales in the lateral line — 1.1., the number of branching rays inthe dorsal fin, the number of gill rakers, the number of branched trunk vertebrae, and the total number of vertebrae). We also attempted to determine the heritability of one biochemical property, the fat content in the body of underyearlings.

This communication gives the first results on the determination of heritability of diagnostic traits based on the 1963 experiments.

Procedure

The experiments were done at "Ropsha," using hybrids of carp and "eastern carp." Work on hybrid selection has been going on in the north since 1949 (Kirpichnikov, 1957, 1958, 1959a, 1959b, 1960, and 2 papers in this collection;

Kirpitschnikow, 1961). Hybrids possess good fishery indexes and have been widely distributed in the northwest. By 1964, the 5th generation Ropsha hybrids had been obtained.

We crossed females of hybrids of strain M and males of strains M, MB, and BM. The characteristics of the spawners are given in Table 1. We planned to determine heritability coefficients by employing two methods: 1) factor analysis of variance in families of half-sibs and full sibs (brothers and sisters), and 2) analysis of progeny regression by fathers.

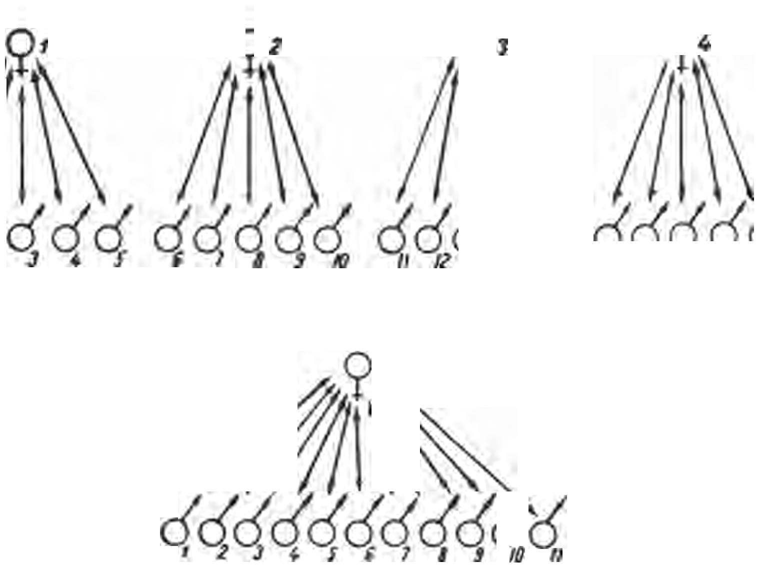

Diagram of crossings for determination of heritability ("Ropsha," 1963):

a — analysis of variance; b— regression of progeny by males.

Crossing schemes (see Figure) were constructed in accordance with the methods of determining heritability. To determine heritability by analysis of variance, 4 females were crossed with 5 males each. Egg laying was stimulated by pituitary extract injections, and we used the dry (Russian) method for their artificial fertilization. The eggs of each female were divided into 5 equal groups (5,000-6,000 eggs in each). Each group of eggs was then fertilized with milt of a different male. The fertilized eggs were cleaned using hyaluronidase in the method developed by Konradt and Sakharov (1963). Some fertilized eggs were spread over gauze frames and placed in the pond; 10-12 hours later, when eggs had lost their ability to adhere to the substratum, they were removed with a scalpel from the frames and transferred to the laboratory for incubation. The eggs were incubated in crystallizers containing 1,000 eggs each.

After hatching and transition to active feding, the larvae were transferred to 33-liter aquariums for pre-raising. Each aquarium was stocked with 70 larvae, which were pre-raised under the most uniform conditions possible until they weighed 150-200 mg. They were then tagged by clipping their fins. The upper or lower lobe of the caudal fin and the right or left pelvic fins were clipped in combination. The tagged fingerlings were stocked in intermediate ponds Nos. 5a, 6a, 6b and into spawning ponds in "Gostilitsy" for raising. Progeny of each female and the five males were stocked together in each pond.

TABLE 1. Characteristics of females and males used for crossings

Breed group	No.	Weight, g	Length, cm	Height, cm,	Breadth, cm
		Females			
7-year-old, 3rd generation 4-way hybrid	15	3,010	49.5	15.5	9.0
Same	16	3,030	48.0	15.5	8.5
	17	2,990	49.5	15.5	8.0
10-year-old, 3rd generation 4-way hybrid	38	4,350	56.0	17.0	9.0
14-year-old, 2nd generation Novgorod hybrid	2	7,130	65.0	20.5	12.0
		Males			
3-year-old, 4th generation strain M hybrid	3	1,300	37.2	12.8	
Same	4	1,000	34.0	12.8	
	5	1,060	35.7	11,6	
	8	840	31.5	11.1	
	10	1,030	35.0	11.7	
4-year old, 4th generation strain MB hybrid	3	1,320	37.5	12.5	6.0
Same	4	1,550	39.5	13.0	6.5
	8	1,520	38.5	13.5	6.5
	18	1,660	38.5	14.5	6.0
	34	1,460	38.5	13.0	6.0
	36	1,720	42.5	13.5	7.0
	38	1,550	42.0	13.0	6.5
	39	1,180	37.0	12.0	5.5
3-year-old, 4th generation strain BM hybrid	2	1,100	34.6	12.4	
Same	5	950	33.8	10.9	
	6	860	32.1	11.4	
	7	1,080	35.0	12.6	
3-year-old, 4th generation strain MB hybrid	1	2,850	46.5	16.5	8.5
Same	9	2,430	46.5	14.5	8.5
	11	2,040	44.0	14.0	7.5
	12	2,400	46.0	14.5	7.5
	19	1,980	44.0	14.0	7.0
	21	2,670	47.0	15.0	7.5
	26	1,840	43.0	13.5	7.0
	28	2,910	47.5	16.5	8.5
	29	2,280	43.5	15.0	7.5
	51	2,230	44.0	15.0	7.5
	57	2,320	44.0	15.0	7.5

TABLE 2. Results of raising underyearlings in experimental ponds ("Ropsha," 1963)

Pond	Initial		Final		Mortality, %
	No.	Average weight, g	No.	Average weight, g	
Intermediate 5a	357	0.193	271	11.46	24.1
Intermediate 6a	299	0.194	289	10.90	3.4
Intermediate 6b	351	0.22	261	10.98	25.6
Intermediate 3	409	0.241	331	30.50	18.8
"Arnold"	428	0.294	382	41.10	10.8
Spawning 6	211	0.297	114	15.20	46.0

Six of the 12 sib-groups produced for regression analysis were stocked into intermediate pond No. 3, and six in the "Arnol'd" pond. Raising ponds with more or less similar conditions were chosen but it was impossible to ensure completely uniform conditions. The underyearlings were raised on natural food. An attempt to feed them an artificial food supplement failed, as the fish would not eat it. The results of raising are presented in Table 2. At autumn recovery, 20 underyearlings were taken at random from each sib-group for processing, and to obtain initial data for calculating the heritability of the traits being studied.

Heritability can be estimated by various methods, all of which are based on measuring the degree of similarity between specimens linked by affinitive relations: parents — progeny, brothers — sisters (sibs), half brothers—half sisters (half-sibs), and so on.

As noted in the foregoing, we used two methods of determing h^2. The simplest method of estimating is by regression of progeny on one parent or on the parental mean (Reeve, 1953; Lerner, 1958; Falconer, 1960).

Regression expresses the functional relation between the value of the trait in parents and their progeny. The regression coefficient (b) expresses the change in a trait of the progeny produced by a unit change in the parents (Plokhinskii, 1961) as a fraction of unity. The index of heritability, according to Falconer (1960) and Rokitskii (1964 b) is calculated by the following formulas: $h^2 = 2b$ (when regression is estimated by one parent) and $h^2 = b$ (when regression is estimated by two parents). The regression coefficient for rectilinear relationships is determined by the equation $y = a + bx$.

We determined heritability by regression of the progeny of male parents.

Analysis of variance is a more precise and sensitive method for the determination of heritability. It has been used by many investigators (Lush, 1939, 1945; LeRoy and Griihn,1956; LeRoy and LOrtsher, 1955; LeRoy, 1962; Falconer, 1960; Plokhinskii, 1960, 1961, 1962; Rokitskii, 1964a, 1964b; and others). Analysis of variance allows us to draw conclusions about heritability without studying the parents, and gives a very accurate estimate of h^2. It makes possible the breakdown of the overall variance into its principal components, and it isolates environmental factors.

We analyzed families of sibs and half-sibs, estimating heritability by constructing a hierarchical, 2-factor distribution matrix in which females were taken as gradations of the first variable, and males crossed with the females were the gradations of the second variable. Phenotypic variance was broken down into observable components by the method described by Falconer (1960):

Sources of variation	Degree of freedom	Mean square	Structure of variance
within females	d – 1	MS_D	$\sigma^2_w + k\sigma^2_S + sk\sigma^2_D$
within males (in progeny from one female)	d (s – 1)	MS_S	$\sigma^2_w + k\sigma^2_S$
within sib-groups	sd (k – 1)	MS_W	σ^2_W

[illegible] MSD, MS, MS [illegible] T [illegible] $\sigma^2_D, \sigma^2_S, \sigma^2_w$ [illegible] T [illegible] MS_D [illegible] 3 [illegible]; MS_S [illegible] 2 [illegible]. O [illegible] F [illegible] σ^2_T:

$$\sigma^2_D = \frac{1}{sk}(MS_D - MS_S)$$

$$\sigma^2_S = \frac{1}{k}(MS_S - MS_W)$$

$$\sigma^2_W = MS_W$$

$$= \sigma^2_P = \sigma^2_D + \sigma^2_S + \sigma^2_W$$

[illegible] σ^2_T [illegible].

H [illegible]. F [illegible]

$$h^2 = \frac{\sigma^2_A}{\sigma^2_T}$$

[illegible] σ^2_w [illegible] T [illegible] T [illegible] "[illegible]" [illegible] "fathers." H [illegible], [illegible] σ^2_D [illegible] σ^2_S [illegible] T [illegible] h^2 [illegible]:

$$h^2_D = \frac{4\sigma^2_D}{\sigma^2_T} \text{(for estimation by females),}$$

$$h^2_S = \frac{4\sigma^2_S}{\sigma^2_T} \text{(for estimation by males),}$$

$$h^2_{S+D} = \frac{2(\sigma^2_D + \sigma^2_S)}{\sigma^2_T} \text{(for estimation by males and females together).}$$

We estimated the error for h^2 by the usual method (Falconer, 1960).

Results

Table 3 presents data on heritability of some quantifiable, morphological traits of Ropsha hybrids, as estimated on fathers by regression analysis of progeny and by analysis of variance.

TABLE 3. Heritability of quantifiable, morphological traits of hybrids estimated by various methods

Trait	Regression	Analysis of variance		
	by fathers $h^2 \pm m$	by males $h_S^2 \pm m$	by females $h^2 \pm m$	by males and females h^2 [illegible]
Number of branching rays in dorsal fin	0.458 ± 0.120	0.355 ± 0.044	0.913 ± 0.149	0.634
Number of scales in lateral line 1.1:				
from left	0.014 ± 0.071	0.706 ± 0.060	0.138 ± 0.0035	0.422
from right	0	0.538 ± 0.051	0.103 ± 0.0028	0.320
Average	–	0.622	0.120	0.371
Number of vertebrae in trunk	0.140 ± 0.088	0.674 ± 0.058	[illegible] 0.086	0.578
Total number of vertebrae	0.098 ± 0.083	0.900 ± 0.068	0.396 ± 0.081	0.648

Eleven families, each consisting of 15-20 descendants and a male parent, were included in the estimation of heritability by regression. Analysis was made of a small number of families and offspring, resulting in a major error in the calculations. The heritability coefficient of 0.458 reckoned by the number of branching rays in the dorsal fin proved reliable. It approximates the h^2 value estimated by analysis of variance. Heritability of the number of scales in the left and right lateral lines was estimated separately. The values obtained are low and insignificant. Similar insignificant results were yielded by the analysis of total number of vertebrae and of the number of vertebrae in the trunk.

The heritability of the same traits as determined by 3 formulas of analysis of variance is more significant. There is a fairly large difference observed between the h^2 values in males and females. An analysis of the causes of this difference is given below. In only one case, that of the number of branching rays in the dorsal fin, is h^2 from females to progeny considerably (almost 3 times) higher than heritability from males. A higher heritability from males is observed for other traits. Because considerably more males than females were included in the estimation of heritability, the traits obtained on the basis of studying half-sibs by males have narrower confidence limits and are, consequently, more accurate. Fair agreement is observed in the values of heritability coefficients for the number of scales in the lateral line on the left and right sides of the body.

Discussion

The heritability coefficients for the number of vertebrae, which were determined on "fathers" by progeny regression, 0.140 and 0.098 *(see* Table 3), were low and insignificant. This is due first to the small number of families and offspring studied, and second, to the many anomalies in the structure of the vertebral column in underyearlings obtained from a Novgorod hybrid female. These anomalies consisted of strong concrescence and even complete fusion of vertebrae, which hampered enumeration and created many errors. These anomalies were found in 50% of the underyearlings studied, and their possible causes could be either a temperature drop or the effect of other unfavorable environmental factors during embryonic development (Kirpichnikov and Lebedeva, 1953), or defective eggs.

Anomalies in structure of the backbone also disrupted the normal arrangement of scales. A high degree of vertebral fusion resulted in chaotic distribution of the scales on the body sides, making it impossible to count the scales in the lateral line. Sometimes, there were no lateral scales or apertures from the beginning point of vertebral fusion. This also was apparently the main cause of the nonsignificance of heritability of number of scales.

Voroshilov (1964) points out the nonsignificance of heritability of different features in hens, as estimated by regression analysis. He believes this to be the fault of small sample size. The 0.458 heritability of the number of branching rays in the dorsal fin in Ropsha carp is significant. We feel this is due primarily to the highly accurate count of the number of rays. Then too, regression analysis gives more or less significant results only for traits with high heritability. In using regression analysis to determine heritability, the variability contributed by environmental factors cannot be completely removed from the total variability.

The analysis of variance presented another picture. The data on heritability of morphological traits show that for almost all these traits there is a fairly wide difference between the heritability from males and that from females. Heritability from males is generally higher, with the exception of heritability of the number of rays in the dorsal fin, which is determined by females. Its value (0.913) from females is considerably higher than its value from males (0.355). The high matrocliny of this trait established earlier by Kirpichnikov (1949) may be the cause of this, the validity of which assumption may be checked by estimating from the 1964 data the heritability of the number of branching rays in the dorsal fin.

High coefficients of heritability were obtained for the number of vertebrae in the trunk, and for their total number. Heritability from males was higher. Apparently the females had a lower genotypic variability owing to the greater homogeneity of their origin. They were taken from strain M, which had been moderately inbreeding, while the males were chosen from 3 strains of Ropsha hybrids. Their genotypic variability ought to be high, and consequently heritability from them should also be high. McLaren and Michie (1955) report a high nonheritable variability of the number of vertebrae in inbred mice which they explain as being due to the greater sensitivity of inbred animals to environmental effects. Factors influencing the physiology of a mother during pregnancy play a large role in the variability of vertebrae number. In fish, the paratypic variability of the

[illegible]

W[illegible] B[illegible] (1948) [illegible] method, [illegible] 0.74. B[illegible]

W[illegible] T[illegible] 150-200 [illegible] T[illegible] ([illegible]) [illegible] C[illegible], [illegible] A[illegible] - [illegible] T[illegible] - [illegible] S[illegible] R[illegible] objective [illegible]

CONCLUSIONS

1. T[illegible] (0.634), [illegible] (0.648), [illegible] (0.578); [illegible] (0.371) [illegible].

2. M[illegible] T[illegible].

W[illegible].

3. T[illegible] - [illegible].

B[illegible]

P[illegible] R[illegible]

B[illegible], D. K. O[illegible] (S[illegible]

P C V S T E A S).– Izvestiya Sibirskogo Otdeleniya AN SSSR, N . 10. 1962.

K ir chnik ov, V. S. Amurskii sazan na S SSSR (T "E C i' N USSR). —Rybnoe Khozyaistvo, N . 8. 1949.

Kirpichn ik ov, V. S. Vyvedenie novoi severnoi gibridnoi porody karpa (R N N B C). —T soveshchaniya po rybovodstvu, M . 1957.

K ir chnik ov, V. S. Geneticheskie metody individual'nogo otbora v karpovodstve (G M I S C B). —DAN SSSR, V . 121, N . 4. 1958.

K ir c hnik o v, V. S. Geneticheskie metody selektsii ryb (G M F S). —Byulleten' Moskovskogo Obshchestva Ispytatelei Prirody, V . 64, N . 1. 1959a.

Kirpichnikov, V. S. Gibridizatsiya karpa s amurskim sazanom primenitel'no k zapadnym oblastyam SSSR (H C "E C " W R USSR). —T V nauchnoi konferentsii po izucheniyu vnutrennikh vodoemov Pribaltiki, M . 1959b.

Kir c hn ik ov, V. S. Geneticheskie metody selektsii gibridov ryb (G M S F H). —T soveshchanii po otdalennoi gibridizatsii rastenii i zhivotnykh, M . 1960.

K ir chnik ov, V. S. Tseli i metody selektsii karpa (G M C S). I C .

K ir chnikov, V. S. L.I. L eb ed e v . K probleme povysheniya zimoustoichivosti segoletok karpa, amurskogo sazana i ikh gibridov (R Winterhardiness Underyearling C , "E C " H). —T Vsesoyuznogo Gidrobiologicheskogo Obshchestva, V . 5. 1953.

K r dt, A. G. A. M. S akha r o . Biotekhnika fermentativnogo obeskleivaniya ikry karpa (T Biotechnique E C E C). —Rybnoe Khozyaistvo, N . 7. 1963.

Pl o kh kii, N.A. Dispersionnyi analiz (A V). N . 1960.

Plokh inskii, N.A. Biometriya (B). N . 1961.

Pl o kh k i i, N.A. Nasleduemost' po ottsam (H F). N . 1962.

R ok skii, P. F. Biologicheskaya statistika (B S). M . 1964a.

R ok i, P. F. Voprosy genetiki i selektsii (T P G S). M . 1964b.

S t ak , G.A. A.A. S sk . K voprosu o vliyanii uslovii sredy na nasleduemost' priznakov (T E E H T). —Izvestiya Sibirskogo Otdeleniya AN SSSR, N . 12. 1962.

V hil v, N. V. Nasleduemost' priznakov yaichnoi produktivnosti u kur pri chistoporodnom razvedenii i skreshchivanii (T H E P T B P -B H C). — Issledovaniya po Genetike, N . 2, LGU. 1964.

Publications in Other Languages

Berge, S. Genetical Researches on the Number of Vertebrae in the Pig. — J. Anim. Sci. , Vol. 7, No. 2. 1948.

Falconer, D. S. Introduction to Quantitative Genetics. Edinburgh and London. 1960.

Kirpitschnikow,V.S. Die genetischen Methoden der Selektion in der Karpfenzucht. —Z. Fisch. , Nos. 1-3, Berlin. 1961.

Lerner, L. M. The Genetic Basis of Selection. —New York, J. Wiley and Sons. 1958.

LeRoy, H. L. Ein korrigierter Heritabilitätskoeffizient. — Z. Tierzücht. Zachtbiol. , Vol. 77, No. 3. 1962.

LeRoy, H. L. and R. Grühn. Betrachtungen zur Heritabilitatsbestimmung auf Grund der Geschwisterähnlichkeit unter Berücksichtigung spezieller Strukturverhältnisse im Analysenmaterial.— Z. Tierzücht. Zachtbiol. , Vol. 68, No. 2. 1956.

LeRoy, H. L. and H. Lörtscher. Die wichtigsten Methoden der Heritabilitätsbestimmung. —Z. Tierzücht. Züchtbiol., Vol. 66, No. 1. 1955.

Lush, I. L. Method of Measuring Heritability of Individual Differences among Farm Animals. —Proc. 7th Intern. Congr. of Genetics. 1939.

Lush, I. L. Animal Breeding Plans. —Iowa State Coll. Press. 1945.

Lush, I. L. Heritability of Quantitative Characters in Farm Animals. Proc. 8th Int. Congress Genetics. —Hereditas, Suppl. 5. 1949.

Mason, I. L. and A. Robertson. The Progeny Testing of Dairy Bull Levels of Production. —J. agric. Sci. , Vol. 47, No. 4. 1956.

McLaren, A. and D. Michie. Factors Affecting Vertebral Variation in Mice. 2. Further Evidence on Intra-Strain Variation. —J. Embryol. exp. Morph., Vol. 3, No. 4. 1955.

Moav, Rom and G. W. Wohlfarth. Breeding Schemes for the Genetic Improvement of Edible Fish. —Prog. Rep., Jerusalem. 1963.

orley, F. H. W. Selection for Economic Characters in Australian Merino Sheep. VII. Interactions between Genotype and Plan of Nutrition. — Aust. J. agric. Res., Vol. 7, No. 2. 1956.

Reeve, E. C. R. Studies on Quantitative Inheritance. III. Heritability and Genetic Correlation in Progeny Tests Using Different Mating Systems. —J. Genet., Vol. 51. 1953.

Robertson, A. Genetics and Improvement of Dairy Cattle. —Agric. Rev., Vol. 2, No. 8. 1957.

Warner, N. I. A Method for Estimating Heritability. —Agron. J., Vol. 44, No. 8. 1952

Wright, S. The Relative Importance of Heredity and Environment in Determining the Piebald Pattern of Guinea Pigs. —Proc. Nat. Acad. Sci. , No. 6. 1920.

MORPHOLOGICAL TRAITS OF HYBRIDS OF CARP (CYPRINUS CARPIO L.) AND TENCH (TINCA TINCA L.)

R. M. Viktorovskii

Among the numerous hybrid combinations of Cyprinidae,both those obtained by man and those encountered in nature, the carp-tench hybrid has received nearly no attention. Kuzema (verbal communication) crossed carp with tench for the first time at the beginning of the 1930's and raised the hybrids to the stage of underyearlings. Later, Nikolyukin also succeeded in obtaining hybrids of these species, and established the viability of these hybrid larvae. Nikolyukin's attempt to raise hybrids in ponds in his experiments failed, and the causes of death were not clarified.

In 1963, we succeeded in obtaining and raising hybrids of these species. This article describes their basic morphological traits and compares them with the parent species.

The eggs of a scaly female "Ropsha" carp (strain B), homozygous in the main scale factors (Kirpichnikov, this collection) were utilized for obtaining hybrids. The eggs were fertilized with a mixture of milts of 2 tench males; both eggs and milt were obtained by means of a pituitary injection. The eggs were cleaned by the method elaborated by Konradt and Sakharov (1963), and were incubated in crystallizing basins in which the water was replaced twice a day and the dead eggs removed daily.

It is impossible to make an exact comparison of the survival rate of carp and hybrid eggs during embryogenesis, because different portions were used for crossings; moreover, the carp eggs happened to be of inferior quality. Only 581 of 1,000 eggs hatched hybrids. Thus, egg mortality, including the unfertilized eggs, was 41.9%. If the percentage of fertilization is estimated as 85-90, the actual mortality rate did not exceed 30%. It is somewhat higher in carp eggs (52.9% including unfertilized eggs).

Over 1,400 hybrid larvae were obtained in the experiment. On 26 June 1963, they were placed into a 400 m^2 experimental pond at "Gostilitsy" in the Leningrad Region for raising. On 24 October 1963, there were 92 hybrids recovered from this pond. The data on survival rate here are not typical, because the pond became very shallow in autumn and many fish may have been destroyed by birds. Because the available data is not sufficient for comparing the growth rate of hybrids and carp, this problem requires further investigation. Although carp stocked in this same pond in the middle of the summer surpassed the hybrids, attaining an average weight of 67g, the latter also grew satisfactorily. In a sample of 20 specimens, weight varied from 26 to 61g, and the average weight was 46.4g. The pond produced 110 kg/ha of hybrids.

To study the morphological traits, 21 underyearling hybrids were fixed in formalin and compared with underyearling "Ropsha" carp with an average weight of 27.6g. These underyearlings had been obtained from the same female and a scaly carp male (4-way hybrid), homozygous in scale factor S (the carp underyearlings had been reared in another pond). Because a tench of the same age as the carp and hybrids weighed 1g less, fish of the same age could not be compared. Instead, we compared 1+ tench that weighed an average of 40 g. The data obtained from this comparison of carp and tench traits are quite similar to those found by Berg (1949).

We studied several discontinuous and continuous traits in carp, tench, and their hybrids (Tables 1 and 2). For these, the hybrid indexes were calculated by the formula suggested by Hubbs et al. (1943):

$$I = \frac{M_g - M_1}{M2 - M5}$$

where M_1 and M2 are mean values of a trait for the male and females of the parent species, and Mg is the same for hybrids.

TABLE 1. Discontinuous traits of carp, tench-carp hybrids, and tench

Trait	Carp (n = 30)	♀ carp X ♂ tench (n = 21)	Tench (n = 30)	Hybrid index (I)	Significance of difference between hybrid and carp (t_{diff})	Significance of difference between hybrid and tench (tdiff)
Number of:						
vertebrae	36.50 ±0.18	35.95 ± 0.16	38.94± 0.16	0	2.2	13.4
gill rakers in first arch to the left. .	22.90 ± 0.25	20.12 ± 0.21	13.47 ±0.16	29.0	8.7	26.8
branched rays in D	18.14 ± 0.18	16.73 ± 0.34	7.90 ± 0.09	14.0	3.7	25.8
branched rays in A	5.00	5.00	7.80 *0.12	0	0	23.5
scales in lateral line	37.85 ± 0.13	[illegible] ± 0.16	103.05 ± 0.54	2.6	8.0	124.0
rows of scales above lateral line	6.00	8.07 ± 0.05	30.42 ± 0.17	8.2	4.1	189.0
rows of scales below lateral line	6.00	7.83 ± 0.12	20.82 ± 0.20	12.4	15.2	820. 0

Externally, carp-tench hybrids are so similar to carp that they can be distinguished from the latter only by a fairly careful examination (Figure 1). At a cursory glance they are distinguished by their greenish color and slimy, slippery, shiny body surface.

Comparison of discontinuous traits of hybrids and carp revealed significant differences in the number of branched rays in the dorsal fin. In hybrids, this number varies from 11 to 19 and is modally only 16-18, while in the carp investigated by us it varied from 16 to 20 and was 17-19 modally. Still more distinct differences were found between carp and hybrids in the number of gill rakers: 19-21 in hybrids, and 20-25 in carp. We found a small but significant difference in the number of scales in the lateral line. The clearest distinctions were found in the number of rows of scales above and below the lateral line. Hybrids had 7-9 scale rows above the lateral line and 7-10 below it. All the carp we examined

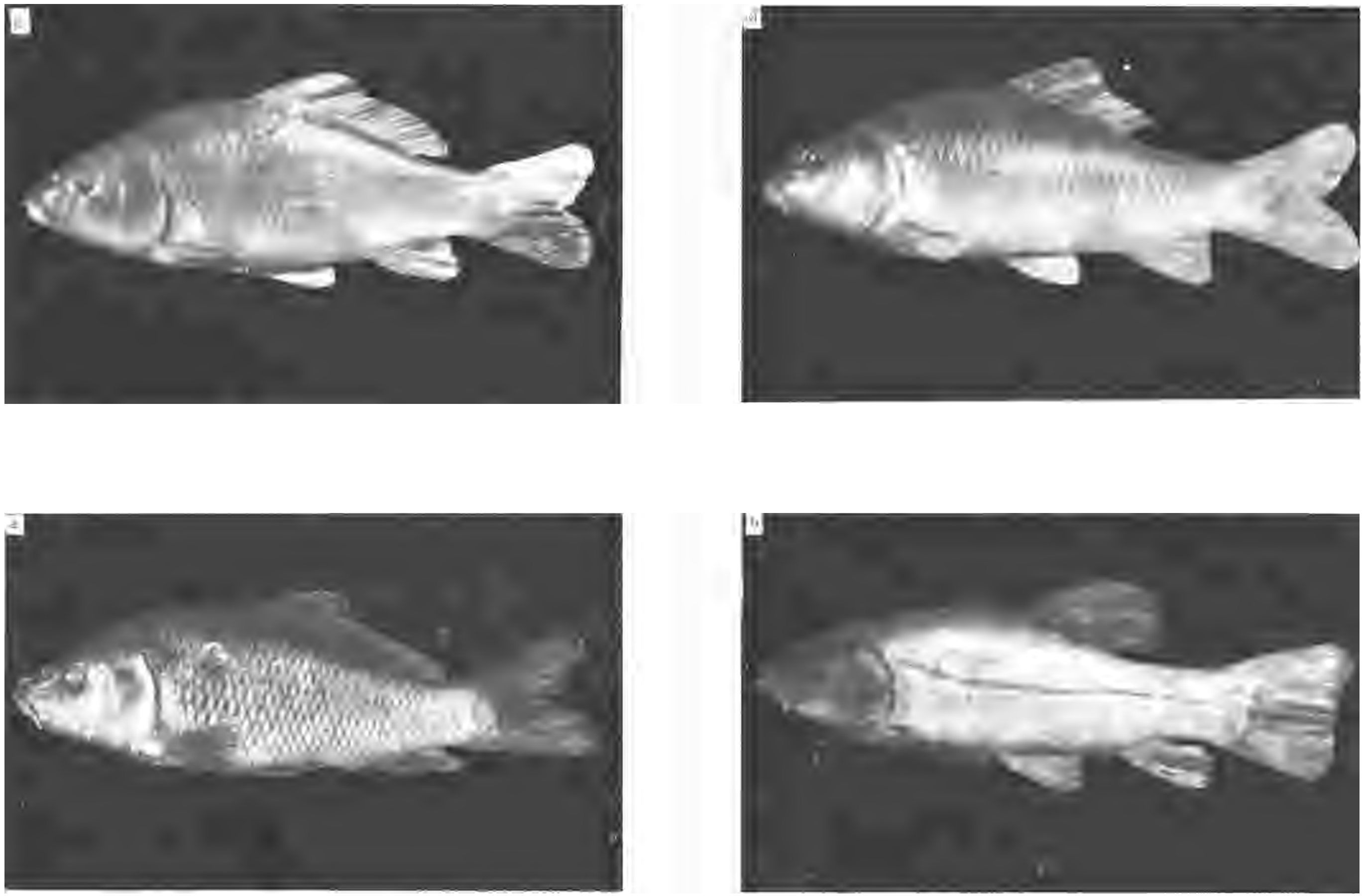

FIGURE 1. Habitus of carp (a), of tench (b), of typical carp-tench hybrid (c), and of carp-tench hybrid with short dorsal fin (d)

TABLE 2. Continuous traits of carp, carp-tench hybrids, and tench

Trait (in % of body length, I)	Carp (n = 30)		carp X tench (n = 21)		Tench (n = 21)		Hybrid index (I)	[illegible]	[illegible]
	mean value	variation limits	mean value	variation limits	mean value	variation limits			
Maximum body height	34.04 ± 0.16	32.2 ‾35.6	33.91 ± 0.21	32.0- 35.4	30.53 ± 0.08	29.0- 30.8	3.5	0.5	15.8
Maximum body breadth . . .	18.81 ± 0.16	16.5-21.0	21.00 ± 0.15	19.7- 22.7	19.00± 0.10	17.9- 19.9		10.0	11.2
Minimum body height	11.98 ± 0.08	11.3-13.3	12.19 ± 0.07	11.4-13.4	14.45 ± 0.05	13.9-15.1	8.5	1.9	32.0
Length of head	32.79 ± 0.15	30.9-34.4	29.73_± 0.10	28.9- 30.7	26.60 ±0.10	25.1 27.6	50.0	16.7	22.3
Antedorsal distance . . .	52.74 ± 0.20	50.1-54.6	50.05 ± 0.19	48.7-52.2	54.87± 0.24	53.0- 59.0	–	9.8	16.0
Postdoral distance . . .	18.67 ± 0.20	16.3-21.1	22.90 ± 0.68	19.7- 29.5	35.31 ± 0.24	32.7- 38.2	25.0	6.0	17.1
Length of D . .	35.25± 0.21	33.2-38.0	33.55 ± 0.40	26.7-35.5	15.22± 0.12	14.0- 17.0	8.0	3.8	44.7
Height of D as % of length of D	52.26 ± 0.63	44.8-59.5	61.23 *0.66	57.0- 68.0	170. 80 ± 2.08	48.0- 193.0	7.0	9.8	51.0
Relation of length of intestine to length of body	2.36± 0.15	2.1-2.6	1.92 ± 0.14	1.6- 2.2	1.00± 0.01	1.0- 1.2	21.6	68.0	76.0

had 6 scale rows above and the same number below the lateral line (according to Berg 5–6 rows). Thus the number of longitudinal rows of scales, especially those above the lateral line, should be considered the most reliable trait for distinguishing hybrids from carp.

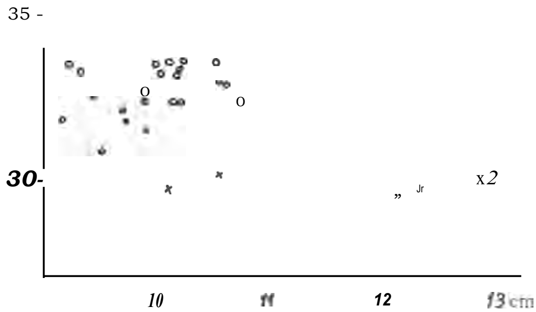

FIGURE 2. Relation between length of body and length of head (in lo to body length) in: 1-carp underyearlings and 2- carp-tench hybrids (Ropsha, 1963).

There are distinct differences between hybrids and parental species in the structure of pharyngeal teeth. In all the carp we examined, the formula of pharyngeal teeth was 1.1.3–3.1.1, but in tench it varied considerably: 4–4, or 4–5, or 5–4, rarely 5–5. An overwhelming majority of hybrids had double-row teeth with the formula 1.3–3.1. Formulas 1.4–3.2, 3–3.1 and 3–3 were encountered in one specimen each. It should be noted that in fish with single-row teeth or partly single-row pharyngeal teeth, a small tubercle took the place of second row teeth.

Both hybrids and carp had two pairs of barbels. In hybrids the last of the spiny rays of the dorsal and anal fins was soft at the end, and in contrast to those in carp, somewhat less serrate.

In the hybrids we produced, the number of vertebrae appeared to be even somewhat smaller than in carp, although tench have many more vertebrae. This probably results from using male carp with too small a number of vertebrae.

It is evident from Table 2 that in most of the continuous traits there were significant differences between the hybrid and the initial forms. There were no differences between hybrids and carp merely in indexes of the maximum and minimum heights of the body. Note also that the body-breadth differences among carp, tench, and hybrids may be due to a better condition factor in hybrids.

It is difficult to establish differences in the length of the head between hybrids and carp because the hybrids were a little larger than the carp. We have tried to express graphically (Figure 2) the relation of head length to body length for both groups of fish. It appears that differences between carp and hybrids in the relative length of head are not determined by differences in their dimensions. It is evident from Figure 2 that the head length of hybrids is intermediate between the parent species.

T[illegible] 3 [illegible] (B[illegible], 1949). T[illegible] W[illegible] 11 [illegible] (F[illegible] 1, [illegible]). T[illegible]:

L[illegible] D [illegible] % [illegible] P[illegible]
B[illegible] B[illegible]

TABLE 3. Coefficient of variability of meristic and plastic characters of carp, carp-tench hybrids, and tench

	Carp	♀ carp X ♂ tench	Tench
Meristic characters			
Number of:			
vertebrae	2.64	1.97	2.31
rakers in first gill arch from the left	5.73	4.27	6.40
branched rays in D	5.55	9.40	6.10
branched rays in A	0	0	8.30
scales in lateral line	2.70	2.61	4.15
scale rows above lateral line	0	4.14	4.44
scale rows below lateral line	0	9.70	7.35
Plastic characters			
In % to body length (l):			
maximum body height	2.64	2.63	1.48
maximum body breadth	4.85	3.18	2.74
minimum body height	3.84	2.60	1.88
head length	2.58	1.42	4.84
antedorsal distance	2.09	1.60	2.41
postdorsal distance	5.78	12.80	3.77
length of D	3.22	5.14	4.85
Height of D as % of length of D	6.57	4.87	6.69
Relation of intestine length to body length	6.47	6.98	3.64

T[illegible] C[illegible] ([illegible]) [illegible]. O[illegible], N[illegible] (1952) [illegible]. T[illegible] C[illegible] [illegible].

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morphological traits of hybrids toward carp. This problem requires additional investigations.

Carp tench hybrids may prove valuable also for pisciculture because of their good growth rate, particularly if they turn out to be sterile.

CONCLUSIONS

1. Viable hybrids of high growth rate were obtained when crossing "Ropsha" carp females and tench males.

2. In many diagnostic traits, the hybrids are much closer to carp, even being carp in some traits.

3. Investigation of several meristic and plastic traits of hybrids showed many significant differences between them and carp. It can be considered proved that the fish obtained is a true hybrid.

4. Hybrids are less variable than carp in most of the traits investigated. Several characters, including the number of horizontal rows of scales, are an exception. This is partially so because one hybrid fish differed greatly from the others, and partially because of the complete invariance of some traits in carp.

Bibliography

Publications in Russian

B e r g, L. S. Ryby presnykh vod SSSR i sopredel'nykh stran (Freshwater Fishes of the USSR and Adjacent Countries). Part 2. Moskva-Leningrad. 1949.

Kirpichnikov, V. S. Pervye itogi i zadachi rabot po organizatsii plemennogo dela na Severo-Zapade RSFSR (Preliminary Results and Further Tasks of the Organization of Selective Breeding in the North-western RSFSR). In this Collection.

Konradt, A. G. and A. M. Sakha r o v. Biotekhnika fermentativnogo obeskleivaniya ikry karpa (The Biotechnique of Enzymatic Cleaning of Carp Eggs). —Rybnoe Khozyaistvo, No. 7. 1963.

Nik olyuk in, N. I. Mezhvidovaya gibridizatsiya ryb (Interspecific Hybridization of Fish). Saratov. 1952.

Publications in Other Languages

Hubbs, C.L., B.W. Walker, and R.E. Johnson. Hybridization in Nature between Species of American Cyprinodont Fishes. —Contr. Lab. vertebr. Biol. Univ. Mich., Vol. 23. 1943.

PRELIMINARY RESULTS AND FURTHER TASKS OF THE ORGANIZATION OF SELECTIVE BREEDING IN THE NORTHWESTERN RSFSR

V. S. Kirpichnikov

Introduction

Recently, pond fish breeding in the Pskov, Novgorod, and Leningrad regions has been developing rapidly. Ten years ago commercial production was 1,500-2,500 centners a year, but by 1964, it was over 12,000 centners. Plans in 1964 call for a yield of 20,000 centners of pond fish in the greater RSFSR region. At least 16,000 centners are to be raised in the three aforementioned regions. To meet the demands of Leningrad and other northwestern cities for live fish, the rapid increase of production should be maintained in the future.

Recently, large fish breeding ponds with a total area of over 1,000 ha became operative in the Leningrad Region. These are the "reservoirs" along the Staroladozhskii canal, which had previously supplied the canal with water. The construction of a large carp farm near Ropsha in the vicinity of Leningrad is nearing completion, and a fish fattening farm is being completed in the Kingissep District. In the Novgorod Region, new commercial carp farms are under construction, and the construction of a hatchery-nursery farm in the Pskov Region must be started in the near future. At the same time, we are increasing the productivity of the ponds of all the old farms, many of which have been in existence 30 years.

Along with pond pisciculture, the use of lakes for fattening pond fish is expanding. The development of chemical methods of controlling trash and predatory fish in ponds, using polychlorpinene (Burmakov, 1958, 1963), now makes it possible to use these for raising carp and Coregonus peled. The need for carp larvae for stocking the lakes will increase annually; several million larvae will probably be needed in the next 2-3 years. The artificial method of producing larvae elaborated in 1962 and 1963 (Konradt and Sakharov, 1963) allows us to avoid constructing additional spawning ponds, even as the expansion of lake pisciculture increases the number of carp spawners needed for producing eggs and larvae.

In the northwest, plankton-eating Coregonus peled is successfully raised together with carp (Golovkov and Kuz'min, 1963), and experiments have been conducted on the introduction of the phytophagous grass carp and other species. However, for the near future, carp remains the basic object of the pond and fattening lake farms. Meanwhile, carp breeding in the northwest, as in many other districts of the USSR, is obviously in an unsatisfactory state. The main trouble is that selective breeding work has been quite neglected. In the first postwar years, the northwestern fish farms started raising 1st generation hybrids of carp and "eastern carp" (Cyprinus carpio haematopterus). These hybrids hibernate better than carp and grow well in the climate of the northwest (Kirpichnikov, 1959b).

Inadequate attention to hybridization gradually resulted in contamination of the spawning stocks with 1st and 2nd generation hybrids. No selective breeding of carp and "eastern carp" was carried out; the spawning stocks soon became mixed and began to degenerate in all the fish farms. The fact that Kursk hybrids and new consignments of "eastern carp" were brought to the fish farms of the Pskov Region contributed greatly to this. They soon mixed with the spawners that had already been there, and now it is impossible to sort out the breeds of spawners at any of the pond fish farms.

The organization of selective breeding work in pond farms of the northwest, therefore, became our most important task. It was necessary to raise breeding stock to replace the existing spawners in all the pond carp farms. We chose the northern hybrid carp, a breed group that was created recently at Ropsha near Leningrad, by hybridization of carp and "eastern carp," and a subsequent selection of hybrids (Kirpichnikov, 1959a). Northern hybrid spawners were brought from Ropsha to two fish farms, "Yazhelbitsy" in the Novgorod Region and "Opochka" in the Pskov Region.

Replacement of the spawning stock in the Ropsha state fish-farm began in 1962. Northern hybrid spawners were transferred there from the "Ropsha" Experimental Station in 1962 and 1963. In subsequent years, all the underyearlings in the Ropsha farm were obtained from hybrid brood stock.

Two strains of northern hybrids, backcross and 4-way (B and M), were used for the breeding stocks.

Backcross hybrids were produced by crossing 2nd generation hybrids (Novgorod selection) with "eastern carp," consequently, getting about 75% "eastern carp" inheritance. They winter better than other hybrids, although not so well as the "eastern carp; they are very hardy; their growth to one year is rapid, but slows down somewhat in the second year. These are streamlined, cylindrical fish which resemble "eastern carp" bodily.

The 4-way hybrids, obtained by crossing 2nd generation Novogorod hybrids with 2nd and 3rd generation hybrids of the Kursk line, have about 60% "eastern carp" inheritance. They are less winter hardy than strain B hybrids, although they winter better than carp. Strain M hybrids lag somewhat behind the backcross hybrids in growth rate to one year of life, but in their 2nd year, their growth rate surpasses the latters'. The body of 4-way hybrids is intermediate between that of carp and "eastern carp"; externally, they resemble 1st generation hybrids.

Our results and the data of Andriyasheva's experiments (this collection) show that crossing the hybrids of these 2 strains leads to good results. Heterosis is manifested largely in survival rate and becomes apparent in the progeny. Thus, in those fish breeding farms that received spawners from Ropsha, we tried to reproduce both strains (alternating them by years) so that we could cross them subsequently.

In outlining our future program we must consider 4 essential questions which affect the development of selective breeding in the northwestern RSFSR:

1. How should selective breeding be organized in carp farms of the USSR?
2. What has resulted from the attempt to organize selective breeding work according to the scheme we chose for the northwestern RSFSR ?
3. What are the fishery qualities of northern hybrids?
4. What are the future tasks in this field?

We elucidate these questions in succession in this article. Two special papers report in detail on the work in "Yazhelbitsy" and in "Opochka" (Zonova and Shatrova; Petrov and Romanova, in this collection). Finally, a separate study (Romanova, Petrov, and Zabegalina, this collection) presents material on fishery characteristics of the northern hybrids. These materials are greatly needed, primarily for determining favorable and unfavorable qualities inherent in hybrids, and how selection work on northern hybrids in Ropsha should be done in future.

The programs at "Yazhelbitsy" and "Opochka" were realized only with the assistance of the fish-combines management and the active participation of the fish farms' pisciculturists. On behalf of the authors of the 4 articles on the organization of selective breeding in the northwest, I express our sincere gratitude to everyone who helped us in our work.

Organization of selective breeding in carp pond farms

In many branches of animal husbandry, and particularly in plant growing, commercial hybridization has been more and more widely applied. Inbred lines, strains, and breeds are crossed only to obtain 1st generation hybrids for the purpose of using their hybrid vigor. No progeny is obtained from these heterotic hybrids, because only the parent lines or strains are bred. This makes it possible to free many fish farms from selective breeding.

Hitherto in carp breeding there has been no division of function between selective breeding farms and commercial farms. According to the old specifications, all the inclusive fish farms should have not only parent, but also 1st generation spawners. Actually, however, the overwhelming majority of carp farms have no selective breeding experts among the pis ciculturists ; thus selective breeding was completely neglected in many places.

Not long ago, we suggested that selective breeding work in carp pond farms should be organized according to a new principle (Kirpichnikov, 1960; Golovinskaya, 1962), the essence of which is as follows:

1) A few selective farms produce new breeds of carp.
2) These selective breeding farms begin by buying pure-strain spawners and, after obtaining progeny from them, raise spawners of their own. Every such farm serves a district or region where there are several (10 or more) pond farms, and plans for a quota of 1st generation and parent stock, in addition to raising underyearlings. If they have forage ponds, they will also raise marketable fish.
3) The inclusive pond fish farms and fish hatcheries rejuvenate their spawner stock periodically by buying spawners in the selective breeding farms but they are completely exempted from raising their own 1st generation spawners. The only breeding work at these farms is the selection of breeders for spawning.

This scheme of organizing selective breeding has great advantages. Discontinuance of raising spawners in commercial fish farms and in a number of fish raising stations is profitable in several respects. First, it eliminates the need for special 1st generation spawner ponds (except for the small area required for maintenance of spawners). No less important is the fact that workers in fish farms where there is no raising of 1st generation spawners do not have to be familiar with principles of breeding. Selective breeders should work only at farms where spawners are raised. The production of special sets of highly productive groups of spawners is, perhaps, the greatest advantage. Females and males can be taken from different strains to produce maximum heterosis in the progeny.

The great fecundity of carp, as well as the fairly long "service" of their spawners (5-8 years), make possible the raising of comparatively small numbers of spawners in this breeding work plan. Spawners need not be transferred from breeding farms to commercial fish farms every year, and only a part of the stock is needed to replace the old fish, sterile fish, and so on.

At the beginning of this article, we mentioned an artificial method of fertilizing and raising carp eggs by cleaning them with the enzyme hyaluronidase (Konradt and Sakharov, 1963). This suggests another, simplified variant of organizing selective breeding.

According to this variant, the breeding fish farms for spawners would have a capacity population increased by the number of mature spawners, but they would raise the 1st generation only to replenish their own breeding stocks. Each breeding farm would have a hatchery with a large number of Weiss incubators and pools for keeping the larvae for 2-3 days. The larvae and some of the eggs would be transported to commercial fish farms. After pre-raising in fingerling ponds, the larvae would be transferred to raising ponds to produce the required number of underyearlings and yearlings. No commercial pond farms would keep any spawners or do any spawning work.

This variant has not yet been tested but it certainly may be very profitable in several regions of the USSR. Its main advantage is the elimination of transporting spawners from fish breeding farms to commercial fish farms. Production of larvae by artificial methods protects them from infection with such parasites as branchial Trematoda, I c h thy o ph thir ius, T r i chod in a, and others. The brood stock have no contact with their progeny and, therefore, the danger of epizootics decreases greatly.

The first of these 2 variants has been tested in the pond farms of the northwest. The experimental base of the Institute is the fish farm "Ropsha," which is an outstanding selection farm. Selection of northern hybrid carp is conducted on a large scale at "Ropsha." By 1964, the 5th generation of selected hybrids had been reared. "Ropsha" supplies the second link (breeding farms) with high-quality brood stock.

The breeding farms "Yazhelbitsy" and "Opochka " (Novgorod and Pskov regions) are at present in the organizational stage. Spawners of 2 northern hybrid strains have been brought to these two fish farms where young of these 2 strains have been raised successfully. Breeding work has begun also in a 3rd fish farm, the Ropsha state raising station, where strain M spawner stock underyearlings were raised in 1963, and strain B in 1965. Unfortunately, both "Opochka" and "Yazhelbitsy" are most unsuitable for breeding work.

Commercial fish farms (both state and collective) in the Novgorod, Pskov, and Leningrad regions, as well as in the adjacent Kalinin Region, will be replenishing their spawning stocks with the spawners raised in the 3 breeding farms. The presence of 2 different northern hybrid strains in those breeding farms makes it possible to contemplate shipping mixed stock to fish farms, females of one strain, males of the other: ♀♀ B, ♂♂ M, or ♀♀ M, ♂♂ B.

To facilitate replenishment with such mixed stock, the descendants of 2 strains should be raised alternately: one breed group should be reproduced in even years, and the other in odd ones. The tagging of the entire 1st generation is obligatory (preferably by branding on the side of the body).

The breeding program is planned in such a way that fairly close inbreeding is admissible to maintain each strain. Shaskol'skii (1954) recently described the advantages of this breeding method. As we noted earlier, crossing spawners of strains B and M produces heterosis. The carp farms which will receive spawners from breeding farms will deal, consequently, with commercial hybridization. There should be no fish left for breeding original stock in these farms.

This is the general outline of the selective breeding program in the northwestern RSFSR.

Preliminary results of selective breeding work in the northwestern RSFSR

Recent experience has shown that our method is basically correct. At present, none of the carp farms of the Pskov and Novgorod regions does selective breeding. **In** 2 fish farms, "Yazhelbitsy" and "Opochka," where the replacement of breeding stocks with northern hybrids began in 1959, enough hybrids have accumulated (about 30 in "Opochka," almost 40 in "Yazhelbitsy") and spawners of the 2 strains (B and M) in both fish farms were in satisfactory condition in autumn 1964.

Number and average weight of [illegible] generation hybrid spawners at breeding farms in autumn 1964

Strain	Farm	Number of fish and weight range by ages									
		0+		1+		2+		3+		4+	
			[illegible]		[illegible]		[illegible]			[illegible]	[illegible]
4th generation backcross hybrids	"Opochka" —					970	1,356			321	2,177
	"Yazhelbitsy" —			559	640			677	2,110		
4th generation 4-way hybrids	"Opochka" —			1,188	567			267	1,793		
	"Yazhelbitsy"	151,000	11.8*	853	560						
	Ropsha raising station			about 1,000	about 300						

* The number of fish stated is that before selection.

Since 1960, the raising of 1st generation hybrid spawners at "Opochka" has been properly organized (Petrov and Romanova, this collection), as has been so since 1961 in "Yazhelbitsy" (Zonova and Shatrova, this collection) and since 1963 at the Ropsha raising station. The total amount of breeding material was rather considerable (Table).

The older groups of the replenishment stock — strain B aged 4+ and strain M aged 3+ in "Opochka," and strain B aged 3+ at "Yazhelbitsy" — attained maturity and as early as 1963 and 1964, males of strain B participated in spawning. This yielded good results. By the principal indexes (weight, condition factor, state of health) the 1st generation could be considered a good one, although results of raising might have been considerably better but for the lack of special ponds, diseases, unfavorable weather and certain years (particularly 1962).

Thus, the first 2 stages of organizing breeding work were satisfactory. Breeding stocks of northern hybrid spawners of both strains were successfully formed and maintained at 2 fish farms where they were satisfactorily raised into a numerous, well selected spawning stock with good indexes for breeding. The 2nd stage has not yet been completed, but as early as 1964 in "Opochka," it became possible to complete mixed stock for commercial hybridization (♀♀ B, ♂♂ M). In 1964, several hundred spawners (over 100 nests) were sent from "Opochka" to other fish farms in the Pskov Region to "Ropsha,"Yazhelbitsy,"Puiga" (Kalinin Region), and the pond farms of the Latvian SSR. The great abundance of the replenishment stock will make it possible to provide all the northwestern commercial fish farms with good-quality spawners in 1965—1967, and some will be sold to other regions.

We encountered 3 difficulties at "Yazhelbitsy" and "Opochka," the basic one of which was a lack of necessary ponds. It was particularly difficult to work at "Opochka," where both rearing ponds were swamped due to a rise of the groundwater level. There were no forage ponds, apart from the very large Izgozh pond, very few good spawning ponds, and no stock ponds. The raising ponds of "Opochka" get their water from the main pond where there are many "wild fish." This, and the inevitable joint maintenance of fish of various ages, led to serious epizootics, which hampered the work even more. At"Yazhelbitsy,"too, there are not enough ponds for proper breeding, and the available convenient ponds, for example, No. 7, were used for raising whitefish.

As the available ponds were not suitable for breeding, there was a high rate of mortality among the breed fish. Thus, hybrids hatched in 1960 could not be raised at "Yazhelbitsy."

The 2nd difficulty was not as decisive, but it will be no less serious in the future; this is the lack of trained selective breeders.

The absence of skilled, competent selective breeders will hamper further development.

The 3rd difficulty is the inadequate attention paid to breeding work by fishery management. The breeding farms have no plan for raising 1st generation replenishment stock and spawners, and this is far from accidental. The importance of selective breeding has been underestimated in fishery combines and in fishing industry administration in the northwestern region. The scientific organizations were given complete control over it, since the administration did not wish to conduct selection and spawner raising themselves. The managers of fish combines apparently have not yet realized that all the work of pond farms depends largely on the quality of carp spawners.

Fishery evaluation of hybrids

The work on hybrids done at "Yazhelbitsy" and "Opochka" gave us data on fishery evaluation of hybrids, the results of which have been presented in special articles so that we shall deal only with the main conclusions here.

1. Fecundity of northern hybrids is high. The total number of eggs spawned by a female at one time averages 450,000—550,000, i. e., 120,000-150,000/kg of female weight. The yield of larvae hatched at the spawning pond at 8-15 days averages 90,000-100,000 per female. The difference between the number of eggs and number of larvae is due to death of embryos and freely swimming larvae in the spawning ponds. This mortality is due firstly to food shortage at high population densities. The exploitation of larger ponds (up to 0.25 ha) in "Ropsha" makes it possible to obtain 120,000-170,000 larvae from each hybrid female. Spawning in wintering ponds larger than one ha at Yazhelbitsy yielded up to 200,000 larvae per female in some years.

These figures can be compared with those for carp only on the basis of published data. The fecundity of hybrids is approximately the same as that of carp, but carp is more capricious during spawning and produces considerably fewer eggs and larvae in some years. Hybrids spawned satisfactorily even in cold, unstable weather, and the yield of fingerlings was practically the same.

2. The growth rate of hybrids of both strains, and of between-2-strain hybrids exceeds that of carp throughout their first year of life. This difference is discernible in the spawning ponds, although it may be concealed at that time by the effect of population density on larvae growth. By autumn, hybrids weigh 15-25% more than Belorussian carp (average 20%), and sometimes even more.

Interestingly, in the cold summer of 1962, carp at Opochka" were less than half the size of hybrids (Romanova and others, this collection). The effect of low temperature on feeding activity of young of hybrids and carp must be thoroughly studied. Unfortunately, there were several methodological errors in the 1962 experiments.

3. The survival rate of hybrid larvae and fingerlings during the first summer is higher than that of carp. The difference is generally fairly great and is significant. Thus, in Zavysoch' e (Novgorod Region) in 1960, the mortality of strain M hybrid underyearlings was 15.2% for the summer, while that of the control carp was 73.4%. In 1962, in 'Opochka in raising pond No. 2, these figures were 71.2 and 93.9% respectively.

These findings shouldpot be overestimated, however, because the low viability of carp can sometimes be explained by their smaller initial weight. Nevertheless, evaluating all the experiments in total indicates that young hybrids undoubtedly were more viable. According to Andriyasheva (this collection), tolerance of unfavorable conditions (cold, starvation) is higher in crosses between the 2 strains than in the initial hybrids.

4. Hybrid underyearlings are better able to withstand cold than are carp. The difference in the survival rate fluctuates from very low (under favorable conditions in the wintering pond and good condition factor of the fish) to quite high. It is difficult thus far to evaluate the winterhardiness of various strains of hybrids precisely; certainly, however, backcross hybrids winter better than 4-way hybrids, and both are better in this respect than carp. Sometimes, extremely unfavorable environment (such as the alteration in water circulation in the Velikie Luki hibernation ponds **in** 1961/1962) causes high mortality in hybrids.

These are the results of underyearling evolution; although far from being definitive, they are fairly clear. The faster growth of hybrids, and their higher viability in summer and winter, are advantages which should be considered decisive in this climate. We should bear in mind the goal of the selection of carp-eastern carp" hybrids at "Ropsha" as one of creating a breed combining the winterhardiness of "eastern carp" and the growth rate of the cultured carp. For the northwest, higher winterhardiness is probably more important.

It is too early to estimate the yearling hybrids. There are data on 3 ponds; in 2 cases, hybrids and carp had an equal weight in autumn, in one case (1962,"Opochka," the whitefish pond), the hybrids lagged behind by about 8%. The reasons for this retardation are not clear; it might also be chance. There are preliminary indications that hybrids consume more natural food, especially benthos, and less artificial food. This difference is probably small, and a careful check is required to establish it. In the northwest, a better consumption of natural food, i. e., a more active search for food by hybrids, can often be advantageous. Due to low temperatures, supplementary feeding is less effective than in the south, and natural foods maintain great significance in carp diet.

An objective appraisal of all the qualities of hybrids in their 1st, 2nd, and 3rd years of life is very important, as it will guide our choice of future methods of breeding and selecting northern hybrids.

Future tasks in organizing fish breeding in pond farms of the northwest

We have already pointed out that the 2nd stage of work, raising breeders suitable for utilizing as brood stock in breeding farms of the northwest, is not yet completed. In "Yazhelbitsy" and "Opochka,"this will require another 2-3, and perhaps 4, years; during this time, hybrids born in 1960-1963 must be raised to maturation and 1-2 more generations must be obtained at "Yazhelbitsy." The main task, however, will be to attain good indexes of growth, weight, condition, and fecundity. A sufficient and suitable pond area should be allocated for the entire replenishment stock.

The 3rd stage, completion of nests of spawners by the new 4th generation hybrids begins at the same time as the replenishment stock is being raised. Here, the following work is impending:

1) (Preliminary) evaluation of hybrids by the degree of development of the sexual products and selection of best females and males;

2) Completion of mixed nests (female from one strain, males from another) and shipment of these nests to commercial fish farms;

3) Selective progeny testing of some of the mixed nests by evaluating both underyearlings and yearlings;

4) Reproducing purebred, elite brood stock from each strain to replenish our own spawners.

Along with these difficult and responsible tasks, other no less important investigations must also begin: testing the industrial method of obtaining carp larvae. Development of this method in the breeding farms will make it possible to test the second of our suggested schemes for organizing selective breeding. We believe it would be most expedient to first test one inclusive commercial fish farm for the possibility of stocking its ponds with larvae obtained and transported from breed spawners in industrial fish farms.

But the basic task is to supply all the fish farms of the northwest with high-quality breeding material from the breeding farms for raising spawners. The replacement of mixed, degenerated carp stocks with top-grade northern hybrid spawners should be completed in 1966, or 1967, at the latest. This measure is of enormous significance, and can be put into effect only with close collaboration between science and industry.

The overall development of pond pisciculture in the northwest depends on the fulfillment of the plan of work presented here. "Yazhelbitsy" and "Opochka," and also the Ropsha fish raising station, should be made into suitable breeding stations.

The success of work begun several years ago on the organization of breeding in the northwest allows us to hope that the problems will be solved. Carp breeding would thus have a firm foundation for its future development.

CONCLUSIONS

1. Experience in organizing selective breeding in the northwest has shown that the division of carp farms into 3 groups, selective, breeding, and purely commercial fish farms, has great advantages. This division makes it possible to supply fish farms with full-value spawning stock, and, what is very important, to free most fish farms from complicated breeding work and from raising replenishment stock.

2. Since 1960, we have obtained 3 groups of 4th generation northern hybrids at "Yazhelbitsy," and 4 groups at "Opochka." Those groups underwent selection in the first and second year of their life. Some of the prospective spawners (males in "Opochka") matured and have already participated in spawning in 1963 and 1964. Brood stock nests of 4th generation hybrids were completed at "Opochka" as early as 1964. By 1966, or 1967 at the latest, the stock of northwestern fish farms will be replaced with high-quality breed spawners.

3. Proper selective breeding work is hampered by the lack of ponds necessary for raising fish, by the absence of competent selective breeding personnel, and by inadequate attention to breeding from fishery management. Urgent measures should be undertaken to eliminate these obstacles, namely:

a) "Yazhelbitsy," "Opochka," and the Ropsha rearing station should be officially declared carp breeding farms for raising spawners.

b) Ponds should be reserved from those presently in use, and new ponds should be designed and constructed to maintain underyearlings, replenishment stock, and spawners.

c) A pisciculturist trained in selective breeding should work at each breeding farm.

d) A plan should be made for the breeding farms for raising replenishment stock and spawners.

4. The good qualities of the underyearlings have been confirmed in fishery evaluation of hybrids in field conditions. Their most substantial advantages are rapid growth and greater viability (in summer, but especially in winter). Their more complete use of natural food is of great significance. In the climate of the northwest, these qualities are decisive. With regard toyearlings (1+) no essential differences have been established between hybrids and carp, but the material available for comparison has been so far insufficient. Further, more accurate experiments on comparison of northern hybrids with carp and mongrel spawners of hybrid origin are required.

Bibliography

And r iy a sh e v a, M. A. Geterozis pri vnutrividovykh skreshchivaniyakh karpa (Heterosis in Intraspecific Crossings of Carp). In this Collection.

Bur ma k i n, E. V. Ikhtiotoksicheskie sredstva i perspektivy ikh ispol'zovaniya dlya bor'by s nezhelatel'nymi rybami (Ichthyocides and Prospects of their Use for the Control of Undesirable Fish). — Izvestiya GosNIORKh, Vol. 47, No. 2. 1958.

Bu r ma k i n, E. V. Khimicheskii metod rybokhozyaistvennogo preobrazovaniya ozer (Chemical Method of Reorganization of Lake Fisheries). — Izvestiya GosNIORKh, Vol. 55. 1963.

G olovins kay a, K. A. Plemennoe delo v prudovom rybovodstve (Scientific Breeding in Pond Pisciculture). —Rybovodstvo i Rybolovstvo, No. 3. 1962.

G ol ovk o v, G.A. and A. N. Ku z ' min. Razvedenie pelyadi v prudakh i ozerakh (Raising C or eg onus p el e d in Ponds and Lakes). Moskva. 1963.

K ir pichnik o v, V. S. Geneticheskie metody selektsii ryb (Genetic Methods of Fish Selection). —Byulleten' MOIP, otdel biologicheskii, Vol. 64. 1959a.

K ir pi c hnik ov, V.S. Gibridizatsiya karpa s amurskim sazanom primenitel'no k zapadnym oblastyam SSSR (Hybridization of Carp with "Eastern Carp" in the Western Regions of the USSR). —Trudy V nauchnoi konferentsii po izucheniyu vnutrennikh vod Pribaltiki, Minsk. 1959b.

K i r pi c hnik o v, V.S. Organizatsiya plemennogo dela v karpovodstve (Organization of Scientific Breeding in Carp Breeding Farms). — Nauchno-Tekhnicheskii Byulleten' GosNIORKh, No. 11. 1960.

K on r a dt, A. G. and A. M. S ak h a r o v. Biotekhnika fermentativnogo obeskleivaniya ikry karpa (Biotechnique of Enzymatic Cleaning of Carp Eggs). —Rybnoe Khozyaistvo, No. 7. 1963.

Petrov, B.E. and Z. T. Romanova. Plemennaya rabota s severnymi gibridnymi karpami v Pskovskoi oblasti(Selective Breeding of Northern Hybrid Carp in the Pskov Region). In this Collection.

Romanova, Z.T., B.E. Petrov, and N. I. Zabegalina. Proverka rybokhozyaistvennykh kachestv severnykh gibridnykh karpov v proizvodstvennykh usloviyakh Pskovskoi oblasti (Evaluation of the Fishery Qualities of Northern Hybrid Carp in Fish Farms of the Pskov Region). In this Collection.

Shaskol'skii, D. V. 0 rodstvennom razvedenii karpa v promyshlennykh prudovykh khozyaistvakh (On Joint Breeding of Carp in Commercial Pond Fisheries). —Trudy VNIIPRKh, Vol. 7. 1954.

Zonova, A. S. and Z. A. Shatrova. Plemennaya rabota s severnymi gibridnymi karpami v Novgorodskoi oblasti (Selective Breeding of Northern Hybrid Carp in the Novgorod Region). In this Collection.

SELECTIVE BREEDING OF NORTHERN HYBRID CARP IN THE NOVGOROD REGION

A. S. Zonova and Z. A. Shatrova

Selection of northern (Ropsha) hybrid carp began at "Ropsha" in 1963. At the end of the 1950's Ropsha spawners were transferred to the "Yazhelbitsy" (Novgorod Region) and " Opochka" (Pskr•v Region) farms, which became the centers of the first stage in organizing selective breeding work on northern carp.

A 3-step system for organizing selective breeding, suggested by GosNIORKh (Kirpichnikov, 1960, and the present collection) and by VNIIPRKh (Golovinskaya, 1962), was taken as a basis. "Yazhelbitsy" and "Opochka" represented the second link in this systcm; they were to become breeding farms, with the task of raising Ropsha carp spawners for commercial fish farms.

In elaborating the actual plan of breeding, we chose a 2-strain system which avoids the harmful consequences of inbreeding. Spawners of 2 strains of Ropsha carp, backross (B) and 4-way (M), were brought to "Yazhelbitsy"; they are described in Kirpichnikov's article (this collection). Crossing of different strains allows us to produce high-quality stock. Replenishment stock of both strains was raised simultaneously at the breeding station.

In 1962 "Yazhelbitsy" was officially declared a breeding farm, which was to provide the pond farms of the northwest with stocking material as well as with high-quality northern hybrid carp spawners in the near future. The spawners should be transferred to commercial fish farms in mixed nests: females and males should be of different hybrid strains.

Parallel with the breeding, the fishery qualities of the 4th generation hybrids were tested at "Yazhelbitsy."

"Yazhelbitsy" has a small network of raising ponds, most of which have no water supply of their own. There are neither spawning nor replenishment ponds at the farm. The areas of spawning and overwintering are very limited; thus, the yearly spawning had to take place in large wintering ponds, and the under-yearlings had to overwinter in two raising ponds. The basic requirement in breeding is preservation of the purity of the strains, and this lack of ponds caused great difficulties in arranging for raising and wintering. The absence of replenishment ponds was one reason why 2 generations of 4-way hybrids were lost.

The initial population of northern carp was formed at the breeding farm over several years by transferring them from Ropsha. There are now 22 nests of 3rd generation spawners at "Yazhelbitsy." Due to the goodbreeding qualities of this stock, we were able to raise enough spawners and also to meet much of the need for commercial stock. Thus, about 1.5 million northern hybrid carp larvae were produced at "Yazhelbitsy," in the 1963 spawning season, and 3 million were produced in 1964.

Unfortunately, some quantity of local mongrel carp had to be used yearly for commercial purposes until 1965, by which time the demand for commercial spawners was fully met through young males hatched and raised here and young female 4-way hybrids brought from "Opochka."

Characteristics of breed spawners

The spawners brought to "Yazhelbitsy" were first tested for homozygosity in scale factors, and there was no segregation in their progeny. Only 4 females were not tested, but they were used for commercial crossings. The spawners were 10-12 years old in 1965, and all of them foraged under comparatively good conditions each year; thus, they had gained quite a bit of weight since their transfer and had a good condition factor. The average weight of 4-way hybrid females was 5,460 g and that of males was 4,100 g. Because of their genetic composition, backcross hybrid carp were smaller and weighed less than the 4-way hybrids. The gradual improvement in the condition of breeding females was unusual, as the condition factor of hybrid spawners generally tends to deteriorate somewhat with age. Thus, in females transferred to "Yazhelbitsy" in 1959, the condition factor subsequently increased from 2.33 to 3.09. In spring, 1965, all spawners had well developed sexual products.

Backcross and 4-way hybrid strains have been bred in alternate years in "Yazhelbitsy since 1960 (Table 1). This avoided mixing the material and later facilitated the formation of mixed nests to supply commercial pond farms. In 1963, we were forced to breed both strains at the same time because we had not been able to raise the 4-way hybrids of the 1960 and 1962 spawnings.

To obtain large quantities of breeding stock, we stocked 4-way hybrid females and backcross males together. Due to a lack of the latter, 15-50% of the males used were 4-way hybrids. Beginning in 1964, the maturation of young spawners fully provided the spawning ponds with the required number of backcross males.

Results of the spawnings of 1959-1964 indicate the good breeding qualities of northern hybrid carp. Firstly, the early spring maturation of breeding spawners in the northwestern regions should be noted, as the fish usually spawned simultaneously and usually completed spawning in 24 hours. Ponds stocked with larvae from such spawning yielded underyearlings of comparatively uniform size by autumn.

On the other hand, the spawning of local mongrel hybrids was prolonged, resulting in wide variation in the weight of their underyearlings in autumn. The selected spawners also had higher fecundity than the local mongrels. In commercial crossings, the northern hybrids usually produced over 100,000 larvae per female (107,000-165,000), except in 1963, when the average yield per female was 90,000 larvae. The local mongrels produced only 70,000-90,000 larvae per female.

It should be noted that in 1962 and 1963, which were cold years, the fecundity of the breeding hybrids remained fairly high. The yield of fingerlings per female did not decrease markedly in those years.

TABLE 1. Indexes of fecundity of spawners used for producing replenishment stock and commercial crossings ("Yazhelbitsy," 1960-1964)

Year of crossing	Breed of spawners	Number of females	Average weight of females, g	Average fertility of females, thousands *	To fertilization
		Breeding crossings			
1960	M × M	2	3,270	365	92
1961	B × B	1	2,880	160	82
1962	M × M	4	4,100	377	59.7
1963	M × M	6	4,325	335	66.0
	B × B	1	3,100	240	–
1964	M X M	7	4,910	418	80.4— 92.4
		Commercial crossings			
1960	M X (M and B)	5	3,940	324	81
1961	M x (M and B)	9	3,280	240	88
1962	M X (M and B)	10	4,000	270	70
1963	M X (M and B)	8	4,500	407	77
1964	M × B	14	4,250	285	74.1
		Control crossings			
1960	Sparse-scale mirror carp	2	7,500	415	88

* Fertility was estimated by the difference in weight of females before and after spawning, assuming that 1 g roe contained 1,000 eggs.

Conditions of raising spawner stock

Underyearlings were always raised in isolated ponds. The only 2 such ponds at "Yazhelbitsy" were raising ponds No. 3a(5.5 ha)and No. 7(2.2 ha). The bed of pond No. 3a is littered with vegetation remnants, and there are trenches with stagnant water. The decay of vegetation frequently resulted in acute oxygen deficiency in the summer. Pond No. 7 is better, but unfortunately, it was frequently used for raising whitefish.

The older groups of spawner replenishment stock were fattened together with commercial stock in raising ponds. We tagged the entire spawner replenishment stock by clipping their fins, to avoid mixing of the population. Because it is known that carp underyearlings are susceptible to infection from older fish raised with them, the stocking density of the older replenishment spawners was kept low. Our experience at "Yazhelbitsy" shows that in the absence of separate commercial and spawner replenishment ponds at farms, spawner replenishment can also be raised in the raising ponds. The number of yearlings stocked should be no more than 150/ha, and the number of 2- and 3-year-olds no more than 100/ha. These densities, with efficient management, do not hamper the fulfillment of the plan, and make it possible to raise high-quality spawners.

Raising ponds were fertilized every 2 weeks throughout the entire growing season. The quantity of mineral fertilizers was calculated so that

1 — 2 mg/l pure nitrogen and 0.2 mg/l pure phosphorus were introduced each time. Depending on the florescence, the time intervals between the fertilization were either prolonged or shortened.

In the second half of the summer, fish received artificial feeds consisting mainly of grain husks, cake, oilseed meal, and meat-bone or fish meal.

The growth of underyearlings was watched carefully throughout the entire summer, as it would largely determine the results of overwintering and, consequently, the prospects of future breeding work. The growth of carp of older age groups could be studied only at autumn recovery, as the low stocking density did not permit their recovery in summer.

Raising 4th generation backcross hybrids

Backcross hybrids of the 1961 spawning. Underyearling backcross hybrids were first obtained in "Yazhelbitsy" in 1961 (Table 2). When recovered from the spawning ponds, the larvae were large and strong, but for technical reasons, they were stocked in pond No. 7 much later than usual (12 July). The fingerlings had been kept for a long time in 2 small ponds with a total area of 1 ha. The prolonged maintenance of fingerlings at high population density caused a great variation in weight. Thus, when stocked in pond No. 7, the fingerlings weighed an average of 1 g, their weight range being 0.5-4.2 g. This range was even wider by autumn (Figure 1). A great variability of weight is undesirable in raising breeding material, because it reduces the efficiency of selection. The individual weight gain of fish is affected not only by their heredity but also by food competition.

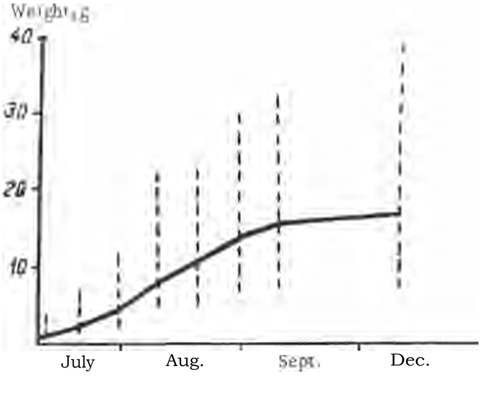

FIGURE 1. Cumulative weight gain of underyearling backcross hybrids in the growing season. "Yazhelbitsy," pond No. 7, 1961.

In subsequent years, the backcross hybrid carp of the 1967 spawning season were raised together with commercial stocking material in various ponds of the farm. As the planned quota of underyearlings was very high, we stocked the prospective spawners in raising ponds at a density of 20-120/ha. The summer weight gain was quite satisfactory, reaching

800-1,000 g, except in the very cold summer of 1962, when it dropped to 370 g. Backcross hybrids usually overwintered well; yearlings and older fish wintered without mortality.

TABLE 2. Raising of 4th generation northern hybrid spawners ("Yazhelbitsy," 1960-1964)

Breed group	Year of hatching	Age	Pond	Area of pond, ha	Recovered		Mortality, %	Total productivity, kg/ha
					number	average weight, g		
B		0+	Pond No.7	2.2	58,300	17	3.0	473
		1+	Pond No.1	25.0	> 1,500	386	–	265
	1961	2+	Pond No. 5 (stocking)	25.0	1,000	1,370	5.0	933
		3+	Pond No.5	25.0	400	2,140	–	983
			Pond No.7	2.2	370	2,110	–	500
	1963	{0+	Fingerling pond	0.4	7,000	55	30.0 (17.0)	962
		1+	Pond No. 6	7.3	1,900	640	–	712
M	1960	0+	"Zavysoch'e" No.2		67,800	30.2	15.2	620
	1962	0+	Pre-raising and fingerling pond	1.0	4,000	8.5	89.0	68
	1963	10+	Pond No. 3a	9.0	132,000	24.5	34.0	647
		1+	Pond No.7	2.2	1,960	450.0	2.5	509
	1964	0+	Pond No. 3a	5.5	151	11.8	30.0	324

In spring 1965, the first group of spawner replenishment stock consisted of 677 four-year-olds, weighed an average of 2,110g. Of these, 285 sexually mature males were selected, most of which were sold, and a few of which were retained for replenishing the local spawning stock.

Backcross hybrids hatched in 1963. In 1963 the nest of backcross hybrids spawned under exceptionally unfavorable conditions. Because of a very limited number of spawning ponds, a small section of pond No. 4 with an area of no more than 50 m^2 had to be used for their spawning. Most of this pond was used for constructing an overwintering pond, and was supplied with water pumped periodically from the river. We obtained 50,000 larvae weighing an average of 9.4 mg at 10 days. The underyearlings were raised in the fingerling pond (0.4 ha), which had been used previously as spawning grounds. We stocked 10,000 larvae in this pond, and introduced a combination of mineral and organic fertilizers which made a rich food supply. In August, the fish also received artificial feeds. The underyearlings weighed an average of 55 g by autumn and productivity of the pond was 962 kg/ha.

The next year, 2,000 yearling backcross hybrids were raised in pond' No.6 (7.3 ha) in which 300,000 carp larvae were also stocked. Productivity of this pond was about 1,000 kg/ha; more accurate determination could not be made because there were several hundred market-aged mongrel carp in the pond. Backcross hybrid carp yearlings grew well; some weighed as much as 800-900 g, but unfortunately, most of the fish were badly infected with carp pox and they had to be culled. In spring 1965, there remained 550 two-year-old-fish, averaging 640 g, for further fattening.

Raising 4th generation 4-way hybrid spawner replenishment

As noted above, 2 spawnings of 4-way hybrids, those of 1960 and 1962, were lost because "Yazhelbitsy" was unsuitable for breeding work. In 1960, because we could not stock the larvae in "Yazhelbitsy," we used a pond at the "Zavysoch'e" farm. The fish had good weight and quantitative indexes (see Table 2), but by the autumn, they all appeared to be badly infected with the trematode *Dactylogyrus solidus*, which caused mass mortality during overwintering.

In 1962, spawning and raising of underyearlings took place at very low temperatures. The mean monthly water temperatures in July and August were only 16.5 and 16° respectively. Introduction of fertilizers did not give the expected results, because the low temperatures led the fish to consume the artificial food poorly. In August, an intensive infection of underyearlings with dactylogyrosis appeared, resulting in mass mortality in the autumn-winter period.

In spring 1965, we had 2 spawnings of 4-way hybrid carp from 1963 and 1964. In 1963, the 4-way hybrid carp were spawned along with the back-cross carp, and the 2 groups were separated completely until they were large enough to be tagged.

In 1963, larvae were obtained from 6 females. The spawning occurred early, 24 May; thus there were abnormally few eggs. Nevertheless, about 100,000 larvae per female were obtained. The abrupt temperature drop affected the growth of the larvae and by the time of their recovery (8th — 10th day) they weighed only 7— 9 mg.

In 1964, the 4-way hybrids were spawned in 2 ponds with areas of 0.2 and 1 ha, in which 2 and 5 nests were stocked respectively. The larvae were recovered on 22 —23 June. The 5 females in the larger pond yielded 1,385,000 larvae, or 277,000 per female. The second pond yielded 82,5000, that weighed considerably less.

It should be noted that in "Yazhelbitsy" and many other northwestern fish farms the raising ponds must be filled with water in April, and stocking small carp larvae in such ponds is poor practice, as predatory invertebrates exterminate them. To obtain fairly large larvae in spawning ponds, large ponds should be used, and spawners should be stocked so that there is 1 nest for every 0.1 - 0.15 ha of pond area. This not only increases the yield of larvae from a nest, but also improves the quality of larvae. At high density and in cold years, where there is not enough zooplankton, an acute food shortage is the principal cause of mass mortality of larvae in spawning ponds.

In 1963 and 1964, the 4-way hybrid underyearlings were raised in pond No. 3a, where 200, 000 larvae were stocked each year. The poor qualities of this pond were described earlier. In 1963, growth of fish was retarded by oxygen deficiency due to decomposition of a large quantity of vegetation remnants. In some sections, the oxygen content of the pond reached the critical point (0.4-0.8 mg/l).

It was impossible to increase the water flow in the first half of the summer. The infection of fish with cataract caused by *Diplostomulum spathaceum* also affected growth and decreased the viability of the underyearlings. The disease lowered the condition factor to 2.62 by autumn. Only 64% of the initial stock was recovered; average weight was 24.5 g, and productivity was 647 kg/ha.

In 1964, the productivity of pond No. 3a was reduced by a large number of trash fish that devoured edible organisms. The production of hybrid underyearlings was only 324 kg/ha. Unfortunately, there was no accurate count of the trash fish. It can be assumed from past experience that the total productivity, including the trash fish, was at least 600 kg/ha. That year the survival rate of fish was 67%, with an average weight of 11.8 g. The low weight gain and considerable weight variation among the underyearlings (from 5-30 g) resulted mainly from food competition between carp and trash fish. The poor raising conditions in those years also affected over-wintering negatively.

Despite all the difficulties, we succeeded in raising and thoroughly selecting the fish. In spring 1965, 1,500 yearlings averaging 20 g and 710 two-year-old 4-way hybrids averaging 530 g were stocked for foraging.

Selection and body build among 4th generation hybrids

There was adequate selection among the 1961 backcross hybrids and the 4-way hybrids of 1963 and 1964. Table 3 presents the figures showing the course of selection. The weight of underyearlings and yearlings was not changed very much by the selection.

TABLE 3. Intensity of hybrid selection ("Yazhelbitsy," 1961-1964)

Breed group	Year of spawning	Age	Number of fish		Intensity of selection, %		Weight, g	
			before selection	after selection			before selection	after selection
B	1961	0 1 2	58,300 28,000 1,400	28,000 3,000 1,000	48.0 10.7 71.4	3.7	17.0 18.9 365	20.1 30.0 370
B	1963	0 1	6,500 1,900	2,000 569	31.0 30.0	9.3	52 520	55 640
M	1963	0 1	60,000 1,960	2,000 853	[illegible] 43.5	1.4	23 450	30 560
M	1964	0 1	Random 20,000	 1,500	— 7.5		— 13	— 20

By 1965, as a result of raising and selection there were the following numbers of 4th generation spawner replacements: backcross hybrids, 550 aged 2+ and 677 aged 4+; 4-way-hybrids, 1,500 aged 1+ and '710 aged 2+.

Measuring and weighing the spawners enabled us to calculate the condition factor and body build (Table 4). The difference between the 2 strains is small, and generally both the condition factor and the other 2 indexes of the 4th generation are close to those of the 3rd generation. Interestingly, in the cold year 1962 all the indexes improved greatly.

TABLE 4. Condition factor and body build of 4th generation hybrids ("Yazhelbitsy," 1961-1964)

Year of spawning	Age	Weight	Condition factor (K)	Body build (l/H)	Index of breadth (B/l)	
Backcross hybrids						
1961	0+	20.1	2.75	2.89		75
	1+	397	3.32	2.76	23.7	50
	2+	1,370	2.93	2.86	19.8	50
	3+	2,110	2.88	2.99	18.4	90
1963	0+	50.0	2.65	2.88	18.2	50
	1+	640	3.11	2.84	20.6	50
4-way hybrids						
1963	0+	24.5	2.69	2.86	18.8	50
	1+	560	3.29	2.47	20.1	50

E[illegible]

E[illegible] hybrid [illegible] "Y[illegible]" [illegible] 1959. U[illegible] B[illegible]. U[illegible], [illegible] 1959 [illegible]. W[illegible] 17% [illegible], [illegible] 1% [illegible] B[illegible].

T[illegible] 1960 [illegible] 2 [illegible] 4-[illegible] 2 [illegible] B[illegible]-[illegible]. T[illegible], N[illegible]. 1 [illegible] 3, [illegible], [illegible], [illegible]. T[illegible] Belorussian [illegible].

E[illegible], [illegible]. H[illegible]. T[illegible] B[illegible]. H[illegible] B[illegible].

T[illegible] 4[illegible]-[illegible] N[illegible].2 [illegible] "Zavysoch'e" [illegible] (T[illegible] 5). G[illegible], [illegible], [illegible]. A[illegible]. I[illegible], [illegible] J[illegible].

W[illegible] 17-18 J[illegible], [illegible] 1.2 [illegible]. T[illegible] (F[illegible] 2). I[illegible]. I[illegible], [illegible]. B[illegible], [illegible]-[illegible] 20%. T[illegible] (from a parasitic infestation, dactylogyrosis), in the middle and at the end of the growing season. Also the smallest fish may have been eaten by predatory fish, as 3 kg of pike and 8 kg of perch were recovered from the pond in autumn.

TABLE 5. Comparison of fishery qualities of northern hybrids and of carp ("Zavysoch'e" and "Yazhelbitsy," 1960—1961)

Farm	Raising pond No.	Area, ha	Breed group	Stocking, thousands	Recovery			Total productivity, **
					number, thousands	average weight, g	mortality, %	
"Zavysoch'e," 1960	2*	4.0	4th generation, strain M Ropsha carp	80	67.8	30.2	15.2	620
			sparse-scale carp	55	14.6	25.4	73.4	
	1	25.0	4th generation, strain M Ropsha carp	500	460	28.7	8.0	528
	6	7.3	4th generation, strain M × B Ropsha carp	130	119	20.1	9.0	445
"Yazhelbitsy," 1961	2	20.7	mongrel hybrids	432	332	19.0	24.0	465
	5	15.5	mongrel hybrids	367	293	14.4	20.0	416

Fourth generation 4-way hybrids and Belorussian sparse-scale carp were raised join ly.

** Productivity includes the marketable carp and trash fish.

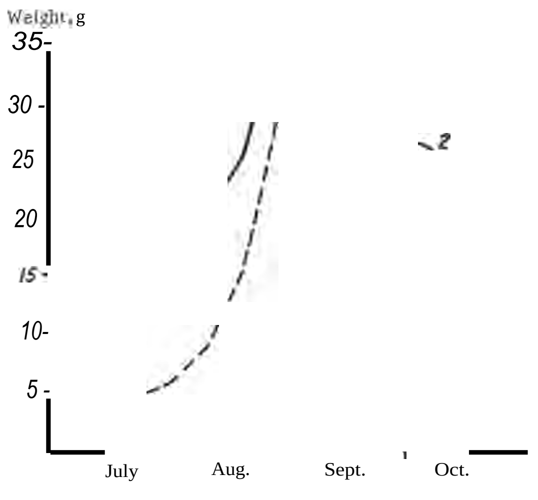

FIGURE 2. Cumulative weight gain of 4-way hybrid underyearlings (1) and carp (2). "Zavysoch'e," pond No.2,1960.

The condition factors of underyearlings of both groups, which were high at the beginning of raising, deteriorated gradually by the end of the summer, and even more in the autumn. This was probably due to an intensive infestation by a gill trematode (D. soli du s). The condition factor of the northern hybrids was somewhat lower than that of the sparse-scale carp because of hereditary differences in the ratio of length to width in the two breeds.

The survival rate of underyearling hybrids (see Table 5) was almost 3.5 times that of the controls.

In 1961 and 1962, we were unable to spawn the Belorussian carp. In spring 1963, several new nests of sparse-scale carp were brought from Belorussia to "Yazhelbitsy," Larvae were obtained in 2 spawning ponds but unfortunately, they were infected with ichthyophthiriasis from the spawners and had to be destroyed. No diseases were observed in the ponds where hybrid carp were spawned.

As it became impossible to continue the comparisons of northern and sparse-scale carp, we attempted to compare the results of mass raising of underyearling northern hybrids with that of mongrels of unknown origin present in "Yazhelbitsy" (see Table 5). The stocking density of the hybrid larvae was 18,000-23,000/ha depending on the natural productivity of the ponds. Productivity was similar in all ponds except pond No. 1, where it was higher.

The superiority in growth and survival rates of 4-way hybrids and 4-way backcross hybrid carp is obvious. Among the mongrels, the larval mortality was 2.5 times greater than that of northern hybrids, and the mongrels were also inferior in growth rate.

Data on commercial raising of underyearlings in 1962 and 1963 are listed in Table 6. In the cold year 1962 all the indexes dropped sharply, productivity dropped to 150-250 kg/ha, and in one pond all the underyearlings died as a result of eye cataracts.

TABLE 6. Results of raising hybrids in production ponds ("Yazhelbitsy," 1962-1963)

Year	Pond	Breed group	Recovery			Total productivity, kg/ha
			quantity,	average weight, g		
1962	6	Northern hybrid – 100%	138,000	12.0	40.0	250
	3	Northern hybrid – 70% and mongrels– 301'o	235,000	6.0	47,0	144
	2	Northern hybrid – 80% and mongrels– 20%	All fish died of cataracts			
1963	1	Northern hybrid – 43% and mongrels – 57%	777	26.9	7.5*	848
	3	Northern hybrid – 100%	216	20.7	47	400
	5	Northern hybrid – 4311 and mongrels– 57%	522	25.2	5.5*	933
	3a	Northern hybrid – 100%	132	24.5	34	647

* The figures for stocking are the accountable data, and are probably understated; the mortality is also correspondingly too low.

In 1963 productivity was very high in several ponds. Northern hybrid underyearlings madeup 75% of the stocking material at the farm. Even in the least productive ponds (Nos. 3 and 3a) the average weight of underyearlings was sufficiently high, and productivity rose to 400 and 647 kg/ha. The higher mortality in these 2 ponds, as has been noted already, was due to a mass infestation of underyearlings with *Diplostomum spathaceum*.

No comparison could be made of winterhardiness of hybrid and sparse-scale carp because of a lack of material (primarily on carp [for controls]) and an insufficient number of wintering ponds. We also have no data comparing the growth rates of different breeds in their second year.

CONCLUSIONS

1. In 1959-1963, in "Yazhelbitsy," spawner stock of northern hybrid carp of the 4-way and backcross strains was formed. These had good weight indexes and condition factors.
2. In spring 1965, "Yazhelbitsy" had four breed groups of 4th generation hybrids: 4- and 2-year-old backcross hybrids, and 2- and 1-year-old 4-way hybrids. The males of the older fish group began maturing in 1965. The first group of young females will be selected in spring, 1966.
3. The work at "Yazhelbitsy" in this period proved the superiority of the 3-step system of organizing selective breeding suggested by GosNIORKh. As early as 1966, this farm will be able to begin forming spawner nests for commercial fish farms of the Novgorod Region.
4. The comparison of northern hybrids with local mongrels and with Belorussian sparse-scale carp showed that:

a) Hybrids are more fertile.

b) In the first year of their life they are more disease resistant than carp and grow faster, weighing an average of 20% more than carp.

We have no data on the winterhardiness of underyearlings and on growth rate of yearlings.

Bibliography

Golovinskaya, K.A. Plemennoe delo v prudovom rybovodstve (Scientific Breeding Work in Pond Pisciculture). —Rybovodstvo i Rybolovstvo, No.3. 1962.

Kirpichnikov, V. S. Organizatsiya plemennogo dela v karpovodstve (Organizing Scientific Breeding in Carp Raising). —Nauchno-Tekhnicheskii Byulleten' GosNIORKh, No. 11. 1960.

Kirpichnikov, V. S. Pervye itogi i zadachi rabot po organizatsii plemennogo dela na Severo-Zapade RSFSR (Preliminary Results and Further Tasks of the Organization of Selective Breeding in the North-western RSFSR). In this Collection.

SELECTIVE BREEDING OF NORTHERN HYBRID CARP IN THE PSKOV REGION

B. E. Petrov and Z. T. Romanova

The spawner stock in the fish farms of the Velikie Luki Fish Combine consisted of "eastern carp" (Cyprinus carpio haematopterus), Kursk hybrids, their 1st and 2nd generation hybrids, and also mongrel carp originating primarily from Galician stock. The uncontrolled crossings among these forms in previous years made it impossible to isolate any of them. Selective breeding of "eastern carp" at the Shipulino farm in 1951-1954 resulted in a spawner stock of that breed which later came to nought because carp farms did not continue selective breeding. The resultant stock degeneration affected production negatively both on fish farms and in pond pisciculture in general.

In 1959-1961, eleven nests of northern hybrids (3rd generation of selection) were brought from "Ropsha" to the "Opochka" fish farm of the Velikie Luki Fish Combine. In 1964, another four 3rd generation 4-way hybrid females were brought there, forming a spawner stock (Table 1). By autumn 1964, there were 14 females and 15 males remaining of the original number.

Our main goal was to raise young spawners for a high quality replenishment stock to replace all spawner stock in the pond farms of the Velikie Luki Fish Combine. Bukhteeva, a laboratory assistant, and Borisova, pis ciculturist of the "Opochka" fish farm, worked on the spawners. In 1960 and 1961, Bogatova, a scientific worker, investigated the food supply of those ponds where hybrid underyearlings and yearlings were raised.

This article reports on the work done at "Opochka" from 1959 to 1964 with the northern hybrid carp spawners.

TABLE 1. Population of northern hyb id carp spawners (1959-1964)

Strain	Sex	No. at spring inventory					
		1959	1960	1961	1962	1963	1964
Backcross hybrids	♀		2	2	2	2	2
		7	10	10	10	10	8
4-way hybrids	♀	4	7	9	9	8	12
	♂	1	8	12	11.	9	9
Total	♀ and ♂♂	12	27	33	32	29	31

Strain	Sex	Year of transfer	Year of hatching	Weight, g 1959	1960	196[illegible]	1962	1964	Fulton's condition factor 1961	1963	1964
[illegible]	♀	1960	1952	—	2 [illegible]90	[illegible]	3 070	[illegible]0	2. 8	[illegible]3	2. 0
[illegible]	[illegible]	1959	1952 and 1953	2,0[illegible]0		[illegible]00	[illegible] 00	[illegible] 820	[illegible] 27	2.20	[illegible]
	[illegible]	1960	1952 and 1953	[illegible]	70	[illegible]0	[illegible],270	[illegible] 570	[illegible].32	2. 6	[illegible]
	♀	1959	1953	2,[illegible]0		3,[illegible] 0	[illegible],500	4 300	[illegible].68	2. 2	70
	♀ ♀	1960	1953	[illegible]	[illegible]20	[illegible] 0	[illegible]940	4,690	[illegible] 39	2.50	53
4-way hybrids	♀♀	1961	1953 and 1954	-	—	3 5 0	3 0	4,[illegible]50	[illegible] 43	2.44	59
	[illegible]	1960	19 3	-	2,430	2,6 0	2.630	3,160	2 5	2.13	2.26
	♂♂	196[illegible]	1953	-	—	[illegible]8 0	[illegible]840	3 200	2. 0	2.09	2.11

Weight, body build and condition of spawners

The spawners brought from "Ropsha" are related to 2 strains of carp-"eastern carp" hybrids, known as 4-way M and backcross B (Kirpichnikov, this collection). Both males and females had first been tested by progeny at "Ropsha" for segregation of scale traits. All the fish brought to "Opochka" are homozygous in scale factor S and produce only scaly progeny. Four-way females, Nos. 3, 14, 18, 47, that had not been tested for segregation were used only for commercial crossings, and not to obtain replenishment spawners.

The general characteristics of weight and condition of hybrids are presented in Table 2, which shows the small yearly weight gain of the spawners . In some years, the weight did not vary at all; only in 1960 and 1963 was appreciable gain seen. This failure to gain weight resulted from the extremely unfavorable conditions of their summer maintenance. Both sexes were usually raised together in an oligotrophic pond, which resulted in uncontrolled spawning in that pond. If the loss in weight during the winter and spawning periods is taken into account, the gain will be somewhat larger, but it was not enough to preserve good breeding qualities in the spawners, especially females. The worst years were 1961 and 1962; therefore, the results of spawnings in 1962 and 1963 were mediocre.

Due to the slow growth, the condition factor of the spawners gradually deteriorated, even as the 1/H index increased greatly. Thus, in 1959 it averaged 2.91 for females, and in 1963 it was 3.16-3.44.

In 1962, most of the spawners became infected with an unknown gill disease, and by autumn, there was an outbreak of ichthyophthiriasis. Spawners and their progeny were treated with prolonged salt baths. In spring 1963, after the spawners' overwintering pond had thawed, common salt was added to the water, in a concentration of 0.65-0.70% NaCl (Bauer and Shchupakov, 1956). The fish stayed in this water from 25 April until 6 May 1963; in that period, water temperature rose from 2 to 17°. This treatment was successful-according to Lopukhina, a GosNIORKh parasitologist, the fish were free of ichthyopthiriasis at recovery on 7 May 1963. All the replenishment spawners appeared healthier.

Since 1960, spawners of strains B and M were used every year to obtain replacement stock. Backcross hybrids were spawned in even years and 4-way hybrids in odd years, so that mixed pairs could be formed for sale later on (♀♀ M, ♂♂ B, and vice versa). These combinations were found to give good results due to heterosis (Kirpichnikov, this collection: Andriyasheva, this collection).

Raising 4th generation backcross hybrids

a) Spawning of 1960 (1st age group). In 1960,inthe same spawning pond, 2 female and 3 male backcross hybrids were spawned (Table 3). Temperatures were favorable for the spawning,which was active, and larvae were recovered and transferred for raising to fingerling ponds 8 days after hatching. The underyearlings were raised throughout 1960 in 2 ponds with a total area of 3.4 ha. To increase natural productivity, the ponds were limed and fertilized (Table 4).

Artificial (mixed) food was placed in the ponds throughout the summer; about 5,000 kg/ha in pond No. 1, and 300 kg/ha in pond No. 2.

TABLE 3. Spawning of backcross hybrids (1960 and 1962)

Year	Spawner No.		Average weight of females, g	Fertility of one female (by weight loss), thousands	Fertilization,%	No. of larvae recovered per female, thousands	Average weight of larvae at recovery, mg
	♀♀	♂♂					
1960	1;5	12;27;34	2,750	340	87.7	87.0	8.2
1962	1	5;41	3,320	70 (?)*	96.8	110.0	11.4

* There may have been an error in weighing the female.

TABLE 4. Liming and fertilizing of ponds

Pond	Year	Quantity of lime and fertilizers, kg/ha			
		quicklime	phosphate	ammonium sulfate	potassium chloride
Fingerling 1	1960	1,070	140		
	1961	10	900	850	30
	1962	860			
	1963	70	180	357	
Fingerling 2	1960	1,050			
Whitefish 1	1962				
	1963		80	240	
Whitefish 2	1961	650	260	530	45
	1962				
	1963		130	376	

• The food supply of the ponds in 1960 had the following indexes (seasonal average):

	Fingerling pond No.1	Fingerling pond No.2
Zooplankton, g/m^3	12.8	9.0
Benthos g/m^2	7.0	5.5

Thus the food supply was moderate with zooplankton prevailing. The sample of hybrid underyearlings had a very satisfactory weight and average condition (Table 5). The productivity of the ponds was fairly high, especially in 1960 in pond No.1 which had more natural food.

TABLE 5. Raising underyearling backcross hybrids (1960 and 1962)

Pond	Year	No. of fish recovered		Average weight, g	Fulton's condition factor	Fat content, %	Mortality, %	Productivity, kg/ha
		total	fish/ha					
Fingerling 1 . . .	1960	34,880	24,900	31.8	about 3		–	792
Fingerling 2 . . .	1960	40,000	20,000	35.5		–		710
Fingerling 1 . . .	1962	49,000	35,000	7.5	2.87	5.0	18.4	261

Note. Mortality for 1960 could not be calculated because of the inaccurate count of fingerlings at stocking.

Most underyearlings (60,500) overwintered in pools. Their winter mortality was only 7.2%. The subsequent course of the raising of hybrids is presented in Table 6. In winter 1961-1962 and 1962-1963, they were in overwintering ponds, and mortality was less than 1%.

In summer, the fish were raised in whitefish ponds. In 1961, oligotrophic whitefish pond No. 2, with a sandy (peaty in some places) bottom was used. Despite the comparatively large amounts of lime, fertilizers, and food supplement that were added, the food supply of the pond remained poor, and the weights of yearlings and the productivity samples were low.

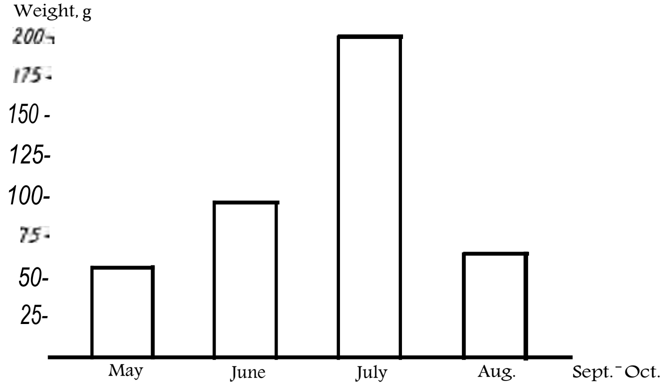

FIGURE 1. Distribution of weight gain of backcross hybrid yearlings by months (whitefish pond No. 2,1960.

Weight gain was particularly poor in August and September (Figure 1). The causes of this autumn retardation are unknown.

TABLE 6. Raising of 1+,2+ and 3+ backcross hybrids

Pond	Year	Age	No. of fish recovered	No. of fish selected for breeding	Mortality %	Condition index			Average weight before selection, g	Total productivity, kg/ha
						factor (K)	(1/H) index	body breadth index (b/1),%		
Whitefish 2	1961	1+	3,634	1,000	20.0	3.10	2.71	21.5	481	380
Whitefish 1 (jointly with yearlings)	1962	2+	915	896	8.5	2.99	2.90	20.9	990	182
Whitefish 2	1963	1+	4,328	1,007	13.4	3.30	2.68	17.9	543	600
Whitefish 1 (jointly with replenishment stock and spawners)	1963	3+	853	844	0.9	2.84	3.09	19.7	1,700	558
including: females	–			331	–	2.97	3.01	20.4	1,930	–
males	–		–	398		2.71	3.15	19.2	1,528	–
sex undetermined	–	–	–	115	–	2.83	3.06	19.7	1,726	–

Mean values of specimens selected for breeding.

In 1962 whitefish pond No. 1, which was similar to whitefish pond No. 2, was allocated for further raising of hybrids. Two-year-old spawner replenishment fish were raised here together with the commercial yearlings. In the extremely cold summer of 1962, the productivity of the pond dropped to 182 kg/ha, and the individual gain of the 2+ fish was only 475 g. The unfavorable conditions encouraged disease (gill diseases and ichthyophthiriasis) and increased mortality. However, by autumn, the 2+ fish were in satisfactory condition and some of them (164 males) had reached sexual maturity. The mature males weighed somewhat less than average for their age (Figure 2). Five fish were dissected among those whose sex could not be determined. Of these, 4 (weighing 710, 960, 970 and 1,120 g) proved to be females with gonads at the 2nd stage of maturity, and ovaries weighing 0.5-3.2 g (maturity coefficient 0.06-0.45). The male weighed 960 g and had testes weighing 2.7 g.

By spring 1963, among the 3-year-old fish, 278 males had been found (31% of the total). All the fish in this age group were stocked with other breeding fish in whitefish pond No.1 (after being branded on the body with the sign A). Fertilizing the pond and adding cake and mixed food supplements (2,580 kg/ha during the summer) resulted in high productivity and weight gain as the summer was rather warm. The sex of most fish was distinguishable at age 3+, and males made up 49% of the population. Their weight and body build was inferior to that of the females (the weight difference was about 20%; Figure 3). The range of the weight distribution was high. The weight of females ranged from 1,300 to 2,600 g, including acute food competition in the pond that summer.

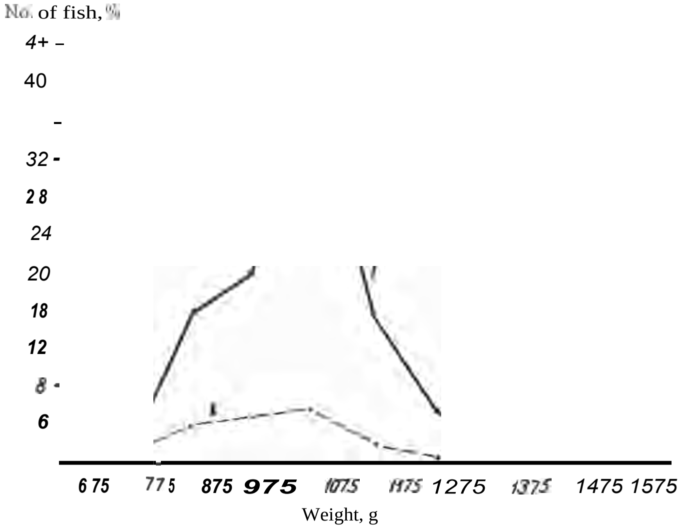

FIGURE 2. Distribution of weight of 3-year-old backcross hybrid spawner replenishment stock (autumn 1963):

1 —all hybrids; 2— sexually mature males.

[This and the following figure were numbered 3 in the Russian text, and the explanations were transposed.]

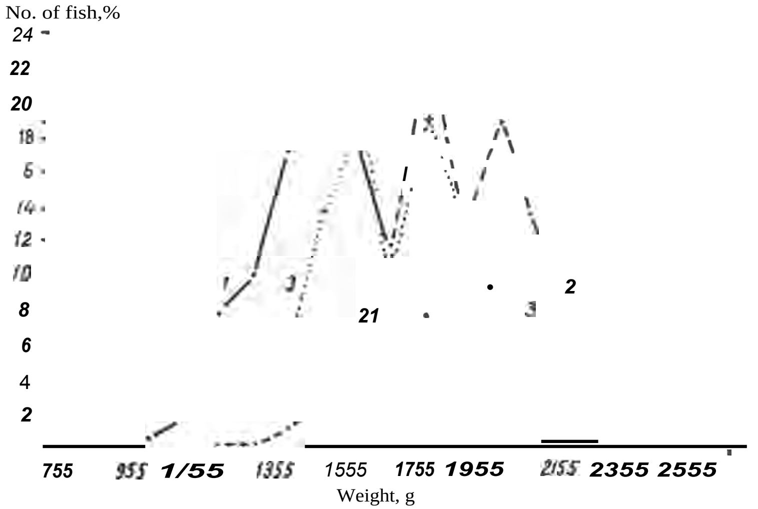

FIGURE 3. Distribution of weight of 3-year-old backcross hybrid spawner replenishment stock (autumn 1963):

1—males; 2— females; 3— sex undetermined.

Five 3+ hybrids were dissected in autumn 1963 to determine the stage of maturity and fertility. Four were females with ovaries at maturity stage III (Table 7).

The dissection showed that some females may mature by 1964, but they will probably be fit for commercial use only in 1965. The males were fully mature spawners in 1964.

TABLE 7. Maturity and fertility of 3+ backcross hybrids

Sex		Weight, g	Weight of gonads,g	Number of eggs/g	Total number of eggs, thousands	Coefficient of maturity
by habitus	on dissection					
9	9	1,670	82.9	1,755	145	4.96
9	9	1,730	63.2	1,990	130	3.76
Not determined	9	1,660	86.1	1,048	90	5.18
	9	1,750	33.4	2,432	81	1.90
"	d	1,750	103			5.88

b) Spawning of 1962 (2nd age group). One female that had spawned in 1960 and 2 new males were used in the 1962 backcross spawnings (see Table 3).

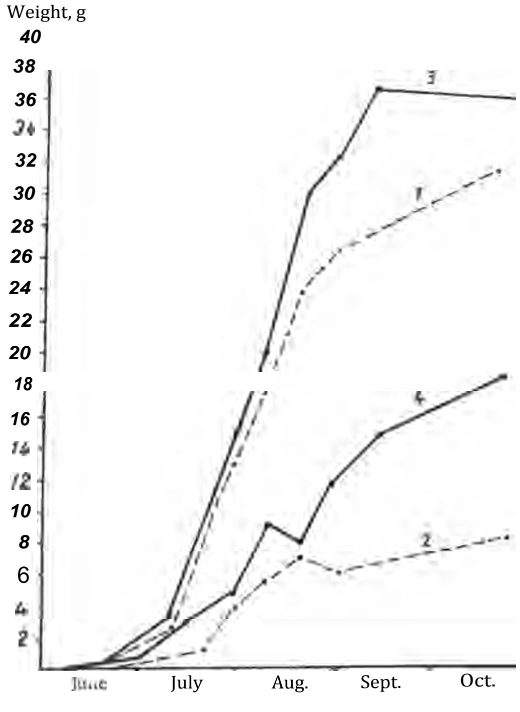

FIGURE 4. Cumulative weight gain of 4th generation hybrid underyearlings in fingerling pond No. 1:

1 —backcross hybrids, 1960; 2 —same, 1962; 3 — 4-way hybrids, 1964; 4 —same, 1963.

Fingerling pond No. 1 was allocated for raising underyearlings; larvae were stocked 9 days after hatching. Previously, in the spring, the pond bed was sown with a vetch-oat mixture; then organic fertilizers were added (see Table 4). In summer months, the underyearlings were given a food supplement, but they did not eat it well, and grew slowly. In autumn, the underyearlings were small, had low condition factors, but a satisfactory fat content. The low temperatures in the summer of 1962 were probably the main cause of the slight gain and poor productivity. The average monthly air temperature in June, July, and August was much lower than it had been in many years. From the second half of August, the underyearlings did not grow at all (Figure 4).

Mortality during overwintering was only 15%. After spring selection, the largest yearlings were stocked in whitefish pond No. 2. Use of an ample quantity of fertilizers and feeds (2,120 kg/ha mixed feeds were added during the summer) increased the productivity of the pond and led to a yield of large yearlings in good condition (see Table 6).

Thus, by autumn 1963, "Opochka" had 844 three-year-old and 1,007 yearling backcross hybrids. Half the 3+ fish were quite mature males; the other half were females, some of which matured in spring 1964. By that time, the 4th generation backcross hybrids were 843 fish aged 4+ (including 375 males and about 100 well matured females) and 987 aged 2+.

Raising 4th generation 4-way hybrids

Four-way hybrids were bred for spawner stock in 1961 and 1963.

Spawning in 1961 was not simultaneous, nor did the females spawn all their eggs. Quite probably, spawning was affected by the transportation of the spawners from "Ropsha" in the spring. The yield of larvae was small, but their weight was satisfactory (Table 8). In 1963 we used other spawners of the same strain (M) for natural spawning in pond No.2 very early (23-24 May). Judging from the quantity of fingerlings, the spawning was satisfactory although the weight of the fingerlings was low because of a sharp drop in temperature. At the same time as the natural spawning, one female and 3 males were isolated for artificial fertilization. Pituitary extract was used, but the quality of the eggs which resulted was poor; many were dead or degenerate. About 100,000 eggs were cleaned by Voinarovich's method (Voinarovich, 1962) and were incubated in an improvised Weiss apparatus. Three days later, the eggs were placed on frames; the hatched larvae rolled down into a tank-receptor.

After 2 days, the larvae, fed on plankton, were stocked for raising in the spawning pond. Unfortunately, the raising progressed poorly, and only 9,000 of the original 74,000 larvae survived (average weight 20 mg). The high mortality rate was due to the large number of predatory invertebrates in the pond. Table 9 lists the results of raising the 1961 and 1963 underyearlings.

Without dwelling in detail on the raising conditions in various years and ponds, we merely note that in 1961 very large quantities of fertilizers (Table 4) were used in pond No. 1. This, and the intensive supplementary feeding, explain its exceptional productivity. The catastrophic drop in productivity, and the negligible weight gain in 1962 are a direct result of the unfavorable weather, which probably also caused the outbreak of fatal epizootics. In 1963, productivity rose again. Although the 2+ fish did not become very heavy, they were fairly large and in good condition. The underyearlings were satisfactory as well.

Overwintering proceeded safely, and in 1961 there was a mortality of only 8.2% among the underyearlings; the yearlings in 1962 had a mortality of 2.7%.

TABLE 8. Spawning of 4-way hybrids (1961- 1963)

Year	Spawner No.		Average weight of females, g	Fertilization, %	Number of larvae recov-eredperfemale, thousands	Average weight of larvae at recovery, mg
	♀♀	♂♂				
1961	46; 56	0; 12; 50; 73	3,510	72.4	38.5	33.1
1963 (natural spawning)	20	46; 64	4,100	85.2	74.0	2.2
1963 (artificial fertilization)	29	22; 27; 33	3,890	86.0	74.0	0.6

TABLE 9. Raising of underyearlings, yearlings, and 2-year-old 4-way hybrids (1961- 1963)

Year	Pond	Age	Re ult of raising			Condition factor	Fat content, %	Total pro-ductivity, kg/ha
			number	average weight, g	mortality,%			
1961	Fingerling 1	0+	34,500	36.4	26	2.93	7.4	898
1962	Whitefish 2	1+	1,940	263	61.2	3.48		104
1963	Whitefish 1	2+	451	10.39	5.6	3.20		558
1963	{ Fingerling 1	0+	55,890	18.7	6.6	3.00	6.8	749
	Whitefish 1	0+	7,160	39.3	20.0	3.01	5.8	558

In autumn 1963, "Opochka" had a 4th generation 4-way hybrid population of 451 fish aged 2+, of which 75 were mature males (16%), and 32, 990 naturally spawned and 7,160 artificially spawned underyearlings selected for breeding.

In spring 1964, "Opochka' s" 4th generation 4-way hybrid population included 433 fish aged 3+ (including 120 males with determined sex) and 5,390 selected yearlings.

TABLE 10. Maturity of 2-year-old 4-way hybrids

Sex upon dissection	Weight of fish, g	Weight of gonads, g	Maturity coefficient
♀	800	6.1	0.76
♀	820	3.0	0.36
	1,080	3.3	0.28
♂	960	19.8	2.05
♂	1,050	13.7	1.30
♂	1,230	18.6	1.80

In autumn 1963, 6 fish aged 2+, the sex of which could not be determined from external appearance, were dissected to determine their maturity. Of these, 3 proved to be males with fairly well developed testes, the other 3 were females with ovaries at maturity stage II (Table 10).

Selection of hybrids during raising, and description of their habitus

The largest backcross and 4-way hybrids were selected as underyearlings or yearlings for breeding. The rates of selection of the three spawnings of hybrids were from 2.2 to 5.7% (Table 11). As a result of the stringent culling of the backcross hybrids, there was a substantial change in weight, improved condition factor, and 1/H index. Thus, in spring 1961, backcross hybrid yearlings had the following indexes:

		1/H
Before selection	2.59	3.03
After selection	2 71	2.97

For 4-way hybrid yearlings in 1962, the indexes were:

		1/H
Before selection	2.81	2.87
After selection	2 90	2.82

TABLE 11. Intensi y of selection of hybrids of various spawning years

Breed group	Spawning year	Age	No. of fish before and after selection	Selection intensity, %	Average weight before and after selection, Ii
Backcross hybrids	1960	1 1+ 2+	56,200-4,535 3,634- 1,000 915-896	8.0 27.51 2.2 97.8	29.2-47.4 481.0-563.0 990.0- 993.0
	1962	1 1 +	41,120- 5,000 4,328- 1,007	12.1) 2.4 23.1	6.5- 11.5 543.0- 655.0
4-way hybrids	1961	1 1+ 2+	31,700- 500 1, 940- 515 465-451	15.7 27.6 } 5.7 97.0	31.8-37.3 263.0-330.0 1,030*

* No selection made.

Marked changes were also achieved upon selection of yearlings.

TABLE 12. Habitus of hybrids of two strains

Age	Backcross hybrids			4-way hybrids		
	year		1/H	year		1/H
1+	1961 1963	3.10 3.30	2.71 2.68	1962	3.48	2.65
2+	1962	2.99	2.90	1963	3.20	2.86

Finally, we note the fairly marked differences between the habitus of backcross and 4-way hybrids. Thus, in backcross hybrids, the condition factor was lower than in the 4-way hybrids, but the 1/H index was higher (Table 12).

The differences in the origin of these 2 strains of hybrids still show their effect in the 4th generation. The backcrosses are closer to the "eastern carp" than are the 4-way hybrids.

CONCLUSIONS

1. By autumn 1964, the 29 northern hybrid carp of the 3rd generation stock population which had been transferred to "Opochka" from "Ropsha" consisted of 2 female and 6 male backcross hybrids, and 12 female and 9 male 4-way hybrids.
2. During 1960-1964 the following number of 4th generation northern hybrid spawner stock was raised at "Opochka": 843(including 400 sexually mature males) backcrosses aged 4+, 987backcrosses aged 2+, and 433 (including 120 males) 4-way hybrids aged 3+, with 5,390 yearling 4-way hybrids. All the young spawners had generally satisfactory weight and good condition factors.
3. Mass selection primarily by weight was made only among under-yearlings and yearlings. The intensity of selection was from 2.2 to 5.7%. The strict selection certainly contributed to the successful raising of a large quantity of quality spawner replacements at "Opochka."
4. In autumn 1964, the nests of commercial spawners consisting of backcross females and 4-way males were formed. Altogether, 186 backcross females and 300 backcross males aged 4+ were sold, as were 159 male 4-way hybrids aged 3+.

Thus, the demand for spawners in all commercial fish farms of the Pskov Region has been met. In addition, some of the spawners were sent to fish farms of the Northwest Administration and the Latvian SSR.

Bibliography

And r iy ashev a, M. A. Geterozis pri vnutrividovykh skreshchivaniyakh karpa (Heterosis in Intraspecific Crossings of Carp). In this Collection.

B au e r, O. N. and I. G. Sh chupakov. Instruktsiya po borb'e s ikhtio-ftiriusom (Instructions on the Control of Ichthyophthiriasis). Leningrad. 1956.

Kirpichnik o v, V. S. Pervye itogi i zadachi rabot po organizatsii plemennogo dela na Severo-Zapade RSFSR (Preliminary Results and Further Tasks of the Organization of Selective Breeding in the North-western RSFSR). In this Collection.

Konradt,A.G.,A.M.Sakharov,and M.A. Zhivotova. Raboty po inkubatsii obeskleennoi ikry karpa i vyrashchivanie iz nee lichinok (Incubation of Cleaned Carp Eggs and the Raising of Larvae). —Rybnoe Khozyaistvo, No. 6. 1963.

V oina rovich, E. Inkubatsiya ikry karpa i podrashchivanie desyatidnevnykh lichinok (Incubation of Carp Eggs and Raising Larvae to 10 Days). — Rybnoe Khozyaistvo, No. 9. 1962.

EVALUATION OF THE FISHERY QUALITIES OF NORTHERN HYBRID CARP IN FISH FARMS OF THE PSKOV REGION

Z. T. Romanova, B. E. Petrov, and N. I. Zabegalina

The work on hybrids carried out in fish farms of the Pskov Region in 1959 and 1960 proved that 4th generation underyearling northern hybrids are more winterhardy and grow faster than sparse-scale carp. In 1961-1963, the evaluation of winterhardiness, general viability, growth, fertility, and other indexes of 3rd generation hybrids continued. Unfortunately, the planned program was disrupted by fish diseases (among the spawners as well) and the 1962 spring-summer cold spell. The evaluation was also hampered by the lack of required pond areas.

Nevertheless, we present an account of our evaluation in the hope that it may help in planning the development of pond farming in the northwestern RSFSR.

Spawning and fertility

In 1964 eleven nests of 3rd generation northern hybrids of both strains were stocked for spawning at "Opochka." Only 6 females spawned; the rest did not lay their eggs probably because of injuries caused by quicklime burns. The fish were spawned in ponds with an area of 0.06 to 0.1 ha each. At the same time, northern hybrids were spawned en masse in a 0.8 ha sedimentation pond at the "Velikie Luki" fish farm. This spawning used 8brood stocks of 4-way hybrids, heterozygous for scale factor S, which had just been brought from "Ropsha." The spawning was simultaneous and rapid.

In 1962, all the spawners in "Opochka" became infected with ichthyophthiriasis, as well as a gill disease unknown to us. That, and the poor weather gravely affected the spawning, which was intermittent, prolonged, and usually required pituitary extract injections. Ten of 11 females had spawned, but in 2 spawning ponds (4 nests) we had to destroy the larvae because of their ichthyophthiriasis infection.

In spring 1963, the spawners were given a prolonged salt bath treatment right in the pond (Bauer and Shchupakov, 1956), after which 10 nests of northern hybrids and 2 nests of sparse-scale carp were stocked for spawning. As the water was warm, the fish spawned very early, on 21 May. The females did not lay all their eggs at once; there was reason to assume that a repeat spawning occurred in several ponds 3-4 days later. The larvae grew very slowly because of a sharp temperature drop (from 20-24° on 22-25 May to 12° on 3 June). Upon recovery, the weight of the larvae varied widely (never exceeding 6 g) and viability was low.

Except for 4 ponds, the spawning ponds in "Opochka" were swamped and intensely overgrown with sedge and other swamp plants, despite the yearly clearing and introduction of fertilizers. Thus, the food supply was relatively low, and the results of the spawning period were mediocre.

The fertility of northern hybrids was determined by the difference between the weight of the females before and after spawning. Carp roe is assumed to contain 1,000 eggs/g. Our females laid 350,000-500,000 eggs (Table 1). This figure is probably understated by 50,000-100,000 as the females gained 50—100 g during their stay in the spawning ponds. Thus, fertility of about 400,000-600,000 *eggs* (120,000-150,000/kg) is probably characteristic of female backcross and 4-way hybrids weighing 3-4 kg. Similar indexes were obtained in 1960 by Bogatova and Romanova (1961). This fertility level is satisfactory. Moreover, there are few sterile female northern hybrids. The fertility of sparse-scale carp was similar but the data on them are few.

TABLE 1. Results of spawning of northern hybrids (M — 4-way, B — backcross hybrids)

Farm	Year	Breed and No. of spawners		Average weight before spawning,	Weight loss of 1 female during spawning, g	Average weight at recovery, mg	Larvae recovered per female, thousands
		♀♀	♂♂				
Hybrids							
"Opochka"	1961	M (2)	M (4)	2,980	80*	33.1	38.5
		M (4)	B and NI (8)	3,400	385	33.6	78.0
"Velikie Luki"	1961	M (8)	M (16)	4,050	388	24.3	98.3
"Opochka"	1962	B (1)	B (2)	3,280	70	11.4	110
		M (8)	B and M (16)	3,640	485	6.6	93.8
"Opochka"	1963	M (1)	M (2)			2.2	74.0
		B (2)	NI (4)			2-5	101.5
		M (6)	B (18)			2-5	85.2
"Velikie Luki"	1963	M (8)	B (32)			about 10	100
Sparse-scale carp							
"Opochka"	1961	1	2			23.1	105.0
	1962	2	4			4.0	66.0
	1963	2	4			3.9	100.5

Data are for or ly one female.

The number of larvae of northern carp hybrids recovered varied greatly between ponds. On the average we recovered 85,000-100,000 per female; the maximum yield was 144,000.

The percentage of egg fertilization in northern hybrids and sparse-scale carp is about the same (Table 2); nor were there substantial differences between the growth rates of hybrids and carp larvae in the spawning ponds. However, comparison of data on the weight of larvae for all 4 years at "Opochka" reveals that the hybrids were almost always somewhat larger than the carp at recovery. This difference can hardly be due to chance.

TABLE 2. Fertilization of eggs of northern hybrids and carp in natural spawning

Year	Farm	No. of fertilized eggs,%
	Hybrids	
1961	"Velikie Luki"	87.3
1961	"Opochka"	76.8 (60.0— 84.0
1962		92.4 (82.8— 96.8)
1963		89.0(83.1— 96.2)
	Carp	
1961	"Opochka"	82.4
1962		90.1 (88.4— 91.0)
1963		90.0 (87.9— 92.4)

TABLE 3. Time and results of northern hybrid spawning

Farm	Year	Spawning dates	Recovery dates	Water temperature, °C		Average No. of larvae recovered per female, thousands
				during spawning	average for entire spawning period	
"Velikie Luki"	1961	1 June	10-11 June	21 — 22	21.8	98.3
"Opochka"	1961	31 May —3June	12— 13 June	22	22.9	68.2
	1962	4— 14 June	23— 28 June	15-18	16.2	96.5
"	1963	22— 27 May	5— 11 June	19-22	18.7	88.3

The temperature of the spawning ponds varied widely over the years (Table 3). As evidenced in the table, even under extremely unfavorable conditions (1962 and 1963), the spawning of hybrids gave a satisfactory yield. The results might have been even better had the spawners been maintained in better condition, diseases eliminated, and the productivity of spawning ponds increased.

Raising underyearling hybrids and carp

a) General description of the underyearling raising ponds. In 1961-1963 in "Opochka," yearling northern hybrids and carp were raised together in raising ponds No.1 and 2, and in fingerling pond No.2. In addition, in 1961, hybrids and local mongrel fish were raised separately in 2 raising ponds at the "Velikie Luki" farm.

Raising ponds No. 1 (12 ha) and No. 2 (10 ha) in "Opochka" are swamped; there is peat over much of them, and they are intensely overgrown with pondweed milfoil, water thyme, sedge, and other aquatic plants. The natural productivity of these ponds was small at the start of the experiments.

Fingerling pond No. 2 (2 ha) in "Opochka" has a loamy bed, and is sparsely overgrown in summer. Raising ponds No. 1 and 2 at "Velikie Luki" (total 21 ha) have a hard, clayey, and sandy bed covered with several years' accumulation of silt. These ponds have little overgrowth, primarily pond-. weeds, arrowhead, water thyme, and in some places, sedge. The ponds get most of their water from the runoff of arable lands.

Both at "Opochka" and "Velikie Luki," the pond water contains calcium bicarbonate, over 200 mg/l salt content. Such water contains ample calcium and is quite suitable for carp breeding (Kirpichnikov et al., 1960).

Lime and fertilizers were added to the experimental ponds to increase the natural food supply; the quantity of fertilizers is listed in Table 4. In some cases, a large quantity of mineral fertilizers was introduced, and the effects may have continued for subsequent years. Relatively little fertilizer was used in the "Velikie Luki" ponds, the amount of nitrogen having been especially small.

TABLE 4. Liming and fertilization of raising ponds

Year	Farm	Pond		Quantity of lime and fertilizers, kg/ha				
				lime	super-phosphate	ammonium sulfate	potassium chloride	manure
1961	"Opochka"	Raising	1	420	1,190	360	0	850
		Fingerling	2	15	720	800	60	2,000
1961	"Velikie Luki"	Raising	1	1,140	170	60	1	570
			2	1,130	120	20	1	870
1962	"Opochka"	Raising	1	750	110	350	5	2,100
			2	950	85	55	6	2,500
1963	"Opochka"	Raising	1	33	140	495	—	2,090
		Fingerling	2	2,550	205	470	—	2,000

TABLE 5. Biomass of zooplankton and benthos in raising ponds

Year	Farm	Pond		Biomass of zooplankton, g/m				Biomass of benthos, g/m² (average for July — Sept.)
				July	Aug.	Sept.	Average for July — Sept.	
1961	"Velikie Luki"	Raising	1	6.2	6.8	6.7	6.6	10.0
			2	7.0	9.6	5.9	7.5	17.0
1862	"Opochka"	Raising	1	1.8	0.6	0.1	0.82	18.0
			2	2.6	0.5	0.07	1.03	26.9
1963	"Opochka"	Raising	1	6.3	3.6	3.9	4.6	4.4
		Fingerling	2	6.1	6.5	2.8	5.1	6.1

In 1963 in "Opochka," enough fertilizer was introduced every 10 days to maintain concentrations of 2 mg/l nitrogen and 0.5 mg/l phosphorus (Vinberg, 1956; Lyakhnovich, 1963); no fertilizers were added after 10 August due to their scarcity.

The food supply in the ponds of the Pskov Region was comparatively high in 1961.

In 1962, an unfavorable year for carp breeding, the "Opochka" raising ponds were very poor in zooplankton, but the benthos biomass was ample, 33 g/m^2 in August. The fish did not eat the benthos well because of the cold, and the midges emerged late.

In 1963, both the weather arid the regular use of fertilizers encouraged the proliferation of edible organisms. The plankton biomass was fairly high, particularly in June and July, as was the benthos as well. By autumn, the abundance and biomass of zooplankton and benthos had dropped. The drop in plankton could have resulted from the termination of fertilizer supplement, while the decline in benthos may have been due to the emergence of the midges, which the fish consumed very readily. The benthos of "Opochka" pond No.1 had a larger proportion of Oligochaeta than midges, while in fingerling pond No.2 the situation was reversed; thus, the benthos of the latter was more nourishing.

The underyearling hybrids and carp can thus be compared under many different food and temperature conditions.

b) Growth and survival rate of underyearlings. In 1959 and 1960, Bogatova and Romanova (1961) raised hybrids and carp in the Pskov Region, obtaining the following weight indexes (at autumn recovery), g:

Year	Pond	Hybrids	Carp
1959	Fingerling 1	14.2	9.9
1959	2	12.8	10.2
1960	Raising 1	20.1	16.2
1960	2	17.0	11.9

The inaccurate count of larvae at stocking in 1959 made impossible the comparison of survival rates of hybrids and carp. The 1960 count was more accurate; the mortality of carp in raising ponds exceeded that of hybrids by 2— 4%, but this difference is not significant.

The results of raising the underyearlings in 1961-1963 are presented in Figures 1 and 2. In one pond in "Opochka" the hybrids surpassed the carp in growth in 1961, but no other differences were found. "In Velikie Luki,"where northern hybrids and mongrels were raised separately, the hybrids in pond No. 2 were somewhat larger than the carp in autumn. This difference might have been still greater if only sparse-scale underyearlings had been compared (due to heterozygosity of spawners, this pond had more than 21% sparse-scale hybrids).

The raising of hybrids and carp in 1962 was of particular interest because of the cold weather. The sparse-scale carp gained less weight than hybrids in both ponds (Figure 1). This lag may have been due partly to the difference in weight at stocking, but it was mostly due to the greater tolerance of the hybrids for low temperatures. The cold summer also affected the hybrids, however; infestation of underyearlings with ectoparasites was sharply increased among them as well. Both hybrid and carp underyearlings had high mortality in 1962, but the survival rate of carp was much lower. It was especially low in the less trophic raising pond No. 2, where only 6.1% of the sparse-scale carp larvae stocked survived.

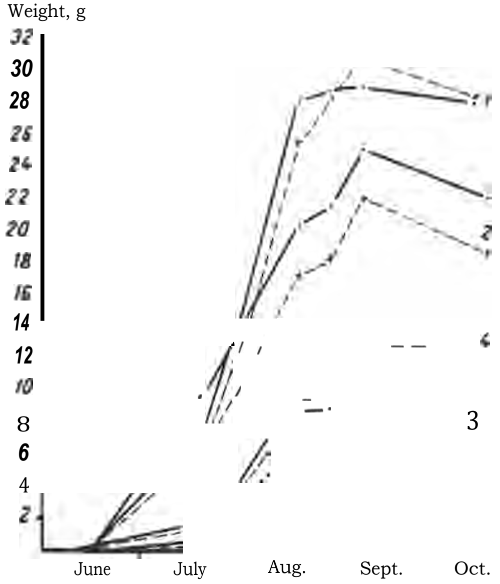

FIGURE 1. Cumulative weight gain of underyearling hybrids and sparse-scale carp ("Opochka," 1961—1963):

continuous lines designate hybrids; broken lines designate carp: 1— fingerling pond No. 2, 1961; 2—raising pond No. 4, 1961; 3—raising pond No.1, 1962; 4— fingerling pond No. 2, 1963.

In 1963 in fingerling pond No. 2, with very dense stocking and warm summer, weight difference between hybrids and carp was small (less than 5%). This may have been because carp eat artificial food more readily and the food supplement had been increased that year.

Growth and survival rates of larvae were compared in ponds with a low (1962), average (1961), and high (1963) productivity. The advantages of hybrids became most apparent in oligotrophic ponds in the cold year.

c) Fatness and condition of the underyearlings. The condition factor of the underyearlings in "Opochka" was not always high (Table 6). Because of their streamlining, hybrids have a condition factor which is usually lower than that of carp; however, if their growth is stunted, carp may have an even greater condition factor than hybrids [sic]. Higher indexes were disclosed in hybrid underyearlings from the "Velikie Luki" farm (1961). The fat content of most carp underyearlings was higher than that of hybrids. In the cold year 1962, this difference was hardly noticeable. In 1963, the carp of raising pond No. 1 had less fat than those of fingerling pond No. 2. This was probably because the former were mixed with mongrel underyearlings resulting from uncontrolled spawning, perhaps even hybrids.

TABLE 6. Condition and fatness of underyearlings of northern hybrids and carp

Year	Farm	Pond	Condition factor		Fat content, %	
			northern hybrids	carp	northern hybrids	carp
1961	"Velikie Luki"	Raising 1		3.45	—	'7.8
		2	3.23	—	5.4	
1961	"Opochka"	Raising 1	2.81	2.94	4.9	8.1
		Fingerling 2	2.97	2.88	6.1	10.1
1962	"Opochka"	Raising 1	2.47	2.83	4.32	4.6
		2	2.82	2.71	3.82	4.03
1963	"Opochka"	Fingerling 2	2.96	3.11	8.4	11.0
		Raising 1	2.93	2.99	6.9	4.3

d) Food consumption of underyearling hybrids and carp. The indexes of intestinal content of northern and mongrel hybrids were the same at "Velikie Luki" in 1961. In 1962, the indexes of intestinal content were somewhat higher, on the average, in hybrids than in carp (Table 7). Similar findings were made in 1963 in the raising pond, but here again, the presence of underyearlings from uncontrolled spawning should be taken into account. In the other pond, the difference was small in 1963.

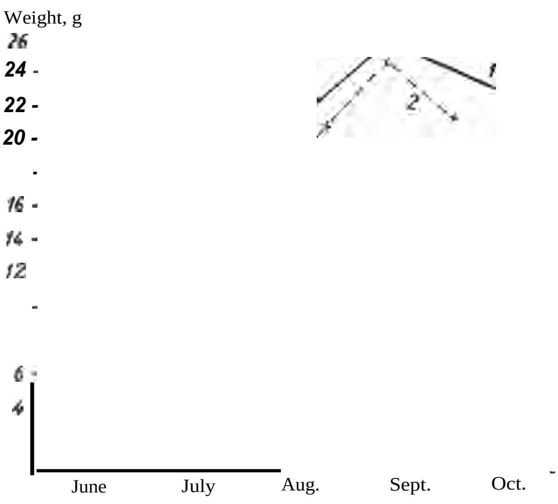

FIGURE 2. Cumulative weight gain of underyearlings of northern hybrids and mongrels ("Velikie Luki, "1961):

1 – northern hybrids (scaly and sparse-scale) of pond No. 2; 2 – mongrel hybrids of pond No. 1.

Analysis of the intestinal content of underyearlings in 1962 showed that the hybrids ate a larger proportion of midges than the carp. This was also found in 1963. Thus, in raising pond No. 1, benthos was found in the intestines in 70% of the sample of hybrids and in 45% of the sparse-scale carp. For fingerling pond No. 2, these figures were 53 and 26% respectively. It follows that hybrids are better at finding natural food.

Underyearlings were given artificial food in all ponds in 1961 and 1963. We tried to depict the natural and total productivity of ponds graphically, using the data on diets and increment of underyearlings (Kirpichnikov, 1960, 1963).

TABLE 7. Indexes of intestinal content of underyearling hybrids and carp ("Opochka")

Pond and year	Breed group	Content indexes,						
		15-21 July	30 July	10 Aug.	20 Aug.	30 Aug.	14 Sept.	average
Raising 1,1962	Northern hybrids	532	583	521	485	422	–	508
	Sparse-scale carp	494	584	528	441	346		478
Raising 1,1963	Northern hybrids	586	438	585	324	460	625	495
	Sparse-scale carp	316	303	531	341	339	561	399
Fingerling 2,1963	Northern hybrids	621	766	632	660	604	604	647
	Sparse-scale carp	568	687	606	594	722	649	637

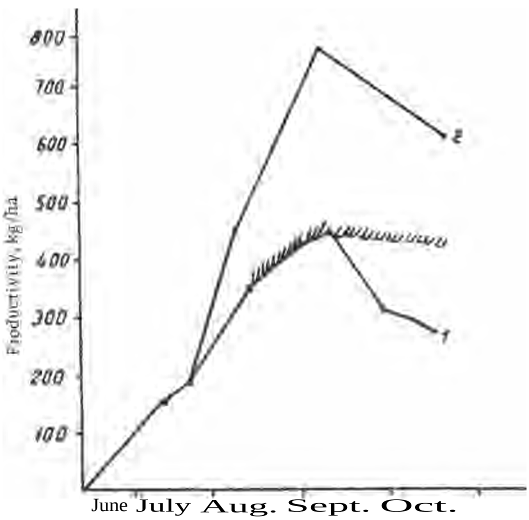

FIGURE 3. Natural (1) and total (2) productivity ("Velikie Luki," raising pond No. 2, 1961):

broken line is the lowest level of natural productivity.

We calculated that in 1961, the natural productivity of "Velikie Luki" pond No.2 was at least 420 kg/ha, i. e., 67% of the total productivity (Figure 3). Thus, the conversion ratio for the supplementary food was at least 13. In 1962, the underyearlings ate practically no artificial foods because of the low temperature of the water.

We took fingerling pond No. 2, which had the highest productivity, as an illustration for 1963. The conditional conversion ratio (the ratio of the weight of the all the artificial food to the total weight gain) was 4.3. Assuming that the conversion ratio is 6.5, we obtain a minimum natural productivity of about 500 kg/ha, and a conversion ratio for artificial food of not less than 8.5 (Figure 4).

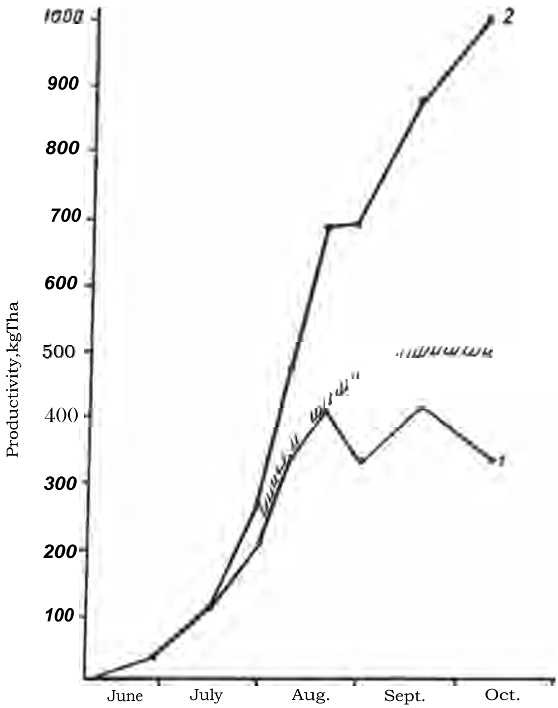

FIGURE 4. Natural (1) and total (2) productivity ("Opochka," fingerling pond No.2,1963). The designations are the same as in Figure 3.

These figures clearly indicate the great significance of natural food in raising the underyearlings, and their poor use of artificial food. The greater affinity of northern hybrids for benthos is thus of particular importance. Selective breeders must encourage hybrids to eat artificial foods.

Overwintering of underyearling northern hybrids and carp

Both in ponds and in pools, the hybrids withstood the winter of 1959-1960 better than carp at "Opochka" (Bogatova and Romanova, 1961). The hybrids [illegible] 1960-1961. T[illegible], [illegible] N[illegible]. 1, [illegible] N[illegible]. 2, [illegible] 13.6% [illegible] 1.1% [illegible].

T[illegible] 1961-1962 [illegible] N[illegible].1 [illegible] "Opochka." N[illegible] (T[illegible] 8). I[illegible] 4 [illegible], [illegible] 21-23%, [illegible]. I[illegible], [illegible], [illegible], [illegible] F[illegible] M[illegible].

TABLE 8. Overwintering of underyearl ng northern hybrids and carp

Farm and year	Place of overwintering	Hybrids			Carp		
		No. recovered	average weight, g	mortality,%	No. recovered	average weight, g	mortality,%
"Opochka," 1961/62	Overwintering pond 1	74,000	19.0	Negligible	38,000	19.0	Negligible
	Pools 1-4	41,100	15.0	21.3	18,700	15.0	23.3
	" 5-7	–	–	–	0*		100
"Opochka," 1962/63	Overwintering pond 2	89,110	10.9	20.1	3,480	7.3	40.3
"Velikie Luki," 1961/62	1	35,200	22.2	68.9	–	–	–
	2	33,400	22.2	81.6	–	–	
	4	23,400	22.2	82.0	–	–	–
"Opochka," 1963/64	2	66,320	20.7	4.6	45,520	20.1	26.0
	Pools	121,000	24.6	19.6	18,900	27.6	51.2

* Pools No.5-7 were stocked with local mongrels and ca p.

I[illegible] "Velikie Luki," [illegible] 4-[illegible] 1961-1962 [illegible] 3 [illegible], [illegible].
U[illegible].

L[illegible]. T[illegible] 0.7 [illegible] 0.9 [illegible]; [illegible] L[illegible] K[illegible] (4.4-9.1 mg/l). I[illegible] (M[illegible]-A[illegible]) [illegible] 3 [illegible]. T[illegible] 0.7-0.8° [illegible] M[illegible] 0.4° [illegible] A[illegible].

T[illegible] M[illegible]; [illegible], [illegible] C[illegible], [illegible].

Apparently, the main cause of the high mortality was improper operation of the wintering ponds. Abrupt changes in circulation always cause fish movement, and, if changes occur during a drop in temperature, they bring disease and death.

The winter of 1962-1963 was very cold — the air temperature on some days dropped below —40°. In these conditions it is especially important to maintain optimum water circulation in ponds during the entire winter, and to guard against sharp drops in the temperature near the bottom.

In overwintering pond No. 2 (area 0.6 ha), where northern hybrids and carp were wintering, water circulation was slow for 52 days, and the entry of water into the pond was stopped completely from April.

This avoided a drop of temperature to the danger level (below 0.6-0.5°); at the inflow near the bottom, water temperature was maintained at 1.5-2° almost all winter.

Until February, the underyearlings were fairly free of parasites. The control recovery on 28 February showed a rather severe infestation of the following parasites:

	Degree of infestation,%
Chilodonella cyprini	100 (1 — 67 in visual field)
Trichodina domerguei	100(1-27
Ichthyophthirius multi finis	30 (1 — 10 per fish)
Dactylogyrus solidus	30(1-18

In addition, Vorticella was abundant.

Despite the increasing infestation, no fish movement was observed until the middle of April. In late April and early May, when water temperature rose to 14°, there was a second infestation of Ichthy o phthirius which caused high mortality among the yearlings. Untimely recovery from the overwintering pond was the main reason for the spring infestation.

At spring recovery, it was evident that the hybrids had again overwintered better than the carp. This was also true for the winter of 1963-1964 (Table 8).

According to Petrov and Romanova (this collection), hybrid underyearlings raised as spawner replenishment had overwintered safely in "Opochka" in all previous years, mortality being 7.2% for 1960-1961, 8.2% for 1961-1962, and 15% for 1962-1963. All these observations indicate that the hybrids are very winterhardy, and obviously superior to sparse-scale carp.

Raising yearlings

The first experimental evaluation of yearlings of northern hybrids and sparse-scale carp was done at the Shipulino fish farm in 1960. The stock consisted of yearlings brought from "Opochka" in spring and stocked in pond No.9. According to Bogatova and Romanova (1961), the hybrids and carp grew at almost the same rate; their autumn weight averaged 387 and 384 g respectively. The mortality could not be determined.

In 1962, 4-way hybrids (scaly and sparse-scale) were stocked together with carp in foraging pond No.3 at "Velikie Luki." While the autumn weight samples of both of them were about the same (225 and 227 g), the survival rate showed that hybrid mortality was only about 3% while that of the carp was 65%.

Somewhat different results were obtained in "Opochka" in 1962. Here, the weights were low, as everywhere in the northwest that year, but the hybrids weighed 203 g, or 10% less than the carp, which weighed 222g. The survival rate of hybrids was 85.6% while that of the carp was 82.5%.

The fat content of the hybrid yearlings was somewhat below that of the carp. Thus, in the "Opochka" whitefish pond, their fat content was 14.5% of wet body weight in hybrids, and 16.3% in carp, while these values at "Velikie Luki" pond No. 3 were 9.9 and 11.8 respectively. The difference in the fat content is also an indirect indication of the great importance of natural food in the diet of hybrids and artificial food for the carp.

CONCLUSIONS

1. The fertility of northern hybrids of the 2 strains (4-way and backcross) proved to be adequately high; it was about 400,000-600,000 eggs per female weighing 3-4 kg (120,000-150,000/kg of female weight). About 90,000-100,000 northern hybrid larvae per female were recovered from the spawning ponds; this is somewhat higher than the carp larvae yield. In cold years, the hybrid larvae yield from spawning ponds was not lessened while that of carp dropped 55%.
2. The hybrids and carp had substantially the same percentage of egg fertilization and growth rate of larvae in spawning ponds. Nonetheless, the carp larvae were generally smaller than hybrid larvae when transferred to raising ponds.
3. In all cases, by autumn,northern hybrids weighed more than sparse-scale carp underyearlings; the average difference was 15-20%. In the cold summer of 1962, carp were even further behind; although all the fish were stunted, the hybrids were twice as heavy as the carp.
4. Underyearling hybrids ate more natural food (benthos), while carp ate more artificial (vegetable) food. Fvidently, this is why the fat content was a little higher in carp than in hybrids.
5. The northern hybrid underyearlings generally overwintered safely, with low mortality. The winter survival rate of sparse-scale carp was much lower than that of the hybrids.
6. Yearling hybrids and carp grow at about the same rate.

Bibliography

Bauer, O. N. and I. G. Shchupakov. Instruktsiya po bor'be s ikhtioftiriusom (Instructions on the Control of Ichthyophthiriasis). Leningrad. 1956.

Bogatova, I. B. and Z. T. Romanova. Vyrashchivanie i zimovka gibridov 4-go pokoleniya v rybkhozakh Pskovskoi oblasti (Raising and Overwintering 4th Generation Hybrids in Fish Farms of the Pskov Region). —Fondy GosNIORKh. 1961.

Kirpichnikov, V. S. Opredelenie estestvennoi ryboproduktivnosti prudov i oplaty korma karpom (Determining the Natural Productivity of Ponds and Return of Supplementary Feeding of Carp). — Moskva, Izdatel'stvo "Rybnoe khozyaistvo." 1960.

Kirpichnikov, V. S. Znachenie estestvennogo i iskusstvennogo korma privyrashchivaniisegoletok karpa (Importance of Natural and Artificial Food in Raising Carp Underyearlings). —Gidrobiologiya i Ikhtiologiya Vnutrennikh Vodoemov Pribaltiki, Vol. 7. 1963.

Kirpichnikov, V.S., N.A. Mosevich, O.N. Bauer, and V. I. Protasova. Optimal'nyi rezhim zimoval'nykh prudov dlya segoletok karpa, amurskogo sazana i ikh gibridov (Optimum Conditions in Overwintering Ponds for Underyearlings of Carp, "Eastern Carp," and their Hybrids). —Trudy Vsesoyuznogo Gidrobiologicheskogo Obshchestva, Vol. 10. 1960.

Lyakhnovich, V. P. Ekonomicheskaya effektivnost' udobreniya rybovodnykh prudov (Efficacy of Fertilizing Fish Ponds). —Rybnoe Khozyaistvo, No.5. 1963.

Petrov, B.E. and Z. T. Romanova. Plemennaya rabota s severnymi gibridnymi karpami v Pskovskoi oblasti (Selective Breeding of Northern Hybrid Carp in the Pskov Region). In this Collection.

Vinberg, G. G. Mineral'nye udobreniya rybovodnyk prudov (Mineral Fertilizers of Fish Ponds). Minsk. 1956.

Part Two

INTENSIFICATION OF FISH BREEDING IN PONDS

AN ARTIFICIAL METHOD FOR PRODUCING COMMERCIAL FISH LARVAE

A. G. Konradt and A. M. Sakharov

Introduction

Like natural fish breeding, pond fish breeding depends on the natural spawning of the brood stock. This breeding method deprives pisciculturists of the opportunity to control and improve the breeding process at the stage of reproduction which is most crucial. Then too, the conditions of spawning vary from year to year. The character of the spawning substrate changes; the degree of destruction of eggs and larvae by fish and predatory invertebrates, weather, and many other factors which influence spawning vary. Thus, the effectiveness of natural spawning, even in well prepared spawning ponds, varies widely.

This is particularly noticeable in the large ponds of hatchery-nursery farms. In natural spawning, the brood stock are in contact with their progeny for a long time. They eat the food supply and are a source of various diseases, creating a constant threat of epizootics. As a result, replenishment of the fish reserves by natural spawning in ponds is not much more efficient than natural replenishment in natural conditions.

Artificial insemination and incubation in fish hatcheries is less dependent on seasonal phenomena, and is completely controlled by man. Artificial maintenance of eggs eliminates contact of the spawners with their progeny; this helps keep pond farms disease-free,and decreases mortality of young. Artificial reproduction of pond fish in the hatchery is also promising for selective breeding, since it can yield a large number of young from many special crossings. However, the evolved ability of eggs of the common commercial carp and some other spring spawning fish to adhere to the substrate appeared to be an almost insurmountable obstacle to the incubation of the eggs in hatching devices. Until recently, there were no efficient methods of incubating eggs of carp, wild carp, bream, and other species.

Removing the mucoid envelope of the eggs by a suspension of silt or by repeated rinsing with water gave satisfactory results for only a limited number of species, while incubation of eggs in their viscous state on various substrates is still in the stage of development. Therefore, a new method for removing the mucoid envelope of the eggs of common commerial fish is necessary.

A method of removing the mucoid envelope of carp eggs by solutions of sodium chloride and urea was recently suggested by E. Voinarovich (Voinarovich,1962; Voynarovich,1962). This was satisfactory but time-consuming. In the climate of the Leningrad Region this method took 5-7 hours.

Since 1962, the GosNIORKh laboratory has been investigating removal of the mucoid envelope by the Voinarovich and other methods. The most encouraging results were obtained with the enzyme hyaluronidase and with tannin. The use of aqueous solutions of hyaluronidase for cleaning carp eggs was suggested by V. I. Tets (1963). Results of our first experiments with Voinarovich solutions and with hyaluronidase have been published previously (Konradt,Sakharov and Zhivotova,1963; Konradt and Sakharov,1963).

Hyaluronidase, a constituent of the seminal fluid, is found in the testicles of higher vertebrates, and participates in the process of fertilization. Thus, use of hyaluronidase for cleaning fish eggs during insemination or immediately thereafter should not disturb the process of fertilization.

In 1963 we suggested the use of aqueous solutions of acetone-treated vertebrate testicles to clean carp and orfe eggs. Treatment of testicles with acetone and subsequent preparation of active, dry powder make it possible to prepare the necessary dose in advance, and reduces the amount of impurities in the solution. Since many fish breeding farms may have difficulty in obtaining fresh vertebrate testicles as needed, we have appended a description of our process and apparatus for acetone treatment of testicles.

Experimental production of carp larvae by artificial methods

The technique of cleaning carp eggs with solutions of hyaluronidase was described by Konradt and Sakharov (1963). There we presented data illustrating that hyaluronidase obtained from fresh pig testicles is harmless, and that the method makes it possible to remove the mucoid envelope of fish eggs in 20-30 minutes. Subsequently we discovered that the process requires 20-60 minutes depending on the water temperature and quality of the testicles. Hyaluronidase powder from acetone-treated ox testicles proved to be less active than preparations from pig testicles.

In all, in 1963 over 970,000 carp eggs were cleaned with hyaluronidase, yielding 600,000 larvae, i. e., 63.4% of all the incubated fish eggs (Table 1).

TABLE 1. Incubation of carp eggs, after cleaning in a solution of hyaluronidase, in 1963

Place of investigation	Water temperature during incubation, °C	No. of incubated eggs, in thousands	Mortality during incubation, %	No. of larvae, in thousands
"Ropsha" station "Gostilitsy"	15-18	188.5	31.6	128.7
Central section. .	16-20	400.0	50.0	200.0
Karelia(Dmitrenko, this collection)	12-18	385.0	25.0	289.0

Note. The high mortality of eggs in the central section of "Ropsha" is a result of their transfer, after cleaning, to Karelia. Total mortality in this table is composed of mortality during incubation at "Ropsha" (33.2%). during transportation (4.5%), and during further incubation and hatching in Karelia (12.3%).

To clean fish eggs in 1963, we used a 10% solution of fresh extract of pig testicles; in Karelia, Yu. S.Dmitrenko (this collection) used a powder derived from acetone-treated testicles. In both cases, the process took 25 to 35 min at 16−20 .

Incubation of carp eggs in Weiss apparatus proceeded satisfactorily; one day after insemination, dead fish eggs were easily collected from the upper part of the apparatus using a rubber siphon.

Carp larvae cannot be removed from the incubation apparatus by water flow. Therefore, to avoid traumatization of the embryos, the eggs were transferred before hatching to racks covered by a metal net with a mesh of 1.5 mm and were placed in a Ropsha trout trough apparatus (Figure 1). Larvae were transferred from this apparatus to a collecting tank using water flow. In 1963 we used tubs to collect the larvae; however, rectangular tanks may be used instead (Figure 2). The collector was placed approximately 40 cm below the apparatus with the racks.

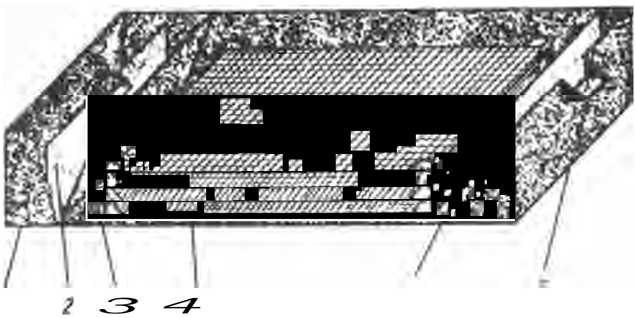

FIGURE 1. Ropsha trough apparatus for hatching carp larvae:

1 — frame of the trough; 2 — wall of the settler; 3 — water baffle; 4 — rack for fish eggs; 5 — safety net with a 1 mm mesh; 6 — overflow trough.

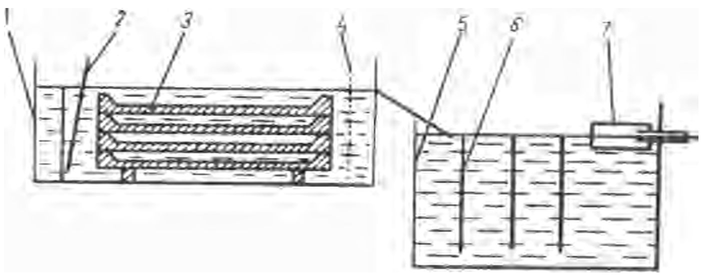

FIGURE 2. Apparatus for hatching and collecting carp larvae:

1 — frame of hatching apparatus; 2 − water baffle; 3 — racks with fish eggs; 4— safety net;.5 — larva collector; 6— larva retention panel; 7 — No.19 gauze to protect against friction.

After transition to active feeding the larvae were transplanted to ponds for further growth. They may be released without preliminary raising directly into small, well prepared ponds which have been filled shortly before stocking. If raising ponds are large (10 ha or more) or if they might be inhabited by trash fish or a large population of predatory invertebrates, it is advisable to first grow the larvae in fingerling ponds. At "Gostilitsy" we used as fingerling ponds 3 carp spawning ponds of 0.1 ha each. Density of larvae per hectare was 85,000, 250,000, and 280,000. The fingerlings were raised in June and July, and yield was quite satisfactory (Table 2).

TABLE 2. Results of pre-raising of larvae in fingerling ponds ("Gostilitsy," 1963)

Pond No.	Stocking		Removal				Productivity, kg/ha
	date	number, in thousands	date	number, in thousands	average weight, g	yield, %	
1	26 June	8.5	22 July	7.7	1.8	90.5	140.0
2	15 June	25.0	9 July	7.5	0.5	78.4	157.8
			22 July	12.0	1.0		
3	15 June	28.0	9 July	25.7	0.4	91.8	102.8

Considering the generally good results of pre-raising, the low yield of pond No.2 draws attention. These poor results probably resulted from the death of some of the fingerlings in the first catch in which a gauze sieve was used, and also from the fact that larvae of pond No.2 stayed in the pre-raising pond longer than other larvae.

Subsequently. fingerlings were raised in ponds No.4 and No.6 (Table 3). The yield of underyearlings from pond No. 4 was 37.2% of the original stock, while a fourth of them was caught in the underlying ponds. Consequently, the figures for this pond are not representative. Some of the fish left the pond, probably because of a defective drain. Clearer results were obtained in pond No. 6. During this period, the young received no supplementary food. Nevertheless, the yield of underyearlings removed in autumn was high, and their weight was satisfactory (Table 3).

TABLE 3. Results of raising underyearlings in nursery ponds after pre-raising the larvae ("Gostilitsy," 1963)

Pond No.	Stocking			Removal				Fish productivity, kg/ha
	number		average weight, g	number		average weight, g	yield, %	
	thousands/ha	total, thousands		thousands/ha	total, thousands			
4 (0.4 ha)	18.90	7.55	0.5	7.0	2.8	25.0	37.2	171.5
6 (1.6 ha)	16.05	25.70	0.4	14.0	22.4	22.4	87.1	308.0

In the best conditions (fingerling pond No.3 and raising pond No. 6), the original 28,000 larvae yielded 22,400 underyearlings, e., 80.1%. The total productivity for pre-raising in the fingerling pond and subsequent raising of the underyearlings in the raising pond corresponded to 410 kg/ha. For the climate of the Leningrad Region, this result is completely satisfactory.

According to the fish disease laboratory of GosNIORKh, the number of parasites in fingerlings hatched from cleaned fish eggs was considerably lower than in those hatched naturally.

Our results confirm the assumption that hyaluronidase has no harmful aftereffects on the embryonic and postembryonic development of the carp. The underyearlings removed in autumn proved to be normal in structure and wintered well.

Thus, the first experimental attempt to produce carp larvae in hatchery conditions was successful. The fresh and dried hyaluronidase used to remove the mucoid envelope completely eliminated the stickiness of fish eggs and allowed us to incubate them in the usual Weiss apparatus. A method of final incubation of fish eggs (till the end of hatching) on racks placed in a circulating trough apparatus was developed. There were experiments on pre-raising larvae produced by artificial methods in fingerling ponds. Small ponds with good food supplies that were filled just before stocking yielded satisfactory pre-raised larvae. Raising underyearlings from such pre-raised fingerlings also gave satisfactory results. This suggests that artificial spawning can be successfully applied in pond carp farms.

Experimental removal of the mucoid envelope of eggs of beluga, sturgeon, orfe, and Coreg onus peled

The use of solutions of hyaluronidase for cleaning eggs of fish which reproduce below 16° is ineffective. In our experiments, the beluga eggs obtained at 11 were not cleaned. Three hours were needed to eliminate the stickiness of sturgeon eggs at 15°. As indicated in the work with carp, this method is ineffective at low temperature.

In the Acipenseridae, hyaluronidase may also be ineffective because the mucoid envelope of the eggs may have a different composition. Because of the properties of tannin and its high molecular weight (about 1,700), we decided to try using it to clean eggs of Acipenseridae, orfe, and C. peled. Earlier, tannin was used without any harmful aftereffects for strengthening the egg membrane of autumn chum (Kol'gaev.1962).

To determine the concentration of tannin solutions which are harmless to the gametes, we examined the effect of different solutions on the motility of C. peled sperm. At a tannin concentration of 100 mg/l, the motility time of the spermatozoids and the character of their movement did not change in comparison to the same factors in the control. Concentrations of 200 mg/l did not change the character of the sperm motility, but it reduced its duration. The forward motion of the sperm disappeared rapidly at a concentration of 300 mg/l, and a 500 mg/l solution destroyed the sperm immediately. Based on these results, all the experiments were done with solutions containing not more than 100-200 mg tannin/liter.

Acipenseridae. Experiments on cleaning eggs of Acipenseridae were conducted in April and May 1963 in the experimental industrial sturgeon hatchery "Pravyi razdor" * of KaspNIRO in the Volga delta.

* We express our deep gratitude to the fellow workers D. P. Karpanin and R. Ya. Kosyreva, of the VNIRO laboratory for replenishment of fish reserves, and also to workers of the hatchery-nursery for their constant cooperation in conducting this work.

After establishing the effectiveness of tannin solutions in cleaning the eggs, we examined the effect of these solutions on the developing embryos, on the hatching, and on the postembryonic development of the larvae. We were most concerned about the possible effect of tannin on the course of hatching because tanning the surface layer of the egg membrane thickens it. The mortality of eggs and of larvae was determined in the experimental and the control groups. Both eggs and larvae were placed in comparable conditions. The eggs were incubated in one-liter Weiss apparatus; the larvae were hatched in crystallizers. At transition to active feeding and thereafter, larvae were raised in aquariums.

During incubation, mortality of beluga eggs cleaned with tannin considerably exceeded that in the control group cleaned with silt. The total mortality of eggs over the period of incubation and hatching was less in the experiment than in the control. The higher mortality of the experimental group during incubation probably results from mechanical damage and not from any negative effect of the tannin solution. Because of inexperience, we cleaned the eggs in small porcelain bowls with very intensive agitation. The control batch of eggs was cleaned in commercial conditions by an experienced pisciculturist. Evidently, our unskillful washing injured the eggs, thus increasing mortality during incubation. The 2 groups of eggs were not kept separately in the Weiss apparatus and mortality was determined in samples of 200-300 eggs taken from its central part.

At the end of incubation (corresponding to the beginning of hatching in commercial apparatus) we selected 200 live eggs each from the experimental and the control groups. These eggs were distributed in the crystallizers as the control after hatching as representative samples of the success of the 2 groups at hatching. Results of the experiment are presented in Table 4.

TABLE 4. Results of incubation of beluga eggs cleaned with tannin ("Pravyi razdor," 1963)

Cleaning substance	No. of eggs	Fertilization, %	Egg mortality, %		Mortality during hatching, %*	Total mortality, %
			at 4 days	at 9 days		
Tannin solution, 100 mg/l	15,000	98.8	13.4	12.0	15.0	27.0
Silt suspension (control)	15,000	98.7	1.7	1.0	53.5	54.5

* Mortality during hatching was determined on a sample of 200 eggs.

In the controls, hatching started 5 hours earlier than in the experimental sample. However, in most of the hatched controls, the egg membrane remained at the front of the yolk sac. Such semi-hatched larvae could not afterwards free themselves from the membrane and died. This was also true of the commercially treated sample of eggs from the same female.

Eggs treated with tannin, although they began to hatch somewhat later, produced only isolated semi-hatched larvae. The hatching of the experimental eggs was more synchronous, ending 2 days earlier than that of the control. As is apparent from Table 4, the total mortality of eggs and larvae after the treatment with tannin was half that of the control. Unfortunately, the experiment could not be replicated because there was only one female beluga in the hatchery.

The sturgeon experiments used eggs of 2 females, and compared 3 types of cleaning. Of these, 2 were the methods described for the beluga and the 3rd was done in commerical Yushchenko apparatus (Table 5).

TABLE 5. Results of incubation of sturgeon eggs cleaned with tannin ("Pravyi razdor," 1963)

Experimental method	Cleaning substance	Volume of fish eggs, l	Cleaning time, min	Mortality at 2days, %	Total mortality after hatching, %
I	Tannin solution, 100 mg/l	0.25	30	47.5	68.6
	Silt suspension (control)	0.25	35	43.7	74.8
II	Tannin solution, 150 mg/l	0.25	30	17.9	49.8
	Silt suspension (control)	0.25	38	14.3	60.6
III	Tannin solution, 150 mg/l	1.5	30	5.3	3.6
	Silt suspension (control)	1.5	40	6.5	7.9

The increased mortality of sturgeon eggs in laboratory experiments probably results from the same factors as in the experiments with the beluga eggs. This is particularly evident when results of incubation in the 2nd and 3rd experiments, on eggs of the same female, are compared. When eggs were cleaned in a small vessel and then incubated in the Weiss apparatus, mortality was much higher than when they were cleaned in a large enameled basin and incubated in the Yushchenko apparatus. The final incubation results were always better with eggs which were treated with tannin solutions.

To examine the possible harmful aftereffect of tannin solutions on postembryonic development, sturgeon and beluga larvae were pre-raised in aquariums with identical maintenance and diet. These experiments were done in triplicate for each species. In all cases, in the experiment and the control, the sturgeon and beluga fingerlings were similar in growth and mortality rate over the entire pre-raising period. The beluga were pre-raised for 15 days, sturgeon fingerlings for 2 months. In June, at the end of the experiment, their average weight was 2g.

Results of incubation of the eggs cleaned with tannin and experimental pre-raising of the larvae obtained from those eggs prove the harmlessness of weak tannin solutions for the embryonic and postembryonic development of Acipenseridae. Eggs treated with tannin were less afflicted by Sapr o-legni a. There were no precise comparisons nor special experiments to determine the effect of tannin on the development of Saprolegni a; this is an area which should be investigated. Because of its antiseptic properties (Kol'gaev,1962), tannin will probably prove to be an effective agent in prevention of Saprole gn i a.

Use of tannin in sturgeon breeding completely eliminates laborious preparation of the fine suspensions of silt necessary for cleaning fish eggs.

Orfe. In the spring of 1963, as part of the studies on artificial fertilization and incubation of orfe eggs, the cleaning effect of hyaluronidase and of tannin solutions was also examined. Success was obtained with both solutions. The hyaluronidase solution cleaned orfe eggs in 3-3.5 hours, while a tannin solution of 150-200 mg/l cleaned them in 25-35 minutes. In each of the three replications of the experiment, in which 100,000 orfe eggs were cleaned and then incubated, mortality was 50%. The 50,000 larvae obtained from these eggs were transferred to nursery ponds. In the autumn, 30,000 underyearlings were recovered with an average weight of 5 to 15g (depending on the pond in which they were raised). Cleaning orfe eggs for commercial raising was also successful, but many of these eggs could not be incubated because of a defect in the water supply of the apparatus.

Our results are good evidence that tannin solutions may be used in large-scale commercial production of orfe larvae by official methods.

C. **peled.** C. peled eggs, like those of other whitefish, are usually not considered sticky, as they lack a surface layer of adhesive material found with eggs of carp and wild carp. Nevertheless in many hatcheries, C. peled eggs stick so much as to be troublesome. At "Ropsha" the eggs stuck together after being placed in water, although they were quite easily separated by careful stirring. In the Weiss apparatus, the eggs stick to the glass and to each other, and thus disturb the functioning of the apparatus. The stickiness continues for 6-10 days, making the work of pisciculturists extremely difficult. According to a verbal report of A. D. Nosal', of UkrNIIRKh, in the "Pushcha-Voditsa" farm near Kiev, C. peled eggs were so sticky that during a laborious preliminary rinsing they formed tight inseparable lumps.

The stickiness of C. peled eggs varies widely and is related to the salt composition of water and its pH. Because C. peled eggs are stickiest in the water bodies near Leningrad, which are slightly alkaline (pH = 8.2), Golovkov and Privol'nev (1961) suggested cleaning these eggs in acidified water. Thus, after fertilization the eggs are placed in water acidified by a few drops of hydrochloric acid or are kept in swamp water.

This method, while it considerably facilitates the work of pisciculturists, does not solve the problem completely. Several days after being kept in swamp water 10-12 hours, the eggs again begin to stick. Even after a repeated cleaning in swamp water, about a day later, C. peled eggs in the apparatus again became sticky. We assumed that this stickiness depends on the degree of hydration. To dehydrate the surface layer of the eggs, we treated them with tannin. Tannin solutions of 20, 50, and 100 mg/l were tested. The first two concentrations did not clean the eggs. The 100 mg/l solution cleaned the eggs completely in 20-40 minutes.

C. peled eggs stop swelling after 2-2.5 hours. In the first experiments with tannin, the eggs were cleaned at the end of the swelling period. The eggs were incubated in a one-liter Weiss microapparatus with a load of 600 ml of swollen eggs. Throughout the incubation period, samples were taken periodically to determine the percentage of eggs developing. The control consisted of eggs cleaned by Golovkov's method (Golovkov and Privol'nev,1961) using swamp water. At the end of the incubation we could not find a significant difference in the mortality rates of the experimental and control groups.

Here, as in the work with eggs of Acipenseridae, we were particularly interested in studying the effect that the thickening of the egg membrane by tannin would have on the hatching of larvae. Thus, at the end of incubation, 3,000 eggs of each group were counted and placed in crystallizers, 1,000 in each. The eggs cleaned with tannin began and finished hatching one day after the control. The total yield of larvae in all the replications except one was almost the same (Table 6). Thus, weak solutions of tannin did not have a harmful effect on the course of incubation of C. peled eggs.

TABLE 6. Hatching of C. p el ed larvae from eggs cleaned with tannin and incubated in Weiss microapparatus ("Ropsha," April 1963)

Cleaning material	No. of repli-cations	N o [illegible]	Hatching by dates, No. of specimens												Total hatch larvae	Mortality during hatching %
			10	11	12	14	15	16	17	18	19	20	21	[illegible]		
Tannin solution, 100 mg/l (experiment)	1	1,000	—	60	185	[illegible]5	[illegible]	56	[illegible]0	5	39	[illegible]	[illegible]	[illegible]	[illegible]5	11.[illegible]
	2	[illegible]	1	[illegible]8	128	08	[illegible]	1[illegible]	67	25	[illegible]1	[illegible]	[illegible]	4[illegible]	[illegible]1	11.[illegible]
	3	[illegible]	—	51	1[illegible]	185	93	[illegible]	92	59	55	4	[illegible]	1	[illegible]58	14.7
Swamp water (control)	1	[illegible]	6	[illegible]5	[illegible]7	[illegible]	47	[illegible]	8[illegible]	[illegible]	12	40	25	—	9[illegible]5	[illegible].5
	2	[illegible]	6	[illegible]2	[illegible]	[illegible]1	5	27	56	[illegible]	5	6	1[illegible]	—	79[illegible]	20.7
	3	[illegible]	8	36	1[illegible]	[illegible]9	57	[illegible]7	11	[illegible]	—	—	-	—	624	37.6*

In some farms, C. p el ed eggs stick together in such tight lumps that they cannot be kept till the end of swelling without a preliminary rinsing. Therefore, the influence of tannin on the eggs was checked a few minutes after fertilization. Here we used concentrations of 200 mg/l.

The experiment involved the eggs of 2 females. For each, the experiment was done in duplicate. After being mixed with milt, the eggs of each female were divided into 2 equal portions, one to be cleaned with tannin, and the other to serve as a control. Fifteen minutes after fertilization, the experimental eggs were treated for one hour with tannin. Then they were rinsed with water, and left in water until the end of swelling.

The change in the diameter of the experimental eggs, in comparison with the control, was used to indicate disturbance in the process of swelling. To measure the diameter in the experimentals and in the controls, samples of 200 eggs each were simultaneously removed and fixed with 5% neutral formalin prepared in a physiological solution of sodium chloride (6 g salt in one liter of distilled water). The diameter of the eggs was measured with an ocular micrometer accurate to 0.01 mm. The first sample was taken immediately after mixing the eggs with the milt;the second, 5 minutes later, after the addition of water; the third, again 5 minutes later; and then, every 10 minutes for 3 hours. Tannin was added 15 minutes after mixing the eggs with the milt.

In the experiment, and in the control, the shape of the curves of egg swelling appeared to be very similar. However, eggs treated with tannin swelled less than the controls; all the points of the swelling curve of eggs treated with tannin are below the corresponding points of the curve of the control (Figure 3). The difference is fully reliable.

Interestingly, in the first minutes after the eggs were put into water, their diameter decreased. Then, for approximately 2 hours the diameter increased and later on it decreased again. Privol'nev (1952, 1953) presented analogous curves of swelling for salmon eggs. He did not analyze the nature of the processes which occur, and explained the results as due to inaccurate measurement. However, the consistent character of the curves he obtained in five separate cases undoubtedly indicates a regular decrease of the size of the salmon eggs at the end of swelling.

Yu.Karinskii (1938) presented similar curves of swelling for herring eggs. The similar shape of the swelling curves of eggs of different species of fish (whitefish, salmon, herring) indicates that a common process oocurs in the first hours after fertilization of their eggs.

Our swelling curves for C. peled eggs indicate that treatment by tannin shortly after fertilization decreases the volume of the perivitelline space of the egg and, consequently, also changes the conditions for development of the embryo. As yet, we have no direct proof that these changes are detrimental to further embryogenesis. The changes of the final size of the swollen eggs in themselves may not disturb the embryonic development. However, the use of tannin solutions to clean C. peled eggs should be undertaken with great caution, avoiding concentrations above 100 mg/l.

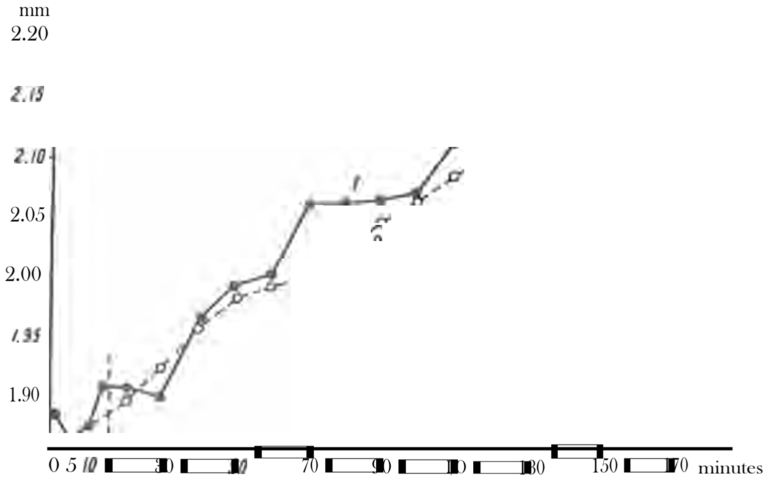

FIGURE 3. Swelling curves of C. peled:

1 — in water; 2 — in tannin solution. Vertical dotted lines — the beginning and the end of the effect of tannin.

If the C. peled eggs are particularly sticky, forming inseparable lumps so that the eggs cannot be kept until the end of swelling without the addition of tannin, it is expedient to employ a combined treatment. Right after fertilization, we placed the eggs in an appropriate solution of hyaluronidase. This solution does not clean whitefish eggs permanently, but while they are in it, the eggs do not stick together and are not damaged. Using hyaluronidase, C. peled eggs can be kept until the end of swelling without forming tight inseparable lumps. Two hours after the beginning of this treatment, the eggs may be cleaned with a tannin solution (100 mg/l) for 20-30 minutes, and then placed in the incubation apparatus.

C. peled eggs may also be cleaned with tannin solutions after first being kept in swamp water. This method caused no observable abnormalities in the course of swelling, nor in further development.

A practical application of this cleaning method was attempted at "Ropsha" in the winter of 1963-1964. Data of these investigations have not yet been analyzed.

In conclusion, we point out that this artificial method of producing carp larvae is recommended by the State Committee for Research in fish breeding farms. However, some of the details of this process require improvement. Thus, we found that the preparations of hyaluronidase from testicles of different animals have different activity. The possibility of cleaning carp eggs with pharmaceutical hyaluronidase has not been sufficiently investigated Combined application of hyaluronidase and tannin requires further improvement. We must find ways to reduce the sometimes considerable mechanical damage of the egg membrane during stirring of the eggs in a hyaluronidase solution. Thus, the necessity of continued experimentation to improve artificial production of carp and Acipenseridae is self-evident.

CONCLUSIONS

1. Aqueous solutions of hyaluronidase do not interfere with the process of fertilization of fish eggs, and can be used for cleaning carp, wild carp, and orfe eggs. Aqueous extracts of fresh pig testicles are most effective in cleaning carp eggs, while hyaluronidase from acetone-treated ox testicles is less effective. Eggs cleaned by this method had a mortality of 25-50% during their incubation in our 1963 experiments.
2. Experimental pre-raising of the larvae in small fingerling ponds showed that if the ponds were filled up shortly before the larvae were transferred to them, and food supply was abundant, the mortality of larvae over 3-4 weeks was only 10-20%. The larvae raised in these ponds appeared to be very similar in weight and viability at further raising.
3. There were no observable harmful aftereffects of treatment of carp eggs with hyaluronidase in 1963. However, we note that the cleaning technique requires further improvement, since mechanical transfer of not yet swollen eggs damages some of their membranes.

Artificial production of carp and wild carp larvae is a considerable technological advance in carp farms and hatchery-nursery farms. The decrease of fingerling mortality caused by the elimination of contact between spawners and progeny is particularly important.

4. Hyaluronidase is ineffective in cleaning eggs of fish which reproduce in water at a temperature below 16°. Acipenseridae, orfe, and C. peled eggs are successfully and rapidly cleaned in weak tannin solutions (100-150 mg/l).
5. The use of tannin in cleaning orfe, Acipenseridae, and C. peled eggs facilitates work with these species. Low concentrations are harmless. For C. peled eggs, tannin cannot be used until 2 hours after fertilization, since treatment by tannin at the beginning of development prevents swelling of the eggs and reduces the perivitelline space.

If C. peled eggs are very sticky, they can be kept in a solution of hyaluronidase or in swamp water until treated with tannin.

APPENDIX

A method of preparing a powder of acetone-treated testicles

Acetone treatment to dehydrate the testicles can be conducted with the simplest equipment in any laboratory. The principal equipment (Figure 4) is a large bottle with a tube in its bottom, a flask for redistillation of acetone, 2 reflux condensers, and a few connecting glass tubes. The large bottle, the distillation flask, and the condensers are connected as shown in Figure 4. The capacity of the bottle and of the distillation flask is arbitrary; however, it is important that the volume of the flask should not be less than that of the bottle in which the testicles are dehydrated. We used a 5-liter bottle and a 5-liter flask, which allowed the processing of 3.5 kg testicles at a time.

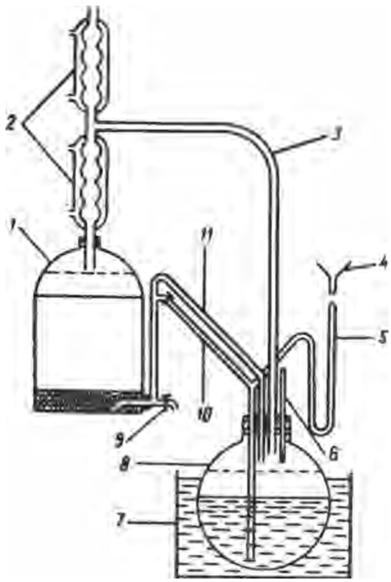

FIGURE 4. Diagram of apparatus for acetone treatment of testicles:

1—large bottle for acetone treatment; 2—reflux condensers; 3—tube for acetone vapors; 4—detachable funnel; 5—rubber tube for withdrawal of contaminated acetone; 6—thermometer; 7—water bath; 8—flask for acetone distillation; 9—stop-cock for decantation of acetone from the bottle; 10—lower joint of siphon; 11—safety joint of siphon. Dotted line indicates the maximum level of acetone in the bottle and in the flask.

The apparatus is a closed system in which there is a continuous replacement of the contaminated acetone with fresh acetone. The acetone vapors formed during boiling in the flask pass through the connecting joint to the condenser, where they condense and run off into the bottle. The excess acetone that reaches the level of the bent tube repeatedly runs off into the distillation flask. Thus, as it is warmed, the most contaminated layer of acetone from the lower part of the bottle is automatically poured off into the flask and is gradually replaced with fresh acetone, the acetone being continually purified by condensation. The upper condenser is open and maintains atmospheric pressure in the system, and the lower condenser guards against the possibility of a rise in the temperature of the bottle, since even a small excess of heat can destroy the enzyme.

The bent siphon tube has 2 joints, one over the other. The lower joint maintains a constant acetone level in the bottle with the testicles, and the upper one is a joint through which the excess acetone runs off if the bottle is overfilled. The bottom of the bottle is lined with a 3-cm drainage layer made of glass balls or of bits of cracked porcelain.

The testicles are stripped of connective tissue and cut into 4-6-mm-thick slices. Then they are covered with 2 volumes of chemically pure acetone and kept in a closed container at 1 —2° for at least 2 hours. Then, the testicle slices are poured into the bottle with the tube at the bottom, which was previously filled with chemically pure acetone to half its volume. The quantity of testicles added does not reach the level of the lower joint of the siphon, and they should always be covered with acetone. The flask is also half filled with acetone and is connected with the bottle after warming is begun. Acetone is inflammable, and therefore the distillation can be conducted only on a water bath.

The temperature of distillation should be between 56 and 65°C. To ensure uniform boiling of the acetone, several pieces of porcelain should be placed in the distillation flask. When heavily contaminated by fats, or if temperature rises above 65°C, the acetone is run off from the flask and replaced by fresh. The used acetone is readily purified by double distillation, first at 62-70° and then at 56-58°C.

Complete dehydration of 3 kg testicles takes about 40 hours. Termination of the acetone extraction process is determined in the following manner. A few drops of acetone on a watch glass are taken from the bottom tap of the flask. After evaporation of acetone on the glass, there should be no remaining fat. An indirect indicator of the end of the process is the absence of yellow color in the acetone.

The dehydrated testicles are removed from the bottle, and, without drying, are ground in a meat grinder. The ground mass is spread in a thin layer and dried at room temperature until the acetone odor disappears completely. The dry powder is kept in hermetically sealed containers. One kilogram of testicles yields about 100 g powder.

To prepare the cleaning solution, 50g of the powder are infused with one liter of a physiological solution (8.5g NaCl/l distilled water) for 3 hours. The infusion is filtered through gauze and the sediment is discarded. The filtrate is the stock solution. For cleaning, it is diluted to 10-20% with pond or river water. The solution can be kept for 10-15 days at 1-2°.

Bibliography

Publications in Russian

Dmitrenko, Yu. S. Transportirovka i doinkubatsiya iskusstvenno oplodotvorennoi ikry karpa (Transportation and Final Incubation of Artificially Fertilized Carp Eggs). In this Collection.

Golovkov, G.A. and T. I. Privol'nev. Novyi metod obeskleivaniya ikry pelyadi (A New Method of Cleaning the Eggs of Coreg on peled). — Nauchno-Tekhnicheskii Byulleten' GosNIORKh, Nos. 13-14. 1961.

Karpinskii, Yu. Nekotorye osobennosti embrional'nogo razvitiya belomorskoi sel'di (Some Properties of the Embryonic Development of the White Sea Herring). — Trudy Mosrybvtuza, No. 1. 1938.

Kol'gaev, A. M. Tanin kak sredstvo protiv razlozheniya obolochek osennei kety (Tannin as an Agent against the Decomposition of Egg Membranes of the Autumn Chum). — Izvestiya TINRO, Vol. 48. 1962.

Konr ad t, A. G. and A. M. Sa k ha r ov. Biotekhnika fermentativnogo obeskleivaniya ikry karpa (Biotechnique of Enzymatic Cleaning of Carp Eggs). — Rybnoe Khozyaistvo, No.7. 1963.

Konradt, A.G., A.M.Sakharov, and M.A.Zhivotova. Rabota po inkubatsii obeskleennoi ikry karpa i vyrashchivanie iz nee lichinok (Incubation of Cleaned Carp Eggs and Cultivation of Larvae). — Rybnoe Khozyaistvo, No.6. 1963.

Pr iv ol 'nev, T. I. Nabukhanie ikry lososya v nachale razvitiya (Swelling of Salmon Eggs at the Beginning of Development). — DAN SSSR, Vol. 84, No. 3. 1952.

Pr iv ol ' ne v, T. I. Izmeneniya vesa ikry lososya pri embrional'nom razvitii (Changes in Weight of Salmon Eggs during Embryonic Development). — Izvestiya VNIORKh, Vol. 33. 1953.

T et s, V. I. Obeskleivanie oplodotvorennoi ikry gialuronidazoi (Cleaning of Fertilized Fish Eggs with Hyaluronidase). — Rybnoe Khozyaistvo, No. 7. 1963.

V oinarovich, E Inkubatsiya ikry karpa i podrashchivanie desyatidnevnykh lichinok (Incubation of Carp Eggs and Pre-Raising of Ten-Day-Old Larvae). — Rybnoe Khozyaistvo, No.9. 1962.

Publications in Other Languages

V oynarovich, E. Hatching of Carp Eggs in "Zuger" Glasses and Breeding of Carp Larvae until the Age of 10 Days.— Bamidgeh, Vol. 14, No. 2. 1962.

TRANSPORTATION AND FINAL INCUBATION OF ARTIFICIALLY FERTILIZED CARP EGGS

Yu. S. Dmitrenko

Expansion of commercial carp raising in small lakes in south Karelia involves transportation of stock from other regions of the country, and will thus be very expensive. Therefore, we attempted to develop a method of producing underyearlings or yearlings directly in Karelia.

The 1962 experiments on the cultivation of carp yearlings in Lake Fadin yarvi, where fish were exterminated by application of polychlorpinene, from larvae delivered from "Ropsha" (Leningrad Region) seemed promising.

However, as experience showed, transportation of larvae from even the neighboring Leningrad Region is quite difficult.

As there was no special pond area in Karelia where larvae could have been spawned naturally and hatched, we had to turn to the methods of artificial carp breeding developed recently (Voinarovich, 1962; Tets, 1963; Konradt and Sakharov, 1963). In our investigations of methods of transportation and of final incubation of artificially fertilized eggs, we attempted to develop a technique for hatching larvae not only for our experimental purposes, but also for commercial fish breeding.

In the spring of 1963, with the active support of the GosNIORKh laboratory of pond fish breeding, we experimented with transportation and final incubation of the artificially fertilized carp eggs, with the results presented in this report.

On 27 May 1963, one hybrid carp female of the Novgorod line (a 2nd generation hybrid of cultured carp and "eastern carp") and one male Kursk carp (a backcross hybrid of the same fish) were given pituitary injections at "Ropsha." The female, which weighed about 6 kg, was given 5 pituitary bodies and the male, which weighed about 3kg, was given 1.5 pituitary bodies of wild carp. After the injection, the spawners were placed in separate tanks in 16-18° water. After 22 hours, the female laid its eggs. Dry fertilization was employed, and the eggs were cleaned for 35 minutes in a solution of hyaluronidase. After fertilization, the eggs were placed in Weiss apparatus, and were incubated 3 days at 16-17°. Mortality during incubation, mainly the death of unfertilized eggs, was 33.2%.

Without waiting for the beginning of natural dropping out of the dead eggs, we decided to transport the eggs on 31 May, when they were in the eye pigmentation stage. There were 3 liters (600,000) of eggs, of which 2 liters were arranged in 6 whitefish frames, 45 X 30 cm, and 1 liter was put in a polyethylene bag filled with 2 liters of water and 2 liters of oxygen. The frames were arranged in one pile and wrapped in paper. For better air circulation four 10-15 cm openings were cut in the pile. An insulated transportation container was not available.

FIGURE 1. Final incubation of carp eggs in Weiss apparatus in Karelia (1963).

The bus trip from Ropsha to Leningrad took 1 hr and 30 min; the eggs were taken by train for the 19 hr trip from Leningrad to the Zastava station of the Oktyabr' Railroad [former Nikolaevskaya Railroad]. During the trip the temperature in the freight car fluctuated from 12 to 24°. The eggs arranged on the frames were sprayed 3 times with 0.5 liter of water from a sprayer, and were in good condition; mortality during transportation was 4.5%. The eggs that were transported in the polyethylene bag with water began to putrify after 12 hours. An intensive invasion of Saprolegnia killed nearly all the eggs.

After arrival, the eggs were spread onto 10 whitefish frames and placed for final incubation in flow-type wood troughs installed in the Makkol'skii brook (in the Veshkelitskie lake area). Water temperature at that time was 14.2°. Incubation temperature was 15-16°. Despite periodic removal of some of the dead eggs, those which remained continued to become infected by Saprolegnia. As this could have led to the death of the entire stock, we quickly prepared a Weiss apparatus where incubation was continued. Mortality during final incubation was 12.3%.

The dead eggs began to separate from the live ones immediately after they were all placed in the Weiss apparatus; after 10 hours the eggs in the apparatus were completely decontaminated.

On 5 June, after 4 days, at about 15°, the first larvae appeared; on 7-8 June, at 14.5°, mass hatching began. In all, 200,000 larvae hatched.

which at 2 days, after passing the resting stage, were transferred to the lakes. The length of a one-day-old larva averaged 6.1 mm. Further observations of the larvae in the lakes indicated good growth.

The experimental transportation and final incubation of artificially fertilized carp eggs invite the following conclusions:

1. Artificially fertilized and cleaned carp eggs tolerate long-distance transportation well.
2. The eggs may be transported successfully for one day at the eye pigmentation stage, after all dead eggs have been removed.
3. The eggs should be transported on frames. We loaded approximately 0.5 liter of clean eggs on each 45X 30 cm frame, but this may be increased to 1 liter (180,000-220,000 eggs).

Bibliography

K on r ad t, A. G. and A. M. S a kh a r o v. Biotekhnika fermentativnogo obeskleivaniya ikry karpa (The Biotechnique of Enzymatic Cleaning of Carp Eggs).— Rybnoe Khozyaistvo, No. 7. 1963.

T e ts, V. I. Obeskleivanie oplodotvorennoi ikry gialuronidazoi (Cleaning Fertilized Fish Eggs with Hyaluronidase). — Rybnoe Khozyaistvo, No. 7. 1963.

V oina rovich, E. Inkubatsiya ikry karpa i podrashchivanie desyati-dnevnykhlichinok (Incubating Carp Eggs and Raising Larvae to Ten Days).— Rybnoe Khozyaistvo, No. 9. 1962.

NUTRITION OF NORTHERN ("ROPSHA") CARP HYBRID FINGERLINGS AT VARIOUS DENSITIES AND TEMPERATURES IN PONDS

M. N. Sergeeva

Introduction

Recently, northern ("Ropsha") hybrids have become the main breeding item in the ponds of the northwestern RSFSR. This new breed was obtained by crossing cultured carp with "eastern carp" and subsequent selection of the hybrids (Kirpichnikov, this collection). The present 4th and 5th generation hybrids owe much of their heredity to the "eastern carp" (from 50 to 75%). The "eastern carp" have a high tolerance of cold, and the hybrids also exhibit this property to a great extent. "Eastern carp" also have a somewhat different diet from the carp. The carp are omnivorous, and voraciously devour midges. The "eastern carp" eat a large proportion of mollusks and higher aquatic plants (Konstantinov, 1952). According to Rudsinski (1961) and Steffens (1964), the Danube wild carp utilize artificial food of plant origin less efficiently than the carp.

Investigation of the diet of northern hybrid carp is thus of great interest; it is particularly important to solve the following problems:

1. Is the diet of the "Ropsha" carp of different composition from that of cultured carp which was not interbred with the wild carp ?
2. To what extent do temperature changes affect the quality and quantity of the diet of hybrid carp?
3. What are the maximum densities at which we can stock northern hybrid carp in our fish farms without decreasing the biomass of the edible organisms, markedly retarding growth rate, or impairing productivity ?

Comparisons of the diets of the hybrid and nonhybrid carp are being conducted currently, and the results will be published later. Data on the 2nd and 3rd problems are presented in this article. We have also collected additional data on the composition of food and food preferences of fingerling northern hybrid carp.

The diet of northern hybrids was thoroughly investigated by L.P.Maksimova (1961), who found that these fish transfer quite rapidly to active feeding on benthos. They also show a preference for weed-dwelling midges and do not consume Oligochaeta. Benthos (particularly Chir on omus plum o s us) are even more important in the diet of yearlings.

The fingerlings eat less plankton than benthos. Yearlings eat even less plankton, although they do eat some throughout the summer.

T[illegible] (Grimarskii [illegible] Tyutyunik, 1961; Assman, 1962; Hrbácek, 1962; [illegible]). T[illegible]. T[illegible], Assman (1962), [illegible] Maksimova (1961), [illegible] D[illegible]apto[illegible] S[illegible]. Maksimova [illegible] C[illegible] cladocerans.

Maksimova (1961) [illegible] Ropsha [illegible]. I[illegible] zooplankton [illegible] (Borutskii, 1960). Maksimova [illegible].

F[illegible], [illegible], [illegible] Maksimova. T[illegible] Kirpichnikov's [illegible] (1960,1963); [illegible] ([illegible] 7-14), [illegible]. A[illegible] Kirpichnikov (1960), [illegible] USSR [illegible].

Maksimova (1961) [illegible] nonhybrid [illegible]. S[illegible]-[illegible] zooplankton [illegible].

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T[illegible] benthos [illegible], [illegible] V. P. Lyakhnovich (1958, 1965, [illegible]) [illegible] Müller [illegible] Merla (1962). T[illegible], [illegible] 2-year-olds, [illegible]. F[illegible], [illegible]. T[illegible] (Karpanin, 1956; Yashow, 1956; Shpet, 1958; Pchelkina, 1959; Ivanov, 1959; Gurzeda, 1960; Grimal'skii [illegible] Tyutyunik, 1961; Merla, 1961; M[illegible] Merla, 1962; Assman, 1962).

H[illegible], [illegible]; [illegible] Assman (1962) [illegible] USSR.

P[illegible]

T[illegible] "Ropsha [illegible] (L[illegible] R[illegible]) [illegible] 1961-1962 [illegible], [illegible]:

I[illegible] N[illegible].5 — 0.073 [illegible]
N[illegible].6 — 0.043 [illegible]
" N[illegible].7 — 0.018 [illegible]

The items of the experiment were "Ropsha" carp fingerlings (4th generation MB strain). The fingerlings received natural food in all 3 ponds until August 1961. At the beginning of August, 2 ponds (Nos. 5 and 6) were divided into 2 approximately equal parts by partitions. In the upper part of each pond the fish were fed a supplement of spleen (42%), bran (32%), meat-bone meal (5%), mixed feed and sprat (13.4%), yeast (4%), fresh aquatic plants (about 3%), and some chalk (0.6%). The lower sections and also pond No.7 were not given the supplement.

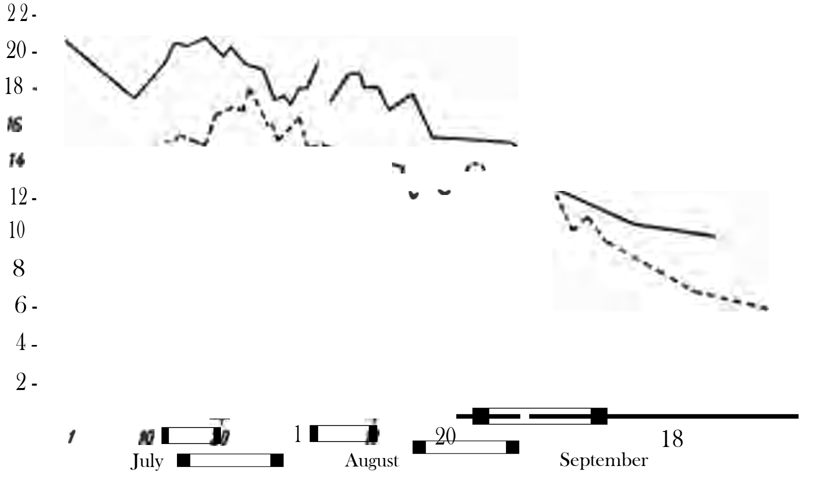

FIGURE 1. Curves of temperatures in the intermediate "Ropsha" ponds:

Continuous line — 1961; broken line — 1962.

The population density of ponds No. 5 and No. 6 in 1961 was not high (17,000-23,000/ha from data at autumn recovery). In pond No. 7, the final density was almost 3 times that in ponds No. 5 and No. 6, being over 55,000/ha.

In 1962, the experiments were done in only 2 ponds, No. 5 and No. 6, and No. 6 was divided into 2 parts. Due to low water temperatures, no food supplement was given. Pond No. 5 had the same population density as in 1961, while pond No. 6 was stocked with three times as many fingerlings (83,000/ha).

The temperatures in 1961 and 1962 proved to be completely different (Figure 1). This permitted a more thorough investigation of the effect of the temperature on the nutrition and food consumption of "Ropsha" carp.

Control catches and also hydrobiological inspections and collection of nutrition samples were made every 10 days. Plankton samples were collected by dredging 50 liters of water from 5 places in the pond and filtering it through No. 38 gauze. Benthos samples were taken with a Zabolotskii bottom dredge in an operating area of 1/40 m^2. In the 1961 investigations, one sample of benthos was taken from each part of the ponds; in 1962, two samples were taken from each. From all fish caught in a routine control catch, 10 specimens were taken at random and immediately fixed in formalin to investigate nutrition. The contents of the intestines of these fish were mixed, and several portions were taken for a detailed investigation. The weight of the organisms used for food was calculated according to tables of standard weights of invertebrates. In calculating the indexes of preferences, we used V. S. Ivlev's (1955) formula:

$$E - \frac{r_1 - p_1}{r_1 +}$$

where r_1 and p_1 are, respectively, the proportion of the given organism in the diet and in the food supply of the pond.

Description of the experimental ponds

The intermediate ponds constitute a chain of ponds with interrelated water supply: they are located in a park and are relatively well shaded by trees. The water supply is spring water which passes through 4 other ponds and before reaching No.5 is greatly warmed.

The very hard water of the Ropsha Silurian springs has an alkaline pH of 7.6-9 and higher. The gas content of the ponds in 1961 and 1962 was favorable for carp. The beds of the ponds are sandy and covered with a thin layer of silt. Temperatures in the intermediate ponds are no different from those in other "Ropsha ponds; 1961 was a relatively warm year and 1962 was very cold. As usual in the Leningrad Region, water temperature began to drop in August, but even at the end of August 1961, the average daily temperatures were not below 16°.

For a number of years, the natural productivity of ponds No.5 and No.6 came to 250-350 kg/ha while that of pond No.7 was 150-200 kg/ha. Thus the productivity of these ponds is average for the northwestern RSFSR.

Five species of rotifers, 2 species of copepods (Cyclops str enuus Fisch and Diapt omus grac ilis Sars) and up to 10 species of cladocerans were most frequently found in the plankton of the ponds. Most of the forips we found were found earlier by Maksimov (1961) in "Ropsha ponds. The benthos was composed of a large group of weed midges and also by species usually inhabiting the bottom of open parts: C hi r onomus f.l. plumosus L. and Glyptotendipes of the group gripecoveni (Kieff.). There were also Oligochaeta, larvae of various insects,and other ordinary freshwater inhabitants.

In 1961, there were 2 outbreaks of florescence, one at the end of July and the other in August, which were caused by phytoflagellates turning the water brown. Florescence was followed by a sharp increase in the number of Daphnia and Cyclops (up to 150,000/m^{3}) in the ponds.

The biomass of the zooplankton in 1961 was apparently low (Table 1), varying from 1.1 kg/ha (pond No. 7) to 6 kg/ha (pond No. 6). There were no differences observed in the biomass of the zooplankton between upper and lower halves of the ponds.

TABLE 1. Biomass of forage organisms and piscicultural indexes in the 1961 experiments

Index	1st period (June-July)			2nd period (August-September)				
	without supplementary feeding			without supplementary feeding			with supplementary feeding	
	Pond No.							
	5	6	7	5 (lower part)	6 (lower part)	7	5 (upper part)	6 (upper part)
Stocking density, thousands/ha*	25.1	28.7	61.4	18.8	About 23	61.4	18.6	About 25
Average biomass of zooplankton, kg/ha		6.0	2.3	3.6	1.4	1.1	3.8	1.4
Average biomass of benthos, kg/ha		283	136	43	69	46	308	168
Weight gain of fingerlings, g/specimen	13.6	12.9	4.9	7.3	4.5	2.8	9.1	7.4
Final weight of fingerlings, g	13.6	12.9	4.9	22.4	19.6	7.7	23.4	22.0
Productivity, kg/ha	311	349	292	129	88	149	160	174

* The average of initial and final values was taken a the index of density.

TABLE 2. Biomass of forage organisms and piscicultural indexes in the 1962 experiments

Index	Pond No.5	Pond No.6	
		upper part	lower part
Stocking density, thousands/ha	23	74	74
Average biomass of zooplankton, kg/ha	3.4	7.4	3.1
Average biomass of benthos, kg/ha	52.2	150	217.2
Final weight of fingerlings, g	4.6	3.4	2.9
Productivity, kg/ha	82	208	175

Note. There was no supplementary feeding in 1962 because of low water temperature.

The benthos was more plentiful in No.5 and No.6 where its biomass sometimes reached 400 kg/ha and more in the upper sections. As an illustration, we present a graph showing the predominant groups of benthos of pond No.6 and changes in the quantitative and qualitative indexes of benthos during the raising season (Figure 2). The biomass of the benthos was highest in mid-July and September. Almost throughout the experiment, the benthos was composed primarily of midges, mainly Chir on o mus f.l.plumosus and Tanytarsus sp.

The biomass of zooplankton and the amount of benthos were apparently lower in pond No. 7 than in No. 5 and No. 6.

Judging by the average values (Table 2), in 1962, the food supplies of the ponds were about the same as in 1961. The zooplankton was still poor; the biomass of benthos was average. Unlike the case in 1961, pond No.5 appeared to have a poorer food supply than pond No. 6, probably because the water entering pond No.5 was somewhat warmer (the difference in water temperature was 1-1.5°). We feel that this is also the reason there was no florescence in pond No. 5, while it was present almost throughout August in pond No. 6.

The quantity of benthos dropped more sharply in August 1961 than in 1962. In 1962, there was no summer decrease, and biomass remained high (pond No. 5) or increased until 21 September (pond No. 6, Table 3).

TABLE 3. Variations in benthos biomass in the ponds kg/ha (1962)

Date	Pond No.5		Pond No.6	
	upper part	lower part	upper part	lower part
19 July	1.2	61.4	11.4	14.4
28 July	14.6	70.8	79.4	94.8
7 Aug.	91.0	38.4	119.0	178.0
20 Aug.	149.6	32.4	161.2	315.0
30 Aug.	43.0	36.4	88.2	74.6
10 Sept.	29.8	33.4	342.2	366.0
21 Sept.	84.2	46.2	248.8	477.8
Average for July-Sept.: for the parts	59.0	45.5	150.0	217.2
for the whole pond	52.2		183.6	

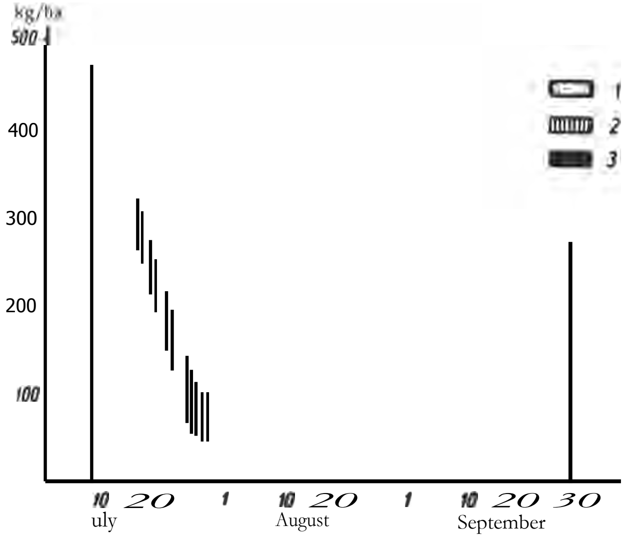

FIGURE 2. Dynamics of the biomass of benthos in intermediate Pond No.6 (upper part) in 1961:

1 - larvae of midges; 2 - Oligochaeta; 3 - others.

Diet of "Ropsha" carp fingerlings at different temperatures

The basis of the diet of "Ropsha" hybrid carp underyearlings, in both the warm weather of 1961 and the cold weather of 1962, was composed of midges, except in the upper sections of ponds No. 5 and No. 6 where the carp were given a diet supplement in 1961; a large part of the content of the intestines of carp in those sections consisted of artificial food.

In 1962, we determined the composition of the diet of the "Ropsha" carp fingerlings by weight. Almost throughout the investigations, the main food was the reed midge Psectrocladius of the psilopterus group. In September, species of Anatopynia varia and Chironomus f. l. plum o s us, until then of minor importance in the diet, began to prevail.

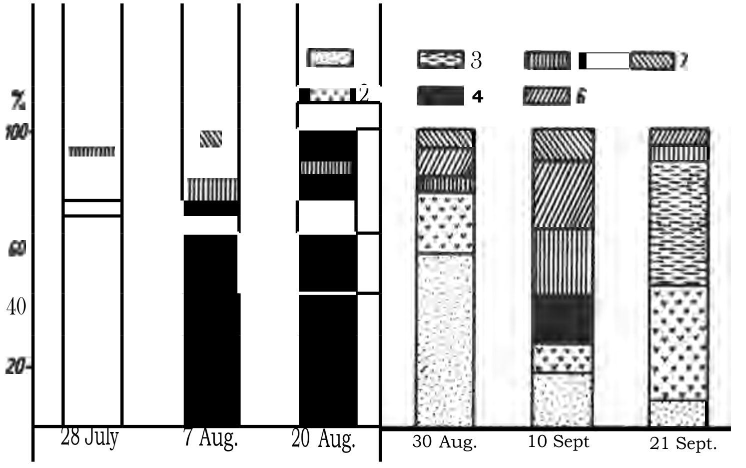

FIGURE 3. Composition of the diet of fingerlings (% by weight) in pond No.6 (1962):

1 — Psectrocladius; 2— Anatopynia; 3 — Chironomus; 4— Corynoneura; 5 —Cyclops; 6— Chydorus; — Alona daphnia.

Figure 3 presents the composition of the diet of carp fingerlings in intermediate pond No.6 from 28 July until 21 September. The situation was similar in the other ponds. In almost all the samples, the benthos were 70-90%, by weight, of the intestinal content. Cyclops plankton were always present.

We noted no essential differences in the composition of the diet between 1961 and 1962. The drop in temperature did not change the composition of the diet of the "Ropsha" carp fingerlings, nor did different population densities.

One index of the rate of food consumption of fish is the intestinal content; its competency is, however, disputed by some hydrobiologists. We agree with Zheltenkova (1964) that, with some exceptions, it is quite possible to judge how well fish are eating from the content of the intestine.

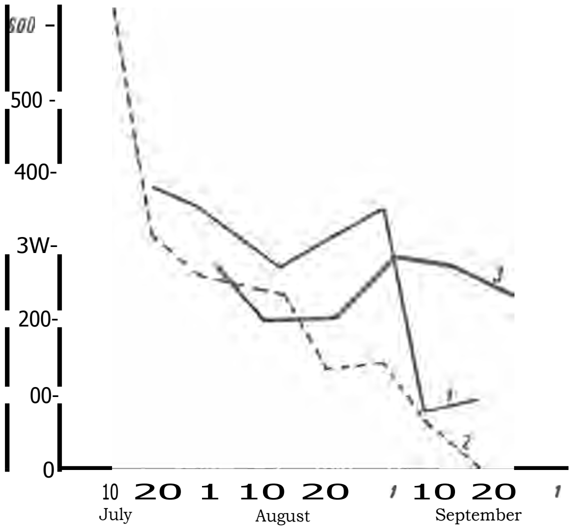

FIGURE 4. Indexes of intestinal content of carp fingerlings in intermediate ponds:

1 — No. 6, 1961; 2— No. 7, 1961; 3— No. 6, 1962.

In densely populated pond No.7 there was a rapid drop in the index in 1961; by mid-August it had dropped to only 100%00, and in September it dropped almost to 0 (Figure 4). On the other hand, in pond No. 6, the curve started to decrease only in September. This difference should be attributed to the different population density of the ponds. In pond No. 7, there were more fish and, as indicated by the lower average productivity of this pond, less food. The unfavorable ratio between the food supply and the population caused a high rate of consumption of plankton and benthos, decreasing their population and biomass (see Table 1). Thus, there was a rapid decrease in the index of intestinal content of fish in pond No. 7. In ponds No. 5 and No. 6, the $\frac{\text{food}}{\text{fish}}$ ratio was not so strained and, consequently, the indexes remained high.

The situation was completely different in 1962. In densely populated pond No. 6, the high index of intestinal content (200-300%00) was maintained for a long time, hardly changing until 21 September. The low water temperature retarded the growth of the fingerlings and they did not weigh even 5 g by autumn. Thus, food consumption was several times lower, and there was apparently a food surplus. This is also evident from the hydrobiological inspection, which indicated that the benthos reserves increased steadily toward autumn, and from measurement of the fingerlings, which found them to be in very good condition in autumn.

Thus in 1962, although population density in pond No. 6 was high (above 80,000/ha),the $\frac{\text{food}}{\text{fish}}$ ratio was favorable,and this was reflected in the values of the indexes of intestinal content. The carp ate less and digested more slowly, but did not starve. The factor which limited growth in 1962 was not food deficiency, but the exceptionally low summer water temperature.

The indexes of intestinal content indicate how abundant food supply is, and should thus never be disregarded.

Growth of "Ropsha" carp and productivity of carp ponds at various population densities

In the 1961 experiments, we tested population densities: from 18,000 to 28,000/ha and above 60,000/ha (see Table 1). In all the ponds where there was no supplementary feeding toward August and September, the biomass of the edible organisms, particularly of benthos, decreased, and weight gain and productivity were lower. We found large differences in growth rate in the different ponds, evidently due to the differences in density (Figure 5). By order of increasing density the ponds are: No. 5 <No. 6 <No. 7. This sequence also holds for the retardation of average weight gain, particularly in the second period of the experiments, when the biomass of edible organisms decreased and the fish clearly starved. In a warm year, increasing density to even 23,000/ha, without supplementary feeding, appeared to be dangerous, reducing weight gain by almost 3 g. In the pond with the highest density, 61,000/ha, the fish grew extremely slowly (see Table 1). Such densities are clearly inadmissible for ponds with average natural productivity without supplementary feeding. In pond No. 7, the high rate of consumption of the edible invertebrates undermined their replenishment.

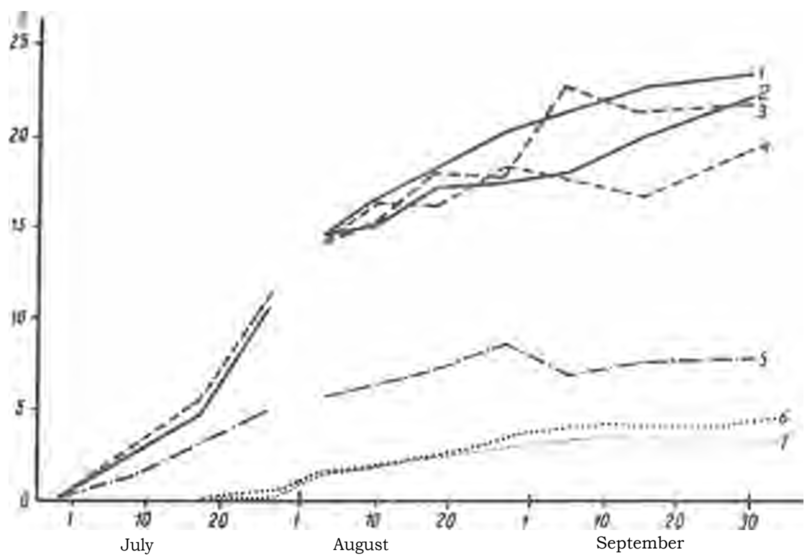

FIGURE 5. Growth of fingerlings in the intermediate ponds:

1 — No. 5, upper part, 1961; 2— No. 5, lower part, 1961; 3 — No. 6, upper part, 1961; 4— No. 6, lower part, 1961; 5 — No. 7, 1961; 6 — No. 5, 1962; 7— No. 6, 1962.

Densities of the order of 20,000 —25,000/ha (without supplementary feeding) should be considered the highest advisable for "Ropsha" carp in ponds of a similar type in normal years.

In the sections where there was supplementary feeding, the pattern was completely different. The biomass of the benthos in August and September was very high. High consumption of the concentrated artificial food is probably the main reason for the preservation of large benthos reserves and the high weight gain and productivity found in both sections which received the food supplement. Apparently, with supplementary feeding, 25,000/ha is not the optimum density; we suppose it can be increased to 35,000-40,000/ha (for ponds of the given category and with feeding of food concentrate).

In the cool summer of 1962, the high densities did not have a marked influence on the biomass of the edible organisms in the ponds. There was, however, a small difference in the weight gain. Thus, where density was tripled, the average weight of the fish at recovery was 25-30% lower than at low density (see Table 2). For these small fish, the slower growth at high density (70,000 —80,000/ha) could have been caused by an insufficient amount of available zooplankton and small midges.

Evidently, in cold years similar to 1962, and in intermediate type ponds, densities of 40,000-50,000/ha are permissible. The lower consumption of benthos by fish in these years promotes the increase of the food biomass in the ponds (Table 3), and considerably reduces food competition, although judging from the individual weight gains, it does not eliminate it.

We should add in conclusion that experimental use of food containing a great deal of spleen showed that "Ropsha" carp eat such food very rapidly and even more willingly than natural food.

Food preference

The 1961 and 1962 experiments confirmed that carp have a stable hierarchy of food preferences. The fingerlings apparently prefer reed midge larvae because they are easily accessible. The fish were usually fed in shallow, well warmed, and overgrown sections of the pond where reed midge larvae are particularly plentiful. The digging midges, such as Chironomus plumosus, Glyptotendipes and others,were inaccessible to the fingerlings because of their ability to burrow into the bottom. The number of species found in the intestines was much smaller than that of the pond benthos (Oligochaeta, dragon-fly or beetle larvae).

Preferences among zooplankton are also definite, although the reasons for this are not completely clear. The fingerlings ate mostly Cyclops, Chydorus, and to a lesser extent,Daphnia and Bosmina. Table 4 illustrates the food preferences.

Values of the indexes of preference were similar in other ponds, and are not presented here. Characteristically, none of the intestines of hybrid carp we examined contained any of the mass pond forms of such plankton as Diaptomus, Polyphemus, Diaphanosoma, Scapholeberis, and others.

TABLE 4. Indexes of preference among zooplankton in pond No.6 in 1961

Date	Chydorus and Alona	Cyclops	Daphnia and Cerio-daphnia	Bosmina
Upper part				
17 July	+0.7	-0.06	±0	-1.0
25 July	-0.5	+0.2	-0.27	-1.0
10 Aug.	+0.4	+0.3	+1,0	-0.1
18 Aug.	+0.9	+0.16	+1.0	±0
28 Aug.	+0.8	+0.2	+1.0	+0.01
5 Sept.	+0.8	+0.6	-0.6	+0.2
15 Sept.	+0.5	+0.6	+0.7	+0.09
Lower part				
10 Aug	+0.06	+0.15	-0.02	-0.09
18 Aug	+0.5	+0.18	+0.01	+0 01
28 Aug.	+0.5	+0.5	+0.3	+0.1
5 Sept.	+0.4	+0.8	-0.1	+0.1
15 Sept.	+0.5	+0.3	+0.02	+0.07

Discussion

The 1961 and 1962 experiments showed that at densities of 17,000-61,000/ha, as well as 80,000/ha in a cold summer, the composition of the diet of "Ropsha carp fingerlings remains nearly the same. They eat mostly small reed midges and Chydorus and Cyclops plankton. This uniformity is evidently maintained only up to a certain limit; at higher densities it will be disturbed. The literature contains many reports of yearling carp eating only plankton, and of carp eating higher plants (Shpet, 1958; Assman, 1962; and others). Reports of so-called forced eating by carp should not be rejected, but we should bear in mind that they all concern cases of a great shortage of food. If food is sufficiently abundant, the diet of carp is very stable, and the food preferences are maintained at different population densities. The diet does not change at different temperatures either. Comparison of data for 1961 and 1962 indicates that even in very cold summers, the constituents of the diet of "Ropsha carp fingerlings remained practically the same.

Analysis of hydrobiological and piscicultural data collected over 2 years revealed a very clear relation between the water temperature, the biomass of the edible organisms, weight gain of fish, and their consumption of food. In this respect, the ratio between the weight of the food and the weight of fish in the pond is particularly important. The lower 1962 temperatures, which retarded growth and thus lowered food consumption, caused an accumulation of benthos in the ponds and a more abundant food supply. Here, the index of intestinal content remained high for a long time. This index can be taken as a good indication of the state of the food supply for carp, although it may not always indicate how well the fish are eating.

It is important, also, to point out that in the warm year 1961, the weight gain of the fish was limited by the food supply, and it began to decrease at densities of the order of 25,000-30,000/ha. Supplementary feeding immediately raised weight gain. Contrarily, in the cold year 1962, the most important factor determining weight gain was water temperature. In the northwestern RSFSR, where cold summers are frequent, the temperature factor is decisive. Ropsha hybrid carp suffer less from temperature drops than other breeds of carp which are not interbred with the wild carp (Kirpichnikov, in this collection); nevertheless, their weight gain is also very dependent on temperature.

A few words should be said about optimal stocking densities in raising ponds in the northwestern RSFSR. Our data allow only approximate determinations of these values, and then only for ponds in which natural productivity is similar to that of the "Ropsha" ponds. These densities at autumn recovery are 20,000-25,000/ha without supplementary feeding, and 36,000-40,000/ha with supplementary feeding in ponds with natural productivity 250-400 kg/ha. This indicates that it is possible to obtain up to 1,000 kg/ha of fish in raising standard fingerlings. These figures should not be considered as fixed. In naturally more productive ponds (to 500— 600 kg/ha) greater density is possible. It should be kept in mind that excessively high densities inevitably retard the weight gain of fingerlings, since the increased consumption is not compensated for by replenishment of the edible invertebrates.

Our last comment refers to the quality of food. It is very important to use concentrated feeds in rearing the fingerlings. Food which contains spleen, as our experiment has shown, is eaten particularly rapidly and willingly. Vegetable foods are known to be inefficient feeds for fingerlings (Kirpichnikov, 1963). Addition of meat products increases consumption and improves assimilation. This, and use of fertilizers, are the most important means of increasing the permissible density of fingerlings and productivity in ponds.

CONCLUSIONS

1. Hybrid fingerlings in intermediate ponds of the fish breeding farm "Ropshe ate mainly Chironomidae larvae and some zooplankton. The composition of their diet at different densities (17,000-80,000/ha) was practically the same in warm and cold years. Low summer temperatures (1962), whichdid not influence the composition of the diet, decreased food consumption and consequently lowered the final weight of the fish.
2. The fish consumed a great deal of natural food in 1961, this influenced the biomass of edible organisms even at a density of 60,000/ha. In the cold year 1962, even a high density (up to 80,000/ha) did not decrease the biomass of edible organisms markedly, because of the lower rate of food consumption. At low summer temperatures, there was a surplus of food throughout the raising period.
3. The optimum density for raising fingerlings without supplementary feeding, which will not lower weight gain or final yield, in ponds in the

northwestern RSFSR, with a productivity of about 250-400 kg/ha, is approximately 20,000-25,000/ha. With supplementary feeding, densities up to 35,000-40,000/ha, are permissible.

4. The 1961-1962 investigations have confirmed previously established data on the food preferences of carp. Fingerlings eat mostly larvae of reed midges, cyclops, and Chydor u s, and do not consume Di a pt o mu s and Oligochaeta at all. In this respect the hybrid underyearlings do not differ from other breeds of cultured carp.

Bibliography

Publications in Russian

Assman, A. V. Vyedanie estestvennykh kormov karpami pri razlichnom kormovom rezhime i razlichnoi ploshchadi posadki (Consumption of Natural Food by Carp with Various Food Regimes and at Various Surface Densities). — Trudy Instituta Morfologii Zhivotnykh, Vol. 42. 1962.

B o r ut s kii, E. V. 0 kormovoi baze (On Food Reserves). — Trudy Instituta Morfologii Zhivotnykh, No. 13. 1960.

Borut s kii, E. V. Vylety khironomid (First Flight of Chironomidae). — Zoologicheskii Zhurnal, Vol. 42, No. 2. 1963.

Grimal ' skii, V. L. and S.N.Tyutyunik. Vliyanie razrezhennykh posadok na pitanie i rost molodi karpa (The Effect of Sparse Stocking on the Nutrition and Growth of Carp Juveniles). — Trudy Kishinevskogo Sel'skokhozyaistvennogo Instituta, Vol. 25. 1961.

Iv a no v, A. P. Opyt povysheniya effektivnosti iskusstvennykh kormov pri kormlenii molodi karpa (Experimental Attempt to Increase the Efficacy of Artificial Foods in Feeding Carp Juveniles). — Informatsionnyi Sbornik VNIRO, No. 5. 1959.

Iv 1 ev, V. S. Eksperimental'naya ekologiya pitaniya ryb (Experimental Ecology of the Fish Diet). Moskva. 1955.

Karpanin, D. P. Potreblenie pishchi molod'yu karpa pri razlichnykh usloviyakh pitaniya (Consumption of Food by Young Carp with Various Food Regimes). — Izvestiya Moskovskoi rybovodno-meljorativnoi opytnoi stantsii, Vol. 1. 1956.

Ki rpic hnikov, V. S. Opredelenie estestvennoi ryboproduktivnosti prudov i oplaty korma karpami (Determining the Natural Productivity of Ponds and the Conversion Ratios of Carp). — Rybnoe Khozyaistvo, Moskva. 1960.

Ki r pi chnikov, V. S. Znachenie estestvennogo i iskusstvennogo korma pri vyrashchivanii karpov-segoletok (The Importance of Natural and Artificial Food in Raising Carp Underyearlings). — Rybnoe Khozyaistvo Vnutrennikh Vodoemov Latviiskoi SSR, Vol. 7, Riga. 1963.

K ons t a nt ino v, A. S. 0 pitanii sazana v nekotorykh vodoemakh basseina Amura (The Diet of Wild Carp in Some Water Bodies of the Amur River Basin). — Trudy Amurskoi Ikhtiologicheskoi Ekspeditsii 1945-1949 gg., Vol. 3. 1952.

Lyakhnov ich, V. P. Estestvennaya kormovaya baza ryb v prudovykh khozyaistvakh Belorusskoi SSR (The Natural Food Reserves of Fish in Pond Fisheries of the Belorussian SSR). — Trudy Belorusskogo Nauchno-Issledovatel'skogo Instituta Rybnogo Khozyaistva, Vol. 2. 1958.

L y a k hn ov ich, V. P. Povyshenie estestvennoi kormovoi bazy ryb v prudakh putem udobreniya (Increasing the Natural Food Reserves of Fish in Ponds Using Fertilizers). — Tezisy dokladov I s"ezda Vsesoyuznogo gidrobiologicheskogo obshchestva,Izdatel'stvo "Nauka." 1965.

L y a k hn ov ich, V. P. Puti povysheniya ryboproduktivnosti prudov Belorussii (Increasing the Fish Productivity of Ponds in Belorussia). In this Collection.

Ma ks imov a, L. P. Pitanie i stepen' ispol'zovaniya estestvennykh i iskusstvennykh kormov gibridami karpa s sazanom (Nutrition and the Rate of Utilization of Natural and Artificial Food by Hybrids of Carp and Wild Carp). — Izvestiya GosNIORKh., Vol. 51. 1961.

Pc he l k in a, N. V. 0 znachenii estestvennoi pishchi dlya dvukhletok karpa v usloviyakh uplotnennoi posadki s primeneniem kormleniya (The Importance of Natural Food for Carp Aged 1 + in Conditions of Dense Stocking with Additional Feeding).— Sbornik Vserossiskogo Nauchno-Issledovatel'skogo Instituta Prudovogo Rybnogo Khozyaistva, "Rybnaya Promyshlennost," No. 52. 1959.

Shp et, G. I. Povyshenie donnoi kormovoi bazy karpovykh prudov putem regulirovaniya vodnoi rastitel'nosti (Increasing Food Reserves at the Bottom of Carp Ponds by Controlling Aquatic Vegetation). — Trudy Ukrainskogo NIIRKh, Vol. 2. 1958.

Zh elt en k ova, M. V. Indeksy napolneniya i sutochnye ratsiony kak pokazateli intensivnosti pitaniya ryb (Indexes of Intestinal Content and the Daily Rations as Indicators of the Rate of Food Consumption of Fish). — In Sbornik: "Pitanie morskikh promyslovykh ryb," Moskva, Izdatel'stvo "Nauka." 1964.

Publications in Other Languages

Gur z ed a, A. Influence of the Pressure Exerted by Carp Fry on the Quantitative Dynamics of Tendipedidae and Cladocera. — Ekol. pol., Vol. 6, No. 3. 1960.

M e r l a, G. Beiträge zur Kenntnis des Wachstums und der Ernährung des Karpfens (Cyprinus carpio L.).— Z. Fisch., N. F., Vol. 9, Nos. 7–10. 1961.

Muller, W. and G. Me r la. Versuche zur Steigerung der Erträge bei Satz -und Speisekarpfen durch Besatz und Futterungsmassnahmen. — Z. Fisch., N. F., Vol. 9, Nos. 1-2. 1962.

Rud z in c k i, E. Vergleichende Untersuchungen über den Wildkarpfen der Donau und den Teichkarpfen. — Z. Fisch., N. F., Vol. 10, Nos. 1-3. 1961.

Steffens, W. Vergleichende anatomisch-physiologische Untersuchungen an Wild- und Teichkarpfen (Cyprinus carpio L.). —Z. Fisch. , N. F., Vol. 12, Nos. 8–10. 1964.
Urbáček, J. Species Composition and Amount of Zooplankton in Relation to Fish Stock. — Rozpravy eskoslovenské akademie v6d, No. 10, Year of Publication 72. 1962.
Ya sh ow (Wir szub ski). Problems in Carp Nutrition. — Bull. Fish. Culture, Vol. 8, No. 5. 1956.

A CASE OF DROPSY IN GRASS CARP

A. G. Konradt and K. A. Faktorovich

Current opinion among practicing pisciculturists asserts that grass carp does not contract dropsy. Akhmerov (1959) expresses a similar opinion. In 1956, he transferred 12 grass carp aged 3+ and 4+ from the "Savinskoe" fish breeding farm in the Moscow Region to the "Angelinskoe" fish breeding farm in the Krasnodar Territory. They were placed in a 0.94 ha pond with yearling mirror carp, carp-wild carp hybrids, crucian carp, and tench. The carp and the hybrids had a severe form of dropsy. That summer dropsy was epizootic in the pond, and killed 50% of the carp and the hybrids. The experiment continued for 4.5 months. Grass carp were not infected with dropsy. On the basis of this experiment, Akhmerov recommended replacing carp by grass carp in commercial farms susceptible to dropsy. A case that occurred in the spring of 1963 at "Gostilitsy" (a branch of "Ropsha") puts this recommendation in doubt.

In spring, 1963, after fish were removed from wintering ponds, 228 three-year-old grass carp were kept temporarily in a small, 50 m^2, pond. In mid-May, when there was a sharp rise in water temperature, the grass carp contracted an illness that caused considerable loss. The diseased fish exhibited a reddening of the integument, bristling of the scales, anal reddening and protrusion, dropsy of the abdominal cavity, and a pale liver, all characteristic symptoms of severe dropsy (see Figure 1).

FIGURE 1. Grass carp suffering from dropsy. Note the skin ulcers and bristling of the scales on the tail.

The grass carp, which became ill in 1961 had been delivered as finger-lings from the People's Republic of China to the experimental base of the Institute of Zoology and Parasitology of the Academy of Sciences of the Turkmen SSR (village of Karamet-Niyat in the Charezhou Region). The ponds of the Karamet-Niyaz nursery get their water from the Kara-Kum canal. The water enters by gravity, and there are no protective filters in the water supply system.

The fingerlings were raised in the Karamet-Niyaz ponds until April 1961, after which 1,200 yearlings were transferred to "Gostilitsy." Ichthyopathological examination before transfer revealed negligible infection by the fluke *Dactylogyrus lamellatus* and almost total infection by the infusorian *Ichthyophthirius multifiliis*. No symptoms of dropsy were observed. To rid the fingerlings of the parasites, the fish were placed in an aquarium with an antiparasitic salt solution (0.7 g NaCl/liter) for 2 weeks. During transportation and maintenance in aquariums, 405 grass carp died. The remaining fish, which were completely freed of *Ichthyophthirius*, were placed in a 3.2 ha carp pond, which also contained 5 spawner, 721 three-year-old and 3,337 two-year-old carp-"eastern carp" hybrids, 1,000 "eastern-carp" underyearlings, 93 three-year-old orfe, and 1,142 yearlings of *Coregonus peled*. The grass carp grew well in 1961. The autumn yield of their yearlings was 78.3% of the initial stock, and average weight increased from 8.4 to 275 g. In the autumn, ichthyopathological examination revealed only one *Trichodina* in 10 specimens. No other parasites were found. No symptoms of dropsy were found in these fish or in the carp-"eastern-carp" hybrids in this pond.

In winter 1961-1962, the grass carp were placed in the Malogorsk pond of the central section of "Ropsha," together with carp fingerlings but separately from the hybrids with which they had been raised in the summer of 1961. In spring 1962, no symptoms of dropsy were found in the *grass* carp or the carp yearlings that had hibernated with them. The ichthyopathological examination conducted by Yu. A. Strelkov, a senior researcher of GosNIORKh, on 23 April 1962, revealed a large number of parasitic infusorians, *Chilodonella cyprini* in this fish. The grass carp were again placed in the carp pond.

With the spring temperature rise (17 May 1962), the 2+ hybrids which had been raised with the grass carp in the summer of 1961 contracted an illness which caused considerable mortality. The affected fish showed bristling of the scales, reddening of the abdomen, hemorrhage in the skin, ulceration of the fins and the skin, fluid in the abdominal cavity, and a pale, somewhat marbled color of the liver, that is, all the characteristic symptoms of dropsy. Single ulcers, localized reddening of the skin and bristling of scales was seen also in orfe which had been raised with the grass carp the previous summer. The grass carp had had no symptoms of dropsy at the time.

Later, B. Babaev, a graduate of the Institute of Zoology and Parasitology of the Academy of Sciences of the Turkmen SSR, wrote in a letter that in 1961, Lake Katta-Shor, which is connected with the Kara-Kum canal and, consequently, with the Karamet-Niyaz ponds, had Cyprinidae affected with dropsy. According to Babaev, in 1962, simultaneously with the epidemic among the "Ropsha" carp, Cyprinidae along the entire Kara-Kum canal contracted dropsy. Grass carp in the Karamet-Niyaz nursery did not contract dropsy then or later.

During autumn recovery in 1962, Strelkov examined the grass carp again. Thirty percent of them showed reddening of the abdomen and hemorrhages on the fins and on the opercula. There were no clearer symptoms of dropsy. There were some infusorians, *Chilodonella cyprini*, *Trichodina*, and plasmodium of *Chloromyxum* of the Myxosporidia in the grass carp. Only in the spring of 1963, as indicated at the beginning of this article, could we diagnose severe dropsy in the grass carp.

Since Cyprinidae had no previously contracted dropsy in "Gostilitsy," and since the fish that fell ill were only those which were raised with the grass carp for a long time, it can be assumed that the grass carp were the source of dropsy in "Gostilitsy." Evidently, the original source of the infection were the Cyprinidae from Lake Katta-Shor. Apparently in 1961 the concentration of the infective agent in the water of the Kara-Kum canal was not very high, which may explain the absence of the illness there. In the following year, 1962, dropsy had spread over the entire Kara-Kum canal. Probably, in 1961 the grass carp, the only cultivated fish in the Karamet-Niyaz ponds, were already carriers of the infective agent, but had not yet revealed clinical symptoms. These carp were then transferred to "Gostilitsy" and raised with the Cyprinidae, orfe, and the "eastern carp" hybrids, causing dropsy in the latter fish, the clinical symptoms of which appeared and were discovered by us the following year in the spring of 1962.

The close contact of the grass carp with the carp that had dropsy during joint raising in the summer of 1962, and also the joint hibernation of the affected carp with the apparently healthy grass carp caused the appearance of clinical symptoms of the disease in grass carp in spring, 1963. Where the infected grass carp were isolated from the slightly diseased Cyprinidae, as in the Karamet-Niyaz ponds, the clinical symptoms of the disease did not appear at all. Apparently, grass carp are much more resistant to dropsy than carp; thus, a prolonged passage of the infective agent through other Cyprinidae not resistant to dropsy is necessary before it can cause clinical symptoms in grass carp. This most probably is the reason for the appearance of dropsy in the grass carp at "Gostilitsy."

The reason that Akhmerov could not infect grass carp with dropsy may be that he did not keep them together with the diseased fish long enough,

Thus we conclude that:

1) under certain conditions grass carp can be infected with and suffer from dropsy;

2) the disease appears during prolonged contact of grass carp with other affected Cyprinidae;

3) stocking grass carp with carp in ponds where dropsy has been recorded is not safe in that it may increase the incidence of dropsy.

Bibliography

Akhmerov, A. Kh. Parazity i bolezni amurskikh ryb v period akklimatizatsii v prudovykh khozyaistvakh RSFSR (Parasites and Diseases of Amur Fish during Acclimatization in Pond Fisheries of the RSFSR). — Trudy Soveshchanii Ikhtiologicheskoi Komissii AN SSSR, No. 9. 1959.

Konradt, A. G. Opyt vyrashchivaniya belogo amura v prudakh Leningradskoi oblasti (Experimental Raising of Grass Carp in Ponds of the Leningrad Region).— Nauchno-Tekhnicheskii Byulleten' GosNIORKh, No.15. 1962.

THE EFFECT OF DIET ON THE NUMBER OF OOCYSTS OF COCCIDIA (EIMERIA CARPELLI) IN CARP

E. I. Zmerzlaya

Investigating coccidia of carp, E i me ria carpelli, in nursery ponds of Derzhov, in the L'vov Region, we found a substantial difference in the intensity of infestation between fingerlings dissected before they were fed with mixed food and those found in fish dissected sometime after they had eaten. The measure of difference was the number of oocysts found upon dissection. In one of the earliest observations, there were 2-47 oocysts within the visual field of the microscope in the intestinal lumen of fingerlings before feeding; the average number of oocysts was 18* and all the fish were infested. However, of 15 fingerlings investigated 1.5-2 hours after receiving food, only 9 (60%) showed oocysts, 1-3 appearing in the visual field. These observations were repeated several times with identical results (Table 1). These variations in the number of oocysts in the intestinal lumen are particularly noticeable in the first hours after feeding. Later, the number of oocysts gradually increases as they are replaced. In carp dissected only 6.5-10 hours after feeding, up to 21 oocysts have been found in the visual field. These variations are particularly noticeable in the anterior part of the intestine, where infestation is generally most intense; here only isolated oocysts were found after feeding.

TABLE 1. Number of oocysts in the intestinal lumen of carp before and after consumption of mixed feed

Date	Before feeding				Date	After feeding			
	No. of fis dissected	% of infestation	No. of oocysts			No. of fi dissected	% of infe	No. of oocysts	
			range	average				range	average
11 July	10	100	2-4'7	18.0	11 July	15	60	1-2	0.9
17 July	10	100	1-44	9.7	17 July	10	90	1-13	2.1
24 July	10	90	1-53	11.5	16 July	10	100	1-21	4.0
16 Aug.	15	100	1-46	13.6	13 Aug.	10	100	1-18	2.0

• Oocysts were counted in the visual field of the microscope at magnification 7 × 40. The oocysts were found without any special methods of concentration, that is, by examination of the direct smear.

In these experiments, we also found that more oocysts were released after feeding than before. Thus, before feeding, usually only isolated Eimeria oocysts in several visual fields were found, the average being 0.1-0.2 per visual field. After they had eaten, all the investigated carp showed intestines completely filled with mixed feed. In many cases, the number of oocysts in the posterior intestinal section increased considerably (up to 4 per visual field, 2.3 on the average).

What caused this range in the number of oocysts before and after eating mixed feed ?

We believe that the mixed feed has a mechanical effect on the oocysts, pushing them out of the intestines; thus, it temporarily reduces the number of oocysts in the intestine. However, because endogenous development continues in the intestines, a large number of oocysts are again formed after only one day, and the more time that passes after feeding, the more oocysts are found. Apparently, the decrease in the number of oocysts after feeding is due to their removal with the food bolus.

We decided to determine if mixed feed affects the rate of ejection of oocysts, if self-purification occurs, and under what conditions. There are few data in the literature on this problem. According to I. I. Bespaly (1959), fish that were highly infested with coccidia and kept in an aquarium with sufficient food became completely or partially freed from them. It was unclear whether self-purification is complete due to interference with the life cycle of the parasite, as in birds and rabbits, or whether complete self-purification is impossible because of the length of the cycle. It also seemed important to determine more accurately the effects of different foods.

Investigating coccidia of rabbits, E. M. Kheisin (1947) proved that if there is no reinfestation, self-purification follows, because schizogony is always limited in time. He also investigated the effect of the host's diet on the duration of the coccidial invasion of rabbits, and he found that the diet mainly influences the pathogenic effects and, partly, the number of gametes formed. The nature of the food has a negligible effect on the time required for development of the coccidia. As a result of a vegetable diet, oocyst excretion ceases 1-2 days earlier than when the animal is on a milk diet (Kheisin, 1937, 1947). Becker (1937) believes that coccodiosis of chickens can be cured by appropriate diet.

Because there are no such data for coccidia of carp, we conducted a series of experiments in aquariums to answer the above question, using fingerlings from a raising pond.

The intensity of infestation on the day the experiment began was up to 28 oocysts per visual field, and all fish were infested. Each experiment continued for a month and was done in triplicate on 40 fish, of which 5 specimens were dissected and examined for the presence of oocysts of coccidia every 5 days. The average water temperature during the experiment was 19.5 (14.6-24.6°).

In the 1st series of experiments, some of the fingerlings were fed only natural foods. Otherwise, all fish received the same treatment; water was changed daily and the aquariums were washed.

In the 2nd series of experiments, all the fingerlings were fed natural food, but some were treated differently. In one group, the water was changed and the aquariums washed thoroughly 3 times a day. In another group, the water was not changed throughout the experiment: it was only aerated and replaced when necessary. At the end of the 1st series of experiments, all fish, regardless of diet, were completely free of coccidia (Table 2).

TABLE 2. Effect of diet on time of excretion of coccidial oocysts in carp

Date	Mixed feed				Date	Natural food			
	lisse	[illegible]	No. of oocysts in visual field			lisse	nfes	No. of oocysts in visual field	
			range	average				range	average
27 June	10	10	1-25	6 2	27 June	10	10	1-25	5.7
4 July	5	5	1-18	5 6	3 July	5	5	1-11	4.2
9 July	5	5	1-15	3 8	8 July	5	2	1-2	1.3
14 July	5	3	1-5	8	14 July	5	3	1-9	1.9
19 July	5	1	1-2	.8	19 July	5	3	1-5	0.7
24 July	5	0	–	–	24 July	5	2	occasional	0.8
					27 July	2	0	–	–

At the end of the 2nd experiment, single oocysts were found in fish from aquariums in which the water had not been changed. Among these, the number of oocysts decreased slowly. The fish from aquariums in which the water was changed daily showed a more rapid decrease in the number of oocysts in their intestines beginning from the second half of the month (Table 3).

TABLE 3. Effect of changing the water in the aquarium on the time of excretion of coccidial oocysts in carp

Date	With water change				Date	Without water change			
	No. of dissectedf	No. of infestedf	No. of oocysts in visual field			No. of dissected	No. of infestedfi	No. of oocysts in visual field	
			range	average				range	average
27 June		10	1-28	11.9	27 June	10	10	1-22	9.7
2 July	5	5	1-26	10.8	2 July	5	10	1-17	9.1
8 July	5	5	1-21	10.3	8 July	5	4	1-7	4.3
13 July	5	4	1-27	9.3	13 July	5	5	1-4	3.7
18 July	[illegible]	1	occasional	occasional	18 July	5	3	1-4	2.2
23 July	5	2			23 July	3	2	occasional	occasional
27 July	[illegible]	0	--	–	27 July	3	2		

At the end of the experiments fish from the pond from which the experimental fingerlings were taken were investigated. The number of coccidial oocysts of these fish was at its former level, up to 23 per visual field (in some specimens they were up to 123; all fish were infested).

From these results we conclude that prolonged (one month) maintenance of fish in aquariums with abundant feeding on either natural or artificial foods frees them of coccidia completely. Fish fed mixed feed stopped excreting oocysts only 3 days before those fed natural food. Abundant feeding of natural foods combined with a frequent change of water causes a sharper decrease in the number of coccidial oocysts. Apparently, this procedure eliminates the possibility of reinfestation almost completely. Abundant feeding of natural food without changing the water does not cause complete decontamination in the same period. These conditions allow the accumulation of enough oocysts for reinfestation, and consequently, more prolonged excretion of oocysts.

TABLE 4. Variation in deg ee of infestation of carp by coccidia during self-purification and reinfestation

Date	No. of dissected fish	% of infestation	No. of occysts	
			range	average
10 June	20	5	15-28	19.0
28 June	20	20	2-33	12.5
5 July	20	25	1-10	2.5
10 July	20	60	1-15	2.2
22 July	20	100	1-8	0.9
29 July	12	100	1-21	2.7

Note. On 22 July, we reinfested the experimental fish.

These experiments indicate that in fish, as in warm-blooded animals, the nature of the food does not have much effect on the duration of excretion of oocysts. Examination of fish from aquariums in which water was not changed indicated that the duration of excretion of oocysts and the range of their number can be influenced by reinfestation. We attempted to confirm this assumption by the following experiment. In an aquarium we placed 200 fingerlings partially infested with coccidia and fed them natural foods. The rate of infestation at the beginning of the experiment was 5%; the number of oocysts was up to 28 per visual field (average 19). During the experiment, the rate of infestation gradually increased, while the number of oocysts at dissection decreased. By the end of the month, all the fish were infested and the number of oocysts in the visual field varied from 1 to 8 (on the average 0.9). In order to verify the assumption that a repeated introduction of oocysts would raise the intensity of infestation, we added 7 fingerlings from the raising pond to this aquarium. All were infested at the time of their introduction to the aquarium, with 5-17 oocysts per visual field (average 7.5). After 7 days, the experimental fish and those added from the raising pond were dissected. All the fish were infested, but the number of oocysts in the intestinal lumen varied. In the experimental fish, it had increased to 21 per visual field, an average increase of 300%. In those fish added from the raising pond, the number of oocysts decreased to 1-3 per visual field, an average decrease of 50% (Table 4). Apparently the experimental fish were dissected during maximum excretion of oocysts. This small experiment confirmed the possibility of reinfestation of the carp by coccidia.

These experiments suggest the following conclusions:

1. The nature of the diet has no essential effect on the time of excretion of coccidial oocysts in carp.
2. Mixed feed has a mechanical effect on oocysts in the intestines, and pushes them out. Thus, after feeding carp mixed feed, they excrete a large number of coccidial oocysts.
3. To diagnose coccidiosis in carp, the fish should be examined before being fed mixed food.
4. Prolonged maintenance of carp infested by coccidia in aquariums with abundant food in conditions that prevent reinfestation completely frees them of coccidia.
5. We found it possible to reinfest carp with coccidiosis in experimental conditions.

Bibliography

Publications in Russian

Be s palyi, I. I. Koktsidioz karpov v prudovykh khosyaistvakh UkrSSR (Coccidiosis of Carp in Pond Fisheries of the Ukrainian SSR).— Trudy Soveshchanii po Boleznyam Ryb, Izdatel'stvo AN SSSR, No. 9. 1959.

K he i s in, E. M. Nekotorye dannye o vliyanii diet na zarazhaemost' krolikov kishechnymi koktsidiyami i smertnost' ikh ot koktsidioza (Some Data on the Effect of Diet on the Susceptibility of Rabbits to Infection by Intestinal Coccidia and their Mortality from Coccidiosis).— Trudy Instituta im. Pastera, Vol.3. 1937.

K he i s in, E. M. Koktsidii kishechnika krolika (Coccidia of the Intestine of the Rabbit).— Uchenye Zapiski Leningradskogo Gosudarstvennogo Pedagogicheskogo Instituta im. A. I. Gertsena, Vol. 51. 1947.

Publications in Other Languages

Becker, E. Control in Experimental Coccidiosis.— Science, Vol. 86. 1937.

INCREASING THE FISH PRODUCTIVITY OF PONDS IN BELORUSSIA

V. P. Lyakhnovich

(BelNIIRKh)

There are presently about 13,000 ha of ponds in Belorussia, of which about 12,000 ha are specialized reserves for fish breeding. Fish breeding ponds, in general, are grouped in complexes and systems which include ponds of all categories specified by the biotechnical standards of carp breeding. Only 10,159 ha of ponds are under the administration of the Department of Fisheries of the Belorussian SSR. The main area consists of 8,714 ha, of which 7,470 ha are forage ponds, and 1,077 ha are raising ponds. The rest of the ponds belong to the collective and state farms of Belorussia, while 2,500 ha are artificial ponds that may be drained and that are reserved for fish breeding.

The forage ponds, with a total area of 7,470 ha, yield more than 30,000 centners of high-quality commercial fish annually, about as much as all the other fishery grounds of the Belorussian SSR (123,000 ha of lakes and 3,600 km of rivers). Moreover, the cost of pond fish in Belorussia is considerably lower, and the average wholesale price is much higher than are these costs of fish from lakes and rivers. Thus, pond fish breeding in Belorussia is highly profitable, while fishing in the lakes and rivers is not.

Belorussian pond fish raising is intensive. Until recently, the main method of intensification was supplementary feeding with various kinds of oil cakes, groats, and loose, mixed fish feeds. With feeding, the total fish production of ponds varies widely, 150-1,400 kg/ha, averaging about 470 kg/ha for forage ponds, and about 500 kg/ha for raising ponds.

Collective and state farms make less use of supplementary feeding and other intensification methods. The ponds are in worse condition than those in the specialized farms; therefore, they are much less productive, seldom yielding more than 400 and averaging less than 200 kg/ha.

Investigations made over many years show that the ponds can be subdivided into 5 groups according to their natural productivity. The characteristics of these groups by the indexes of primary production, and especially by the development of phytoplankton, were presented in earlier reports by our colleagues at the BelNIIRKh laboratory of hydrobiology (Lyakhnovich et al., 1961; Chernyakova, 1961; Lyakhnovich and Prosyanik, 1964). According to Lyakhnovich (1961) and Vinberg and Lyakhnovich (1964), there is a relationship between abundance of natural food supply (zooplankton and zoobenthos) and natural fish productivity of carp-breeding ponds, which is expressed by the equation $y = 18 + 2.1x$, where y is the natural productivity and x is the average biomass of the organisms.

On the basis of data on the biomass of zooplankton and zoobenthos of 30 raising and 34 forage ponds of fish farms, and 85 ponds of collective and state farms, we have attempted to determine their natural fish productivity using this equation. Thus, we may evaluate the present state of the ponds of the republic and suggest possible ways of increasing productivity of the ponds. As indicated in the foregoing material, supplementary feeding is used in raising fish in the Belorussian ponds, which makes it difficult to determine the true natural productivity, i. e., how much of the productivity is due to the natural food supply. The graphic method of determining natural productivity developed by Kirpichnikov (1960) is unsuitable for forage ponds.

TABLE 1. Natural food supply and natural productivity of carp ponds of the Belorussian SSR in 1956-1963

Ponds				Edible biomass			[illegible] kg/ha
category				[illegible]	[illegible] kg/ha	zooplankton, [illegible]	
State	I	10	33.3	< 50	37	54	96
	II	10	33.3	51-100	70	51	165
" Raising	III	4	13.4	101-150	120	69	270
	IV	3	10.0	151-200	180	64	395
	V	3	10.0	>200	310	86	670
	I	12	35.3	< 50	26	42	72
	II	7	20.6	51-100	63	45	150
" Forage	III	6	17.6	101-150	116	59	260
	IV	4	11.8	151-200	165	72	345
	V	5	14.7	> 200	350	75	755
	I	37	43.5	< 50	23	20	66
	II	18	21.2	51-100	75	32	175
Collective farm	III	9	10.6	101-150	120	39	270
	IV	17	20.0	151-200	180	39	395
	V	4	4.7	> 200	210	34	460

All the ponds investigated were divided into 5 groups according to the edible biomass (zooplankton and benthos) (Table 1). Characteristically, more than half of all the ponds have an average edible biomass of less than 100 kg/ha, i. e., are in the 2 lowest groups. Ponds with a high and very high edible biomass make up no more than 25% of each category.

We noted differences in the ratio of zooplankton and benthos to the total edible biomass of ponds of the different groups. In the well utilized ponds of the fish farms that were drained for winter, the proportion of plankton increases markedly, with increase in the total natural food supply. Thus, on the average, zooplankton made up 54 and 51% of the edible biomass in groups I and II, while in raising ponds of group V its proportion increased to 86%. This pattern was also evident in the forage ponds of fish farms.

In collective and state farm ponds, the proportion of zooplankton in the edible biomass is considerably smaller and it increases less rapidly with the increase of total food supply. The high proportion of benthos, which was more than 60% of the total edible biomass, is apparently due to the presence of a considerable layer of silt deposits at the bottom of these ponds, while development of zooplankton is limited by a heavy overgrowth.

From the average values of the edible biomass for each group of ponds in all 3 categories,natural productivity was calculated according to the equation. For the third of the raising ponds in group I, the estimated natural fish productivity was 96 kg/ha. Another third, group II, has a natural productivity of up to 165 kg/ha. More than half of the forage ponds have a natural productivity of up to 150 kg/ha. The highly productive ponds (above 400 kg/ha) are 10% of the raising ponds, and 14.7% of the forage ponds. The collective and state farm ponds, which are used mainly as forage ponds or for mixed aged stocking (Lyakhnovich and Leonenko,1962), have lower productivity in groups I and V in comparison with the specialized pond farms.

Since the ponds were chosen at random, the assumption can be made that the distribution of the investigated ponds into groups is representative for ponds of the given category. On this basis we calculated mean natural productivity. For the raising ponds, this value was 230 kg/ha, for the forage ponds it was 250 kg/ha, and for the collective and state farm ponds, it was only 195 kg/ha. Interestingly, the planning organizations assume an average natural fish productivity of 200-220 kg/ha for raising and forage ponds.

Because the data for Table 1 were accumulated by us over 8 years (1956-1963), and the quality and productive properties of the ponds improved somewhat each year, it should be assumed that the present values of natural productivity are 10-15% higher than those given in Table 1.

Hydrological, soil, climatic, and other natural conditions in Belorussia are not so diverse as to affect the differences we established in natural fish productivity, especially as ponds located close to each other very often may belong to extremely different productivity groups. Thus, for example, in 1963 in the "Volma" fish farm, 1,270 kg/ha commercial fish were obtained with supplementary feeding from Pond No. 9, which had an area of 152 ha and a natural productivity of 480 kg/ha. In the same year and in the same farm, only 160 kg/ha were obtained from forage Pond No.7 (134 ha), about $^1/_8$ less than from Pond No. 9 and $^1/3$ less than the natural productivity. The condition of Pond No.7 is so poor that intensive fish raising in it is not possible, and the fish are raised here only on natural forage. Similar examples can be found in any of the 13 pond farms of the republic. This indicates that the yield of fish production per unit area is often determined more by natural conditions than by the quality of farm management. The productivity of the ponds thus can be raised greatly by systematic management. Hence, the main problem is to raise the natural productivity of all the ponds to the level of group V. This would make it possible to raise 18,000,000 standard fish for stocking, weighing an average of 30g, and to produce 65,000 centners of commercial fish in the present pond area,without using artificial food,which is scarce and expensive. More realistically, in the next 3-5 years an increase of the natural productivity of the poor ponds to the level of medium ones, that is, the level of group III, can be considered. At a constant proportion of remaining pond groups, in the overall balance, this would yield an average of 336 kg/ha of commercial fish in the specialized farms and 264 kg/ha in the collective and state farms. If all 9,500 ha of usable foraging areas were exploited, the annual yield of commercial fish would reach 30,000 centners without additional expense of artifical food, of which 6,850 tons are used at present in Belorussia, at a total cost of 550,000 rubles. If, in addition, natural productivity is raised to the indicated level, at a conversion ratio of 7, total Belorussian commercial pond production could reach about 40,000 centners.

The low total productivity of the Belorussian ponds is due to their low natural productivity. It is well known that in shallow, swampy poor ponds, overgrown with plants, even supplementary feeding, ordinarily a powerful device, does not produce the proper effect. The calculations of G. G. Vinberg indicate that using any method of intensification in stagnant ponds restores the oxygen balance satisfactorily only if at least ½ of the total production is obtained on account of the natural food supply, by utilization of the primary production of the water body (Vinberg and Lyakhnovich, 1965). It is not accidental that densely stocked and intensively fed ponds often have mass mortality due to oxygen deprivation, even where productivity is high. This is the result of an improper ratio between production obtained by use of natural processes to that obtained by use of artificial food.

Thus, increasing natural productivity is the main and decisive prerequisite for intensification of pond fish breeding, that of Belorussia in particular. The relatively low natural productivity of the Belorussian ponds is caused by a series of factors, some beyond control and others which may be controlled in various ways.

I. Uncontrollable factors

The location of the republic determines the air and water temperature, duration of growing season, amount of sunlight, etc. The average monthly temperatures of May, June, July, and August place Belorussia between the isotherms of 15 and 17°, which is sufficiently favorable for warm-water pond fish breeding. However, the climate is not uniform throughout the republic. According to the most recent data, Belorussia is subdivided into 6 soil-climatic zones: I—northern (lake), II— central (watershed), III— western, IV — eastern, V — southwestern and VI—southeastern. Pond fish breeding in Belorussia is concentrated mainly in the western, southwestern, southeastern and the central zones, where the sum of effective temperatures of the growing period reaches 1,600-1,770°, and the growing period about 12-20 days longer than in the northern zone.

While temperatures are more favorable in southwestern and southeastern farms ("Karpin," "Stradoch'," "Beloe," "Krasnaya zortka" and "Tremlya"), the soil fertility, drainage, and pond beds are poorer there than in the central and western farms ("Volma," "Al'ba," "Byten'" and " Vileika"). Belorussian soil is known to be infertile; thus, water running off the topsoil is poor in minerals and biogenous elements. Above all, the swamps, due to poor drainage in the fish farms of the Polessie zone, increase the content of humic matter. All this is detrimental to the productivity of the ponds. However, the soil becomes more fertile due to agricultural technology and intensification based on the use of chemicals, which is widespread in the

Soviet Union. In due course, this will undoubtedly improve the productivity of the water bodies.

Thus, the negligible differences in the natural conditions of fish breeding in different parts of Belorussia cannot cause the above-indicated differences in the natural productivity of the ponds.

II. Controllable factors

1. The water supply is a problem of foremost importance in most pond farms. Only somewhat more than 30% of the pond area of the republic is provided with enough water for intensive farming. These are the "Volma" and "Byten'" fish farms, the "Khotova" nursery, and others. In most farms, however, there is a periodic, often chronic, acute water shortage at the most crucial period in raising fish, namely, in the summer, This is partly because many of our farms ("Beloe,""Krasnaya zor'ka,""Tremlya," "Vileika," and others) we re designed for an extensive, or only slightly intensive farming, where a slight water shortage would not cause such catastrophic results as in highly intensive farming. The other, equally important reason for the water shortage is the redistribution of the topsoil runoff resulting from felling of forests, drainage and reclamation of swamps, and construction of dams.

We must try to find additional water supplies as soon as possible for the ponds where there is a water shortage. In particular, the water supply problem at "Beloe,""Krasnaya zor'ka," and "Tremlya" can be solved by constructing waterworks. The reconstruction programs for "Karpin" and "Strad-och'," where the water supply problem is not solved, should be reexamined.

2. The second major determinant of natural productivity is depth of the ponds. Calculation of fish productivity per unit area drew the pisciculturists' attention away from the depth of summer ponds, that is, from the volume of water, which in fact determines the productivity. The wintering ponds in fish farms are built to definite specifications of depth and area, but the summer "productive" ponds, which justify the existence of the farm, are constructed according to the farm's layout and topography.

The average depth of the Belorussian forage ponds is 0.7-1.0 m, and that of the raising ponds is 0.4-0.7 m. These depths are clearly insufficient for high productivity. According to Table 1, the higher the productivity of the pond (either raising or forage), the larger the proportion of zooplankton. This pattern is found not only among Belorussian fish breeding ponds, but throughout those of the European USSR (Vinberg and Lyakhnovich, 1965) and also Germany (Schäperclaus, 1961). With other conditions being equal, however, the biomass zooplankton per unit pond area corresponds to the volume of water. The higher the volume, the higher the biomass, so that the summer depth of ponds must be increased considerably.

Carp ponds have no temperature stratification of the water in summer; in addition, proper contact between the water mass and the bottom deposits should be assured. In other words, there should be complete mixing of the water. This ensures an active ion exchange between the water and the bottom, which apparently has a major role in productivity. There are also grounds for believing that the trophic water layer coincides with the mixing zone; thus, the summer depth of the carp ponds should not exceed the depth which is fully mixed by wind.

According to Patalas (1960), the depth of such mixing depends on the length of the wave developed by the wind in the given water body. The latter, in turn, depends on the wind velocity and the length of acceleration of the wave, that is, on the effective length of the water body, according to the equation of V. G. Andreyanov (1939):

$$X= 0.304\ W\ 1/2,$$

where λ is wavelength, in meters; and W is wind velocity, m/sec.

On the basis of Patalas' data (1960) it can be assumed that the depth to which water is mixed is equal to four wavelengths:

$$H= 4X.$$

According to the data of the Central Administration of the Hydrometeorological Service of the Belorussian SSR, the average summer wind velocity in Belorussia is 3-5 m/sec. In calculating optimal pond depths (Table 2), we have taken the lower of these values. Calculations were worked out for ponds of areas corresponding to squares of integers from 1-10. In this case, the assumption was made that the length of the wave acceleration on the ponds is equal to the area's square root; that is, the ponds have approximately a rectangular shape close to a square. Under these conditions, 1 ha of water will be mixed to a depth of 1.16 m, 49 ha will be mixed to 3.04 m, and 100 ha to 3.64 m.

TABLE 2. Optimal depths of summer carp ponds in Belorussia

Index	Calculation value									
Area of the water body,ha	1	4	9	16	25	36	49	64	81	100
Length of the wave acceleration, km	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Wave length (X) at W= 3 m/sec	0.29	0.41	0.50	0.57	0.67	0.70	0.76	0.81	0.87	0.91
Depth of mixing, m	1.16	1.64	2.0	2.28	2.68	2.80	3.04	3.24	3.48	3.64
Average optimal depth,m	0.58	0.82	1.0	1.14	1.34	1.40	1.52	1.62	1.74	1.82

The depth to which water is mixed, however, should not be accepted as optimum for fish ponds. Constant ion exchange of the water with the bottom should be assured. The assumption can be made that the intensity of the ionic exchange depends considerably on the degree of water mixing, that is, on the rate of exchange of the waters bordering the bottom. We assume that the average depth of the pond can be half the depth to which the water is mixed. These values are presented in Table 2 as the optimum average depths of summer carp ponds.

For optimum productivity, the depth of individual sections of the pond should not deviate more than 20% from the average.

These considerations seem especially useful now in Belorussia, as well as in other parts of the Soviet Union, since extensive reconstruction of the pond farms and large-scale construction of new fish breeding ponds are taking place. The principles presented here as the basis for calculating optimal depths of summer ponds can be easily applied to any district, making proper corrections for differences in average wind velocity.

3. The third factor limiting the natural productivity of Belorussian ponds is their condition; the condition of the ponds in many of the pond farms, and in almost all of the collective farms and state farms of the republic i unsatisfactory. Improvement of the ponds involves the following points:

a) Drying the bed of the ponds during drainage. Most of the forage and many of the raising ponds are not suitable for [illegible] treatment during drainage, even if they are dried for a year, because of the [illegible] of the bed due to the high bottom water level. This seriously disturbs attempts to improve the beds of the ponds, reduces to zero the effectiveness of [illegible], and contributes to overgrowth and swamping.

b) The stumps and debris on the pond beds are characteristic of all the pond farms, remaining in many farms after pond reconstruction work has been completed (forage ponds Nos. 1, 7, and 8 at "V[illegible]," the R[illegible] system of ponds in "K[illegible] zor'ka," the forage ponds at "S[illegible]," and others). The stump remnants on the pond beds not only prevent [illegible] treatment of the ponds, but also gravely hamper the control of pond bed overgrowth.

c) The overgrowth of the ponds by higher [illegible] (soft and stiff) is a plague of pond fish breeding in Belorussia. The presence of large areas of shallow waters contributes to vigorous development of [illegible] and higher [illegible], and contamination and unevenness of the bed of the shallows hamper use of reed mowers as an effective control of overgrowth. Draining the ponds is of no use either, because this does not result in sufficient drying for [illegible] treatment of the pond bed. In Belorussia there are few relatively clean ponds which are free of higher [illegible], and thus suitable for intensive exploitation. The clean ponds are those at "Beloe," ponds No. 6 and No. 9 of "V[illegible]," "[illegible] "I[illegible]," "D[illegible]" and "Al'byanskii" forage ponds at "Al ba," "Kosishche" and No. 5 at "Byten'" and a few others. Among the collective and state farms, the only clean ponds are these of the "P[illegible]" collective farm of the K[illegible] district and those of the "V[illegible]" state farm.

In overgrown ponds, neither fertilization nor supplementary feeding is effective, although both are ordinarily powerful means of increasing fish productivity. Until recently, experts were disputing about which part of the pond should be overgrown by soft [illegible]. It can be stated decisively that clean ponds, completely free from overgrowth of both stiff and soft plants over the entire surface of the water, are most suitable for intensive exploitation. Overgrowth must be combated by all available means until it is completely eliminated. This could be achieved by increasing the depths of the ponds to correspond to the aforementioned calculations, clearing and removing the stumps and drying the bed.

The accomplishment of all these technical measures will increase the natural productivity of the ponds to 200-250 kg/ha on the average, and will create unlimited possibilities for the application of such effective and rapid means of intensification as fertilization of the ponds and feeding the fish concentrates.

[illegible]

values considerably, no fertilizers should be added, regardless of the content of the biogens in the water, until the intensity of the plankton photosynthesis starts to decrease.

Both these methods are simple enough; their indications are based on determination of the quantity of oxygen dissolved in the water (which can be done at every pond farm). Biological tests for the requirement of fertilization can be limited to 2-3 determinations during the summer on several characteristic ponds of the farm; determinations of the primary production should be conducted regularly 2-3 times monthly on each pond. They should become an inherent part of the management of pond fertilization.

Domestic and industrial waste waters of sugar, starch-molasses, and other food factories are, as yet, unused reserves for increasing the natural productivity of the ponds in Belorussia. Recent experiments by P. Wolny in Poland, using the purified domestic sewage of the city of Kielce, gave exceptional results (Wolny, 1962). Ponds filled with city sewage and stocked with carp yearlings gave a natural production of 1,100 kg/ha, thus exceeding by 8.5 times fish productivity of unfertilized ponds of this district in Poland. At the "Al'ba" farm in Belorussia, a low and unregulated inflow of domestic waste waters in the "Ivanov" forage pond provides a constant, high productivity. Plans for new fish farms to be built close to large cities and other centers of population which have a sewer system should certainly include an inlet for purified sewage to the summer ponds. This will increase the natural productivity of the ponds greatly, while reducing the expenditure on synthetic fertilizers and protecting the natural water bodies from pollution and hypereutrophy.

We must also mention the combined carp-duck farms. In Belorussia, duck farms are found at "Volma," "Al'ba" and "Lakhva," but this combination is inefficient both for raising ducks and for raising carp. The problem is that the ducks are kept overcrowded in a small section of a large pond, partitioned by net; they pollute this part of the pond intolerably, making it completely unsuitable for fish breeding. At the same time, crowding the ducks into a small area does not allow them to gain weight by eating the natural food present in the water. Combined carp-duck farms are contemplated now in which the ducks are to be distributed over the entire available area of shallow water, so that there will be no more than 200-250/ha. At "Lakhva" 80,000 ducks are raised annually. By the existing norms, this flock should be distributed over an area of 400 ha, but it is kept on an area $^1/10$ as large. This situation also exists in other carp-duck farms.

While carp monoculture presently produces exceptional yields in various districts of the USSR, including Belorussia, a few words should be said about the prospective introduction of plant eating fish in addition to the carp into ponds of the republic. Some work has already been done in this area. In autumn, 1963, 6,000 grass carp and silver carp fingerlings were taken from the "Yakot'" farm near Moscow. They endured the transportation very well and overwintered without any mortality in one of the wintering ponds of the "Izobelino" farm. When raised together with the carp, the grass carp grew quite as well as the yearling carp.

The silver carp have, so far, lagged in growth, even where an intensive florescence is maintained by fertilization, and there is no shortage of phytoplankton. At present, while Belorussian ponds are shallow and intensely overgrown with higher hydrophytes, the grass carp should become [illegible] phytoplankton [illegible].

CONCLUSIONS

1. A[illegible] (y) [illegible] (x): [illegible] = 18 + 2.1x, [illegible] 5 [illegible] B[illegible] SSR. I[illegible] 66 [illegible] 755 [illegible]/[illegible]. O[illegible], [illegible] B[illegible] 230-250 [illegible]/[illegible], [illegible] 195 [illegible]/[illegible].

2. T[illegible] B[illegible]. I[illegible] B[illegible].

3. T[illegible] B[illegible] SSR, [illegible]:

[illegible]) [illegible];

[illegible]) [illegible];

[illegible]) [illegible], [illegible] hydrophytes;

[illegible]) [illegible];

[illegible]) [illegible];

[illegible]) [illegible]-[illegible], [illegible], [illegible].

B[illegible]

P[illegible] R[illegible]

Andreya[illegible]v, V. G. Vetrovaya volna ozernykh vodoemov (T[illegible] W[illegible] W[illegible] L[illegible] W[illegible] B[illegible]). —Izvestiya Nauchno-Issledovatel'skogo Instituta Gidrotekhniki, V[illegible]. 24, N[illegible]. 25. 1939.

B[illegible]ov, I. V. Issledovanie fotosinteza v vodoemakh Siluriiskogo plato Leningradskoi oblasti (I[illegible] P[illegible] W[illegible] B[illegible] S[illegible] P[illegible] L[illegible] R[illegible]). —Vestnik LGU, N[illegible]. 7. 1948.

Che rnyako va, E. L. Biomassa fitoplanktona v rybovodnykh prudakh kolkhozov i sovkhozov Belorussii (Biomass of Phytoplankton in Fish Breeding Ponds of Collective and State Farms of Belorussia). — In Sbornik: "Pervichnaya produktsiya morei i vnutrennikh vodoemov," Minsk. 1961.
K irpichnikov, V. S. Opredelenie estestvennoi rybopruduktivnosti prudov i oplaty korma karpom (Determination of Natural Productivity of Ponds and the Gains Produced by Supplementary Feeding of Carp). — Moskva, IzdatePstvo "Rybnoe khozyaistvo." 1960.
Lyakhnovich, V. P. Sootnoshenie kormovoi biomassy i ryboproduktsii v karpovykh prudakh (Edible Biomass Ratio and Fish Yield in Carp Ponds). —Trudy Vsesoyuznogo Gidrobiologicheskogo Obshchestva, Vol.11. 1961.
Lyakhnovich, V. P. Ekonomicheskaya effektivnost' udobreniya prudov (Economic Profitability of Pond Fertilization).— Rybnoe Khozyaistvo, No. 5. 1963.
Lyakhnovich, V. P. and E.P. Leonenko. Perspektivy razvitiya prudovogo rybovodstva v kolkhozakh i sovkhozakh Belorusskoi SSR (Prospects for Developing Pond Fish Breeding in Collective and State Farms of the Belorussian SSR). —In Sbornik: "Voprosy rybnogo khozyaistva Belorussii," Minsk. 1962.
Lyakhnovi ch, V.P. and L.V. Pro syanik. Razvitie sine-zelenykh vodoroslei v prudakh raznoi pruduktivnosti (Development of Blue-Green Algae in Ponds of Different Productivity). —In Sbornik" "Ekologiya i fiziologiya sine-zelenykh vodoroslei," Moskva. 1964.
Lyakhnovich,V.P., R.M.Surinovich,andN.T.Kazanova. Pervichnaya produktsiya prudov kak pokazatel' ikh ryboproduktivnosti (The Primary Production of Ponds as an Indicator of their Fish Productivity). —In Sbornik: "Pervichnaya produktsiya morei i vnutrennikh vodoemov," Minsk. 1961.
V inb e rg, G. G. Nablyudeniya nad intensivnost'yu dykhaniya i fotosinteza planktona rybovodnykh prudov (Observations on Respiration Intensity and Photosynthesis of Plankton in Fish Ponds). —Trudy Limnologicheskoi Stantsii v Kosine, Vol. 21. 1937.
Vinberg,G.G. and V.P. Lyakhnovich. Sovremennoe sostoyanie udobreniya prudov (Recent State of Fertilization of Ponds). —In Sbornik: "Biologicheskie osnovy rybnogo khozyaistva vnutrennikh vodoemov Pribaltiki," Minsk. 1964.
V inb e rg, G. G. and V. P. Lyakhnovich. Udobrenie prudov (Fertilization of Ponds). Moskva. 1965.

Publications in Other Languages

Patalas, K. Punktowa ocena pierwotnej produktywnosci jezior okolic Wegorzewa. —Roczn.Nauk roln., VoL 77-B-1. 1960.
Schäper claus, W. Lehrbuch der Teichwirtschaft. Berlin. 1961.
Wolny, P. Przydatnosc oczyszczonykh scieków miejskich do hodowli ryb.— Roczn. Nauk roln., Vol. 81-B-2. 1962.

DEVELOPMENT OF FISH BREEDING IN PONDS IN WESTERN SIBERIA

V. N. Zlokazov and V. A. Iganat' ev

(Novosibirsk Department of SibNIIRKh and Novosibirsk Fish-Breeding Improvement Station)

INTRODUCTION

The development of pond fish farming in Siberia is intimately linked with the attempts to acclimatize Cyprinidae in local water bodies (Ioganzen and Petkevich, 1951).

Acclimatization of the wild carp in the Ob' Basin was begun in 1910 by I. V. Kuchin, who first introduced several hundred fingerlings into the water bodies of the Eastern Urals.

More systematic work began in 1929. From 1929 to 1941, over 120,000 wild carp were stocked in the Chany, Sartlan, Ubinskoe,Khoroshee, Ik, Berchikul' and other lakes. The wild carp grows and winters well in these lakes, reaches sexual maturity and spawns. It has not yet become a commercial fish in any of these water bodies, although some adults and young fish are being caught currently.

The main cause of the unsuccessful acclimatization of this fish is the considerable number of predators (pike, perch, ruff) which eat carp eggs and young in all of the water bodies where wild carp has been introduced. Another factor is the absence of suitable spawning grounds. The wild carp likes to lay its eggs on meadow grass which is flooded by rising waters. In Western Siberian water bodies, even when there is a spring flood, the water level has usually dropped by the time spawning temperatures (17° and above) are reached. Another important factor which limits the population of wild carp is the periodic recurrence of fatal frosts.

The first attempt to raise carp in Siberian ponds was made in 1932, when 5,000 yearlings and 30 carp aged 2+ were stocked in various ponds. In the autumn, only some of the fish could be recovered from 2 ponds; the rest of the carp remained for the winter and died in the winterkill. However, the attempt proved that carp grow well in Siberian ponds; at 2 years, the fish weigh 500— 700 g.

In 1934, the first carp hatchery in Eastern Siberia went into operation south of the Krasnoyarsk Territory near the town of Uzhur. Carp have been spawned here every year since 1935. However, because of poor farming practices and lack of experienced personnel, the Uzhur hatchery-nursery is quite substandard in all aspects of fish farming. Somewhat better results were reached in the Ust'-Abakansk district, where an inclusive carp farm was organized in 1956. In 1961, the farm had a total pond area of 218 ha. Here commercial fish are raised on a steadily increasing scale.

South of the Irkutsk Region, experimental spawning, raising of under-yearlings, and overwintering in netted ponds gave interesting results (Egorov, 1958).

In the post-war years, there was much work on acclimatization in Western Siberia, especially in ponds. Repeated attempts were made to stock the ponds with crucian carp, tench, bream and carp; however, these had no practical results.

The main pond fish, carp, is successfully raised where the sum of the heat on days with a temperature of 10 and above is over 1,600 degree-days and temperatures are at least 15° for over 70 days (Sukhoverkhov, 1960).

Many years of observation show that the sum of degree-days in the Novosibirsk and Kemerovo regions for the growing season exceeds 2,000°. There are 71 —78 days with an average daily temperature above 15° (Table 1).

TABLE 1. Dates when the average daily temperature goes above 0, +5, +10 and +15°, and number of days when temperatures exceed these minimums in Western Siberia (multiannual data of GMS*)

Observation point	0'		5°		10°		15°	
	dates	No. of d	dates	No. ofd	dates	No. of d	dates	No. of days
Kemerovo	18 Apr.-19 Oct.	183	1 May — 10 Oct.	153	18 May-14 Sept.	118	8 June-21 Aug.	73
Kiselevsk	16 Apr.-22 Oct.	188	29 Apr. — 6 Oct.	159	20 May-14 Sept.	116	10 June —28 Aug.	72
Novokuznetsk	10 Apr.-23 Oct.	195	27 Apr. — 5 Oct.	160	18 May-16 Sept.	120	8 June-26 Aug.	78
Novosibirsk	18 Apr.-21 Oct	185	2 Oct. — 5 Oct.	155	17 May-16 Sept.	121	9 June-24 Aug.	75
Barabinsk	19 Apr.-20 Oct.	183	4 May— 3 Oct.	151	15 May-16 Sept	123	6 June-25 Aug.	77
Bolotnoe	18 Apr.-18 Oct.	182	3 May— 5 Oct.	154	21 May-13 Sept	114	10 June —21 Aug.	71

* [GMS—Hydrometeorological Service]

The ponds of these regions are located on various types of soils, although the leached out and slightly podzolic, loamy chernozems prevail. Boggy meadow soils on the bottom of ravines and in river valleys are the most productive. In certain places, fertile, granular chernozems are found. The slightly hilly terrain, and the abundance of gullies, valleys, and ravines favor the construction of a complete system of fish farms. The numerous shallow rivers with well-developed floodplains allow the construction of both large inclusive carp farms and hatchery-nurseries.

Thus, the soil and climate of the southern districts of Western Siberia favor successful development of intensive carp breeding. Temperatures in southern Siberia during the growing season are similar to those in the central area of the mid-belt of the USSR, especially the Moscow Region (Table 2). The pond farms near Moscow, where soil is not as rich, average 6 centners/ha of commercial fish, while the better farms may yield 15-17 centners/ha.

Since 1960, the Novosibirsk section of GosNIORKh (now SibNIIRKh) began developing pond fish farming in the Novosibirsk and Kemerovo regions.

The Agricultural Administration of the Novosibirsk Region and the State Farm Trust of the Kemerovo Sovnarkhoz undertook an investigation of the expediency of carp farming in Western Siberia. It was necessary to train local fish farmers in advanced working methods, to plan ways of using existing rural ponds for raising commercial carp, to work out reconstruction measures, and to plan the construction of new water bodies on soil not suited for agriculture.

TABLE 2. Degree-days for the periods when temperatures are above +5,+10 and in different parts of the Soviet Union (multiannual data of GMS)

Observation point	5°	10	15°
Kemerovo	2,138	1,876	1,311
Kiselevsk	2,184	1,868	1,299
Novokuznetsk	2,232	1,937	1,412
Novosibirsk	2,183	1,926	1,352
Barabinsk	2,139	1,933	1,387
Bolotnoe	2,124	1,821	1,281
Minsk	–	2,068	–
Moscow		1,957	–
Sverdlovsk	–	1,709	–

In spring 1961,174,000 carp yearlings were delivered and stocked in ponds in the Novosibirsk and Kemerovo regions. This attempt failed, because the local pisciculturists had no experience in raising commercial carp. Some of the ponds had fair yields, however, indicating that carp can be raised in Western Siberia and carp farming in this area can be profitable.

In 1962, work on carp raising was expanded. Along with the need to increase its profitability was the need to spawn the carp, to adapt fingerling raising methods, and to organize hibernation. The pilot project was conducted in the Novosibirsk Region at the Oyashinsk state farm; in the Kemerovo Region it utilized some of the foraging ponds and the new hatchery-nursery.

In 1962, carp were spawned and underyearlings raised successfully for the first time in Western Siberia. At the Oyashinsk state farm, 20,000 young were raised, with an average weight of 65g; in the Kemerovo hatchery-nursery and raising ponds, 160,000 young averaged 14 and 16g.

By 1963, there were 12 farms in the Novosibirsk Region raising commercial carp. The first cycle of the Oyashinsk hatchery-nursery was completed. At a planned capacity of 500,000 carp yearlings, 790,000 fingerlings were raised and stocked for overwintering. At the Kemerovo hatchery-nursery, overwintering was successful, yielding 123,000 yearlings (mortality was 25%). For the first time, all the ponds were stocked with native fish. That year, 390,000 more fingerlings were raised and stocked for overwintering.

The development and the expansion of pond fish farming were made possible by training local personnel. At monthly courses organized by the Novosibirsk Regional Fish Farming Improvement Station at the Novosibirsk Agricultural Institute, 24 persons were trained in 1962, and 25 in 1963. For state and collective farm managers and for specialists of the Territorial Production Administration, one-day seminars on pond fish breeding were organized in the summer at Oyashinsk. In 2 years, six such seminars were conducted, and 140 persons participated.

TABLE 3. Last and first frost and length of the frostles period in Western Siberia (multiannual data of GMS)

Observation point	Date of last spring frost			Date of first autumn frost			No. of days without frost (average)
	average	earliest	latest	average	earliest	latest	
Kemerovo	28 May	18 May	10 June	13 Sept.	28 Aug.	29 Sept.	106
Kiselevsk	24 May	27 Apr.	20 June	5 Sept.	26 Aug.	5 Oct.	114
Novokuz-netsk	17 May	23 Apr.	9 June	20 Sept.	29 Aug.	14 Oct.	125
Novosibirsk ..	22 May	8 May	7 June	18 Sept.	29 Aug.	8 Oct.	119
Barabinsk	19 May	23 Apr.	12 June	20 Sept.	3 Sept.	11 Oct.	122
Bolotnoe	21 May	8 May	1 June	22 Sept.	4 Sept.	8 Oct.	123

Spawning and overwintering are the most vulnerable periods in carp breeding. In Western Siberia, spring frosts usually end by 20-25 May, but in some years they may continue until 10-20 June (Table 3). The ice remains on the ponds for 6-6.5 months and is up to 1.5 m thick. Development of a method for spawning the carp and overwintering the fingerlings in such severe conditions is of prime importance for Siberian carp farming. This article will discuss the results of experimental spawning of carp and raising young and marketable fish. Another article will discuss overwintering.

Carp spawning

As there were no special spawning ponds at Oyashinsk in 1962, the spawners brought from the Bryansk Region (5 females and 8 males) were stocked in 3 foraging ponds, 2 of which had been filled for the first time, and had proper spawning conditions (shallow water, recently flooded meadow grass); conditions in the 3rd were unfavorable, and the carp did not spawn.

We saw the first carp eggs scattered on the washed off rhizomes of reeds on 25 May, 13 days after the spawners were stocked. The average daily water temperature in the spawning period was 18°, but it then dropped to 14.5°. In the 2nd pond, active spawning was observed on 27 May from 5 till 6 o'clock in the morning at a water temperature of 17°. During egg development, the average daily temperature of the water ranged from 20.3 to 23.3°.

In the Kemerovo hatchery-nursery, the 1st spawning also occurred in a foraging pond with an area of 3.5 ha, in which were stocked 20,000 yearlings, 5 spawners, and 40 fish aged 2+, delivered in mid-May from "Ropsha." These last contracted severe dropsy during transportation. The fish spawned on 3-4 June at a water temperature of 17-18°. The larvae hatched on 7-8 June at 21 —23°.

On 22 June, 15 female and 15 male spawners were brought from Latvia. These were immediately placed in 3 spawning ponds. On 24 June, from 1—10 a.m., all the carp spawned once in all 3 ponds. The water temperature at spawning and during development of the eggs varied from 20.3 to 23.3°. The stems and leaves of rye that had been sown in the ponds in the autumn of 1961, and also horsetails and young shoots of awnless brome served as a substrate for the eggs. The larvae began to hatch on 28 June from 12noon and continued until 10 p.m. The larvae were transferred to raising ponds from the 1st spawning pond at 6 days and from the 2nd at 11 days. To encourage the development of small forms of plankton, 8-10 pails of infusion from cow manure and hay were added to the raising ponds every 2 days. The larvae were recovered from the spawning ponds by gradually draining the water and catching the fish with gauze dip-nets. The fingerlings were counted by volume.

In the 1st hatchery-nursery, there were only 28 spawners (14 females and 14 males) in the 1963 spawning season. Some of these were, according to age and preparedness to spawn, clearly not satisfactory for breeding. The spawners were stocked in 5 spawning ponds on 9 June at a water temperature of 16°. Subsequently, the air temperature dropped to 13°, prolonging the spawning to 2 days (11 and 12 June). Larvae hatched after 6 days, on 17-18 June. The fingerlings were recovered and transferred to raising ponds at 5-8 days. About 500,000 larvae were obtained, an average of 35,000 per female. These rather modest results are due to the poor quality of the females, the drop in water temperature during spawning, and development of the eggs in unsatisfactory conditions of the spawning ponds.

Spawners were brought to Oyashinsk at the beginning of May from the "Tremlya" farm in the Gomel' Region. Somewhat later, "eastern carp" spawners were delivered from Khabarovsk. At the approach of spawning temperatures (8 June), a very severe ichthyophthiriasis infestation was detected in all spawners. In order to get rid of the parasite, the fish were kept for 7 days in a 0.65% solution of sodium chloride. The treatment was almost completely successful, but spawning was delayed until 17-18 June, when 52 females and 69 males were stocked in 10 spawning ponds of 0.1 ha each.

To provide a spawning substrate in these still not completely formed ponds, we planted oats and rye in the early spring. In ponds Nos. 9 and 11 artificial spawning grounds were created from branches of pine and willow. In pond No. 11, carp females were crossed with "eastern carp" males. In other ponds, only carp were spawned.

On 18 and 19 June, at average daily water temperatures of 20.3 and 21.1° there was synchronous active spawning in all the ponds and 4-5 days later, on 22-23 June, the larvae hatched (Table 4).

The temperature and oxygen supply in ponds was favorable during the development of the fish eggs and maintenance of the larvae. Thus, the concentration of oxygen did not drop below 3.5 mg/l even in the early morning hours; the average daily water temperature ranged from 17.6 to 22.3°.

Fingerlings were recovered and transferred for raising at 4-15 days. Naturally, recovery at 4 days after hatching yielded the maximum number of fingerlings per female (57,000— 76,000) while recovery on the 8th—15th day yielded only 33,000 per female. The lowest yield, 26,000 per female, was recovered from pond No. 11, where female mirror carp were interbred with male "eastern carp" which had been weakened and traumatized during transportation.

TABLE 4. Results of carp spawning at the Oyashinsk hatchery-nursery in 1963

No.of pond	Number of spawners		Date of recovery	Age of larvae, days	Total recovered larvae, thousands	Yield of larvae per female, thousands
7	5	7	1 June, 7 —8 June	8-15	166	33
8	5	7	1 July,□7-8 July	8-15	166	33
9	5	7	7 —8 July	15	165	33
10	5	8	29 June	6	351	70
11	5	10	2 July	9	128	26
12	5	6	29 June	6	180	36
13	5	6	28 June	5	177	35
14	6	6	28 June	5	257	43
15	6	6	26 June	4	341	57
16	5	6	27 June	4	380	76
Catchment area	—	—	—	—	115	—
Total	52	69	—	—	2,426	—

Average larva yield in 1963 was 47,000 per female. We should remember that the spawning ponds had a very poor spawning substrate, and the too few males were of low quality. Nevertheless, each 0.1 ha spawning pond averaged 242,000 fingerlings, and in some ponds as many as 350,000-380,000 were recovered. Thus, we can expect to hatch 5-6 million fingerlings at once in the 16 Oyashinsk spawning ponds.

In 1964, when the 1st cycle at the Oyashinsk hatchery-nursery was over, and construction of the hatchery-nursery in Kemerovo was completed, the possibilities of establishing optimum conditions for carp spawning in Western Siberia were considerably increased.

Raising young

In 1962, young carp were raised in 3 "Oyashinsk" foraging ponds, which were also stocked with yearlings. Joint raising of fingerling and yearling carp stocked very densely (3,500-5,000/ha) was inefficient. When the pond was drained to recover the yearlings, the underyearlings were traumatized. Furthermore, sorting the fish according to age hampers recovery. The carp fingerlings were eaten by predatory invertebrates. This probably explains why only 500 and 200 fingerling underyearlings were recovered fromponds, Nos. 1 and 3, respectively, at "Oyashinsk" despite normal spawning.

In pond No.2 (9 ha) with stocking density of 18,000 yearlings per ha,20,000 fingerlings with an average weight of 65 g were recovered. Even more fingerlings were left in pond No.2 for wintering, as it was practically impossible to recover them from the undrained sections of the pond.

The young carp grew rapidly in this pond. Maximum growth occurred in the hottest period, 10 June to 7 August; in the last 10 days of July the fish gained an exceptional 1.9 g/d,ty (Table 5). Some fish weighed 120 g by autumn, while others weighec only 7 g.

TABLE 5. Growth rate of carp fingerlings in Oyashinsk state farm in pond No. 2 (1962)

Date of control catch	Size of sample	Days since hatching	Average weight, g	Length of growth period, days	Average daily gain, g
19 June	20	18	0.5	14	0.06
3 July	3	32	1.4	7	0.8
10 July	33	39	7.3	10	1.3
20 July	17	49	20.3	12	1.9
1 Aug.	[illegible]	61	42	6	1.0
7 Aug.	6	67	48	29	0.4
5 Sept.	17	96	59	32	0.2
7 Oct.	20,000	132	65		

In the 3.5 ha foraging pond No. 1 at "Kemerovo", 20,000 carp yearlings were raised together with fingerlings of uncontrolled spawning. Some 30,000 fingerlings averaging 23 g were recovered. Conditions in the raising ponds were rather unfavorable. Pond No.2 began to be filled only on 25 June, and pond No.3 on 8 July. The former was only 3/4 full, the latter only 1/3 full. During the summer, the water level dropped even more. These ponds were stocked with larvae from a very late spawning that took place on 24 June. Nevertheless, the weight of the fingerlings was satisfactory at the end of the growing season. The condition factor was also satisfactory (2.9-3.1) (Table 6). Since the ponds were not completely filled it was impossible to determine their productivity.

TABLE 6. Results of raising carp fingerlings in the Novosibirsk and Kemerovo regions (1962)

Name of farm and No. of pond	Recovery date	Age of fingerlings, days	Average weight, g	Fulton's condition factor	Recovered fingerlings, thousands
"Oyashinsk",					
pond No. 2. .	10 Oct.	132	65	2.8	20
"Kemerovo":					
pond 1 . . .	7 Oct.	124	23	3.1	30
pond 2 . . .	3 Oct.	98	16	2.9	120
pond 3 . . .	1 Oct.	95	13.6	2.9	40

In 1963, fingerlings were raised at "Kemerovo" in the same raising ponds with a total area of 12 ha. The average stocking density was 40,000/ha. There was little supplementary feeding; the ponds were fertilized only with superphosphate. In autumn 390,000 fingerlings were recovered and transferred for overwintering; of them 307,000 averaged 15 g, and 83,000 averaged 18 g. The productivity of the raising ponds was 4.5-7.5 centners/ha, averaging 5.1.

At "Oyashinsk," 2 nursery ponds totaling 12 ha were prepared for the carp fingerlings. The young were also stocked in 14 other ponds, including a large foraging channel-pond and all the undrainable gullies of the farm. In the autumn we could drain only 8 ponds from which 790,000 fingerlings, 15.9 g, were recovered and transferred for overwintering. Table 7 records the results of raising fingerlings in the 3 main ponds. The highest indexes were reached in pond No. 2, where each hectare yielded 53,600 fingerlings with high productivity and a good survival rate. The better survival rate is probably due to the fact that the pond was stocked with large, 15 day-old larvae. Unfortunately, the high stocking density and completely insufficient food supply, due to fertilization of the ponds, resulted in low average weight (13.8 g) in this pond. The supplementary food, added to pond No.2 totaled 94 centners (15 centners/ha) and 19 centners in pond No.4 (about 3 centners/ha).

TABLE 7. Results of raising carp fingerlings in the 3 main ponds at "Oyashinsk" (1963)

Pond (area in ha)	Stocking of larvae			Fingerling recovery			Marketable fish recovery, centners	Productivity, kg/ha	
	date	age, days	No., thousands	No., thousands	average weight, g	mortality, %		fingerlings	a 1+
Foraging (17.9)	27-28 June	4-5	815	301	16.5	63.0	8.77	277	46
Raising pond No. 2 (6.3)	8 Aug.	15	369	337	13.8	8.5	–	738	–
No. 4 (5.7)	2 July	9	128	95	18.7	25.8	–	312	–

Of particular interest for the Novosibirsk Region is our experience in raising fingerlings in ordinary gully ponds. The cost of constructing such ponds is much smaller than the cost of constructing banked up raising ponds. Large-scale enconomical construction of such ponds can at least double the capacity of the "Oyashinsk" nursery. This assertion is based on the yield of 301,000 carp fingerlings, averaging 16.5 g, in a foraging gully pond where carp yearlings were raised at the same time (see Table 7). The low yield of fingerlings (37%) is due to the fact that 2 months after it was filled, the pond was stocked with larvae only 4-5 days old. It is better to stock a pond of this type with yearlings only, or with fingerlings that have been pre-raised in fingerling ponds.

Based on the preliminary successes at the hatchery-nurseries, we plan in the near future to grow fingerlings with an average weight of 25 g and with a condition factor of at least 3 at a recovery density of 50,000/ha.

Raising marketable fish

In 1961 yearlings were raised with good results at Oyashinsk state farm. Under the supervision of N. G. Efremov, the state farm pisciculturist, a pond with 3.6 ha water area was built in the spring; 11,000 yearlings averaging 20g were brought from the European USSR and stocked in this pond on 12 May.

Supplementary feeding began late that year (after 1 August); by mid-September, 67 centners of food had been used, including 46 centners of grain-siftings, 10 of mixed feed, 7 of oil cake, and 4 of corn. The pond yielded 25.5 centners of marketable carp averaging 370g; the maximum weight was 700g. Productivity was 6.7 centners/ha. Thus, the very first year, investment in water body construction yielded a good return.

Even better results were obtained in some farms of the Kemerovo Region. At the "Leninugol'" state farm carp were stocked in a 2 ha pond which was densely populated with crucian carp. Supplementary feeding began at the end of July; by mid-September 34 centners of concentrated feed had been used. In the autumn 9 centners of carp averaging 400 g, and 8.6 centners of crucian carp were recovered. Total productivity was almost 9 centners/ha. About 2 centners of concentrated feed produced 1 centner of fish.

At the "Yasnaya Polyana" state farm, in a 1.5 ha pond, 18 centners of commercial carp, averaging 540g, were raised; the productivity was apparently nearly 12 centners/ha. Only 40 centners of feed were used (2.2 centners ground unpeeled oats and barley/centner of fish).

At the Prokop'evsk state farm, a 3 ha pond was stocked with yearling hybrid Ropsha carp and 30 yearling C. peled averaging 22 g. The fish received a total of 49 centners of ground oats and barley from June to September. In autumn, 30 centners of carp averaging 540g (maximum 980g) were recovered; productivity was 9.5 centners/ha. The total expenditure on fish breeding in the state farm, including the cost of the yearlings and transportation expenses, was 1,883 rubles, yielding a gross return of 2,886 rubles. The profit was thus over 1,000 rubles. While production of 1 centner of fish required 1.6 centners of feed, production of 1 centner of beef requires about 8 centners, and 1 centner of pork requires 11 centners of feed. Thus, the pond that was built on previously unproductive swamps was very profitable.

This pilot project revealed the high quality of the Ropsha hybrids; they were able to withstand prolonged transportation, they readily adapted to the new habitat, grew well, and justified the expenditure on food. Apparently, in forming the stock of new pond farms of Western Siberia it is important to use Ropsha carp.

It should be noted that the yearling C. peled also grew well. They weighed 22g at stocking, and 300g in autumn. Unfortunately, there were not enough C. peled to draw definite conclusions.

In 1962, "Oyashinsk" raised for market 48,000 yearlings from the Bryansk Region, 23,000 from the Leningrad Region, and 50,000 from the Vladimir Region; 73,000 yearlings were delivered to Kemerovo.

That year, 3 ponds in the Oyashinsk state farm (16.4 ha) and 4 ponds in the Kemerovo Region (11.5 ha) were stocked. Density varied from 1,700-7,000/ha. The results of raising are presented in Table 8. Owing to more regular pond fertilization and supplementary feeding, productivity was high, averaging over 10 centners/ha. In one pond of the Oyashinsk state farm it was over 15 centners/ha.

TABLE 8. Result of raising commercial carp in Western Siberian ponds (1962)

Farm	Area, ha	Stocking of yearlings		Autumn recovery			Mortal-ity, %	Product-ivity, kg/ha
		fish/ha	total stock	total stock	average weight, g	total, cent-ners		
Novosibirsk Region								
"Oyashinsk":								
pond No.1	3.6	5,000	18,000	12,300	484	59	31.5	1,600
" No.2	9.0	1,800	16,000	10,950	474	65	31.5	707
" No.3	3.8	3,700	14,000	9,800	514	50	30.0	1,287
Total	16.4		48,000	33,050		174		
Kemerovo Region								
Leninugol'	2.5	4,600	11,500	8,200	390	32	28.7	1,240
Yasnaya Polyana	2.0	7,500	14,000	5,480	310	17	60.9	816
Prokop'evsk	3.5	5,700	20,000	14,060	370	52	29.8	1,438
Hatchery-nursery	3.5	5,700	20,000	12,000	300	36	40.0	987
Total	11.5		65,500	39,740		137		

TABLE 9. Calculation of feeding and of natural fish productivity for No. 3 Aranovka foraging pond (Oyashinsk state farm, 1962)

Date	Average weight, g	Weight gain (Pt) from beginning of raising		Amount of food given from beginning of supplementary feeding, kg/ha		Pa (at a — concentrat kg/ha	P_a (at a — grain siftin	P_n total,	P_n functioning, kg /ha
		per, fish, g	total, kg/ha	concentrates	grain siftings				
8 May	12	–	–	–	–	–	–	–	–
7 June	35	23	59	–	–	–	–	–	59
20 July	170	158	401	690	419	138	42	180	227
1 Aug.	292	280	722	1,270	657	254	66	320	402
13 Aug.	327	315	812	1,800	1,100	360	110	470	342
6 Sept.	512	500	1,290	1,980	3,420	395	342	737	553
17 Oct.	514	502	1,295	2,050	4,750	410	475	885	410

Note. P_t, P_a and P_n – total, food, and natural fish productivity.

We have attempted to determine the natural productivity graphically (Kirpichnikov,1960). Comparing the growth of fish in the ponds with the expenditure of food supplement, as recommended by Kirpichnikov, we were convinced that weight gain in May, June, and even July, was determined mainly by the consumption of natural food (Figure 1 and Table 9). Assuming the provisional conversion ratio of concentrated feeds to be 5 and that of grain siftings to be 10, we calculated the values of the minimum natural productivity for 3 ponds. Figure 2 shows the cumulative weight gain curves and natural fish productivity in each pond. It seemed rather high, especially in 1962 (over 600 kg/ha in one pond, over 900 kg/ha in the other). The conversion ratios calculated by us for artificial food were unjustifiably high (Table 10).

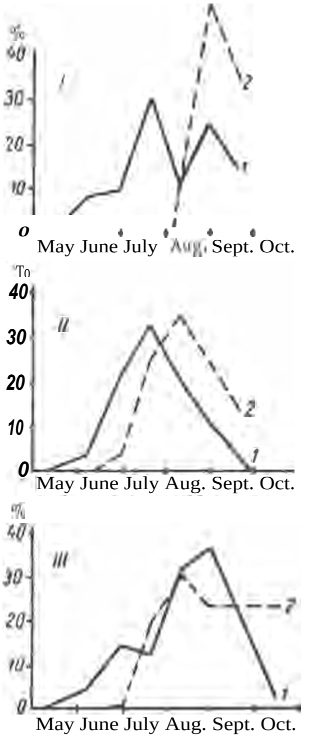

FIGURE 1. Curves of growth and feeding rates in the foraging ponds of the Oyashinsk state farm:

I and II – pond No.1,1961 and 1962; III – pond No.3,1962; 1 — weight gain, To; 2 — supplementary food, %.

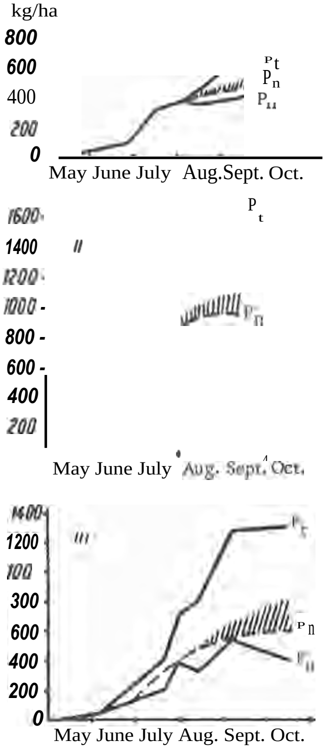

FIGURE 2. Total and natural productivity of the foraging ponds of the Oyashinsk state farm:

I and II – pond No.1,1961 and 1962; III – pond No.3,1962.

TABLE 10. Conversion ratio of artificial food in foraging ponds of the Oyashinsk state farm

Year	Pond No.	Food composition, To		Conversion ratios, calculated graphically
		concentrates	grain siftings	
1961	1	3.4	68.6	9-15
1962	1	39.9	60.1	10-13
1962	3	30.1	69.9	10-14

The reason for this is the low quality of the food and the haphazard feeding; most of the food was added to the ponds in August and September, when lower water temperatures discourage intense eating and digestion. Lowering the conversion ratio by developing a technique for preparing and delivering the food, and also improving its quality, will considerably increase the profitability of Siberian carp breeding.

To increase the natural productivity of the Oyashinsk state farmponds, they were fertilized with ammonium nitrate and superphosphate in 1962. The fertilizers were applied in aqueous solution every 5 days to provide 8 centners/ha ammonium nitrate and 4 centners/ha superphosphate over the entire growing season.

Observations of the fish enabled us to follow the weight gain of the yearlings throughout the growing season (Figure 3). The fish grew faster in 1962 than in 1961: in all 3 ponds, the yearlings weighed close to 500 g in autumn. The rapid increase in weight was observed during all 3 summer months (June-August), the maximum gain was in July and the first ten days of August (Table 11).

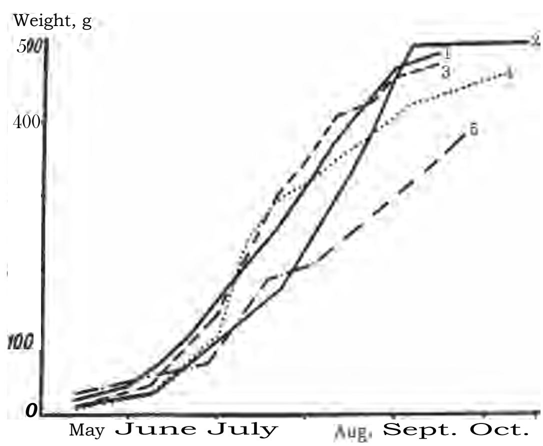

FIGURE 3. Cumulative weight gain of yearling carp in foraging ponds of the Oyashinsk state farm:

1 – planned weight gain; 2 — pond No.3,1962; 3—pond No.1, 1962; 4 — pond No.2,1962; 5 — pond No.1,1961.

Analysis of the profitability of commercial carp raising in the Novosibirsk Region gave interesting results. In 1962,a total of 761 centners of feed was used on the "Oyashinsk" yearlings, of which 524 centners were grain-siftings with a high content of grains of weeds, chaff, and dust. Each kg of fish produced required 2.3 kg of feed, while animal husbandry uses 3-5 times as much feed. Apparently, fish farming also requires far less labor (1.7 work days per centner of fish). Correspondingly, the cost of the production was considerably less (38.60 rubles/centner). One year of fish breeding in a state farm netted 6,647 rubles.

TABLE 11. Growth of carp aged 1+ in pond No.1 (Oyashinsk state farm, 1962)

Date of sample	No. of specimens	Weight, g			Individual gain (by periods), g	Average daily gain, g
		maximum	minimum	average		
8 May	18,000	–	3	12	28	0.9
7 June	33	70	32	40	56	4.3
20 June	15		–	96		
30 June	74	215	50	142	46	4.6
10 July	29	400	140	226	84	8.4
20 July	21	450	220	311	85	8.5
1 Aug.	45		–	352	41	3.4
10 Aug.	166	–	–	410	58	6.5
22 Aug.	130	–	–	431	21	1.7
1 Sept.	71	670	320	465	34	3.4
16 Oct.	183	–	–	484	19	1.3

Total production of commercial carp in the Novosibirsk and Kemerovo regions was 150 centners in 1961, over 300 centners in 1962, and over 500 centners in 1963. Three years of experience have shown that commercial production may be greatly expanded, and tens of thousands of centners of carp can be raised. At "Oyashinsk" alone, plans are to bring the annual production of commercial fish to 6,000-7,000 centners per year in the next few years. The long-term plan calls for 100,000 centners from the Novosibirsk Region and 25,000 centners from the Kemerovo Region by 1980.

CONCLUSIONS

1. The soil and climate of the southern districts of Western Siberia favor development of intensive fish farming. Three years of experience in raising of carp in the Kemerovo and Novosibirsk regions indicated that carp farming can be highly profitable and is very promising here.
2. One of the most vulnerable links in Western Siberian carp farms is spawning. Experimental spawning of carp in special ponds (1962-1963) was successful. Each female produced 26,000-76,000 larvae. The best spawning time is the beginning of June. Spawning in foraging ponds was less effective.
3. The experimental raising of fingerlings in nursery ponds was quite satisfactory. Fingerlings weighing up to 18-20g can be raised at densities of 20,000-50,000/ha. By fertilizing ponds to increase fish productivity, and by improved feeding, we can obtain standard fingerlings weighing 25g at a density of 50,000 specimens/ha. The fingerlings raised in 1962 proved to be sufficiently winterhardy.
4. The greatest success was achieved in raising commercial carp. In a number of ponds in the Novosibirsk and Kemerovo regions, the carp averaged over 350g in the autumn, and in the Oyashinsk state farm, they weighed over 450g; productivity averaged 10 centners/ha, reaching 14-16 centners/ha in some ponds.

5. Natural as well as total productivity of the ponds was high (4-10 centners/ha). This indicates that improvement of the feed quality and more extensive supplementary feeding will raise productivity even further.

6. Analysis of the profitability of commercial carp raising in Western Siberian ponds showed that the cost of carp raising at "Oyashinsk" was considerably lower than the cost of producing livestock. In one year, carp breeding in the state farm netted 6,647 rubles.

Bibliography

Agroklimaticheskii spravochnik po Kemerovskoi oblasti (A Handbook of Agroclimatology for the Kemerovo Region).— Gidrometeoizdat. 1959.

Agroklimaticheskii spravochnik po Novosibirskoi oblasti (A Handbook of Agroclimatology for the Novosibirsk Region). Moskva-Leningrad. 1959.

Bashmakov, V. N. Uzhurskii karpovyi pitomnik kak baza kolkhoznogo prudovogo rybovodstva v Krasnoyarskom krae (The Uzhur Hatchery-Nursery as a Base for Kolkhoz Pond Fish Farming in the Krasnoyarsk Territory).— Trudy Tomskogo Gosudarstvennogo Universiteta, Vol.142. 1956.

Egorov, A. G. Razvitie karpovodstva v Irkutskoi oblasti i Buryatskoi ASSR (Development of Carp Breeding in the Irkutsk Region and the Buryat ASSR). Irkutsk. 1958.

Greze, N. I. Iz opyta vyrashchivaniya segoletka karpa v Sibiri (An Experiment in Raising Carp Underyearlings in Siberia). —Zhurnal Voprosy Ikhtiologii, No. 10. 1958.

Ioganzen, B. G. and A. N. Petkevich. Akklimatizatsiya ryb v Zapadnoi Sibiri (Fish Acclimatization in Western Siberia).— Trudy Barabinskogo Otdeleniya VNIORKh, Vol. 5. 1951.

Kirpichnikov, V. S. Opredelenie estestvennoi ryboproduktivnosti prudov i oplaty korma karpom (Determining the Natural Productivity of Ponds and Carp Food Conversion Ratios).— Moskva, Izdatel'stvo "Rybnoe khozyaistvo." 1960.

Mamontova, L. Udobrenie prudov chernozemnoi zony (Fertilization of Ponds of the Chernozem Zone).— Rybovodstvo i Rybolovstvo, No. 2. 1962.

Razvitie prudovogo rybovodstva v Sibiri (Development of Pond Fish Breeding in Siberia).— Sbornik rabot, Novosibirsk. 1962.

Sukhoverkhov, F. M. Spravochnik rybovoda (The Pisciculturist's Handbook).— Sel'khozgiz. 1960.

Zamornye yavleniya v ozerakh i mery ikh preduprezhdeniya (Phenomena of Mass Mortality of Fish in Lakes and Preventive Measures). — Sbornik rabot, Novosibirsk. 1959.

Explanatory List of Abbreviated Names of USSR Institutions, Periodicals, etc. Appearing in This Text

Abbreviation	Full name (transliterated)	Translation
AN SSSR	Akademiya Nauk SSSR	Academy of Sciences of the USSR
BelNIIRKh	Belorusskii nauchno-issledovatel'skii institut rybnogo khozyaistva	Belorussian Scientific Research Institute of Fisheries
DAN SSSR	Doklady Akademii Nauk SSSR	Proceedings of the Academy of Sciences of the USSR • [periodical]
GosNIORKh	Gosudarstvennyi nauchno-issledovatel'skii institut ozernogo i rechnogo rybnogo khozyaistva	State Scientific Research Institute of Lake and River Fisheries
KaspNIRO	Kaspiiskii nauchno-issledovatel'skii institut morskogo rybnogo khozyaistva i okeanografii	Caspian Scientific Research Institute of Marine Fisheries and Oceanography
LGU	Leningradskii gosudarstvennyi universitet	Leningrad State University
MGU	Moskovskii gosudarstvennyi universitet	Moscow State University
SibNIIRKh	Sibirskii nauchno-issledovatel' skii institut rybnogo khozyaistva	Siberian Scientific Research Institute of Fisheries
TINRO	Tikhookeanskii nauchno-issledovatel'skii institut rybnogo khozyaistva i okeanografii	Pacific Scientific Research Institute of Marine Fisheries and Oceanography
UkrNIIRKh	Ukrainskii nauchno-issledovatel'skii institut rybnogo khozyaistva	Ukrainian Scientific Research Institute of Fisheries
VNIIPRKh	Vsesoyuznyi nauchno-issledovatel'skii institut prudovogo rybnogo khozyaistva	All-Union Scientific Research Institute of Pond Fisheries
VNIOR Kh	Vsesoyuznyi nauchno-issledovatel'skii institut ozernogo i rechnogo rybnogo khozyaistva	All-Union Scientific Research Institute of Lake and River Fisheries
VNIRO	Vsesoyuznyi nauchno-issledovatel'skii institut morskogo rybnogo khozyaistva i okeanografii	All-union Scientific Research Institute of Marine Fisheries and Oceanography