FISHERIES RESEARCH BOARD OF CANADA

Translation Series No. 286

THE BIOLOGY AND PRODUCTION OF THE STOCKS OF BLACK SEA KUMZHA (SALMON/TROUT)

By G. P. Barach

Kandidat of Biological Sciences
(Georgia Fish Protection and Management
Service--Gruzrybvod)

Original title: Biologiia i vosproizvodstvo zapasov chernomorskoi kumzhi (lososiia-foreli).

From: Akademiia Nauk SSSR, Ikhtiologicheskaia Komissiia, Trudy Soveshchanii, No. 7, pp. 235-242, 1957. [Trudy Soveshchaniia po Rybovodstvu, 1954]

Preliminary translation by W. E. Ricker

Distributed by the Fisheries Research Board of Canada
Biological Station, Nanaimo, B. C.

1960

This is a preliminary translation prepared for the use of the Fisheries Research Board of Canada. It is not a definitive English version of the article, and it has not been checked or approved by the author.

The present article is an attempt to solve some questions concerning the natural and artificial production of stocks of Black Sea salmon[1] on the basis of a study of its biology. The studies were made in 1951 and 1952 under the auspices of the Georgian Branch of the Azov-Black Sea Research Institute for Fisheries and Oceanography (AzcherNIRO) and in 1953 according to a plan outlined by the Georgian Fish Protection and Management Service (Gruzrybvod).

SYSTEMATIC POSITION OF THE BLACK SEA SALMON

L. S. Berg referred the Black Sea salmon to the Atlantic species kumzha, as one of the 3 subspecies which he recognized for the Ponto-Caspian-Aral ichthyological province--in conformity with this view the Black Sea subspecies is named Salmo trutta labrax Pallas. To the same subspecies of kumzha Berg also referred the river trout inhabiting rivers of the Black Sea basin, considering them to be a non-anadromous river "morpha" of the anadromous kumzha. Anadromous salmonid fishes are considered by Berg, and the other ichthyologists who agree with him, to be primarily-marine fishes which are adapted to reproduction in fresh water. The anadromous kumzha (salmon) is the basic type; the freshwater non-anadromous kumzha (trout) is a form which arose from it--a "morpha" distinguished by characteristics which are temporary in the sense that it transmits them to its progeny only if the external conditions remain the same.

On the question of the evolution and genetic relationships of the anadromous forms (salmon) and non-anadromous forms (trout) of the genus Salmo, I hold the opposite opinion, and regard them as primarily-freshwater fishes. The Black Sea salmon, and the brook trout which inhabits the rivers of the Black Sea basin in which the salmon reproduce and live one or two years of their youth, constitute two mutually connected forms of existence of a single subspecies of kumzha, which is a freshwater fish by nature, and either takes the opportunity to leave the river and live in the sea and return to the river for reproduction, or else remains for the whole or part of its life in the river.

In line with this opinion I suggest that the Black Sea kumzha must be named Salmo fario labrax Pallas; its migratory [page 236] form--S. fario labrax forma trutta; and its non-anadromous form--S. fario labrax forma fario. These two forms do not have the character of systematic units of the category of morphae; I consider that neither of them should be regarded as having been derived from the other.

---

[1]Throughout this translation salmon = losos, trout = forel, while kumzha is retained in the Russian form.

The origin of the anadromous form I consider to be not a result of adaptation of a marine species to reproduction in fresh water, but a result of the extension of the feeding migration of a freshwater species out to sea. It is more correct to speak, not of the spawning migrations of the Black Sea salmon, but of the feeding migrations of the freshwater kumzha (trout). Thus what is called the spawning migration of the salmon is really the return of migrant trout to their native medium for reproduction.

THE UNITY OF THE NON-ANADROMOUS AND ANADROMOUS POPULATIONS OF BLACK SEA KUMZHA

It is a widely held and undisputed opinion that the river life of the young is the decisive period for the production of stocks of salmonid fishes. The sea provides almost unlimited opportunities for increase in the numbers of salmonid stocks, but these opportunities are limited by the survival of the young in the river before their migration to the sea. It would be expected therefore that all of the young fish which hatch from the eggs laid in the river by female salmon and live there up to the necessary age, would go down to sea and swell the numbers of recruits to its salmonid stock. The whole key to the matter lies in the hatching of the young and their protection up to that particular moment. The fry output depends on the number of spawners coming back to spawn and on the size of the spawning area and its preservation--that is, on the aggregate of non-biological and biological conditions affecting the development of the eggs and the life of the young fish up to the time of their seaward migration.

My observations and studies lead to the conclusion that, among the factors influencing the natural production of salmonid stocks, great importance should be attached to the factor of migration to sea, something which has not been considered up to this time. Under this head I include the conditions of river life which stimulate, or prevent, the seaward migration of young salmonids which have attained the necessary age. Not all the surviving progeny of salmon migrate to sea and become recruits to the anadromous stock; part of them remain in the river and assume the condition of the non-anadromous population. On the other hand, from the eggs laid by a female non-anadromous trout there may also come individuals which go to sea and change over into anadromous salmon, as well as individuals which remain in the river and retain the characteristics of the freshwater form--the trout.

As a result, both the reproduction of the salmon, that is, of migrants returning to the river, and the reproduction of the trout--the non-anadromous individuals of this same kumzha--I regard as a single source for the reproduction of both, that is, of young fish among which in the first year the future migrants cannot be distinguished. They are all a completely homogeneous mass--the fingerling kumzha. The sex ratio in this age-group is 1:1.

The united river stock of Black Sea kumzha becomes separated into two parts--non-anadromous and anadromous--usually in its second year of life.

The migratory instinct in kumzha is to a considerable degree associated with sex; it is predominantly the females which migrate to sea, while the majority of the males remain in the river, where they quickly attain sexual maturity. Among downstream migrants of the Chernaîa River the females comprise 88% and the males 12%. This is also approximately the sex ratio in the stocks of migratory salmon returning to the river for spawning: on the average over a period of years in the Chernaîa River stock there were 85% females and 15% males. The reverse ratio is found in the non-anadromous Chernaîa River population: 74% males and 26% females.

[page 237] From this I have drawn the conclusion that "the dynamics of salmonid stocks in the Black Sea are determined not only by the reproduction of the salmon and the survival of their young, but also by the reproduction of the trout and the factors which stimulate (or alternatively, discourage) downstream migration of the young fish to the sea" (Barach, 1952).

The fact that in the salmon and trout spawning rivers there always remains a part of the young fish, these being recruited to the non-anadromous population--a sort of unutilized reserve of salmon--gives us reason to believe that the seaward migration factors are of decisive importance in the production of the salmon stock. By them is determined the quantitative ratio in which the separation of the common stock of young fish into non-anadromous and anadromous portions occurs in different rivers and in different years, or in other words, it determines the dynamics of abundance of both types.

Among the factors affecting migration, hydrological conditions, and particularly food conditions, must have considerable importance. In my time I have observed, since 1949, an increase in the number of females in the composition of the non-anadromous population of the Chernaîa River, indicating a weakening of the migratory tendency. Along with this I have demonstrated a marked decline in the population of the Chernaîa River as the result of an intensive fishery for trout during those years. "We may postulate that the improved food conditions resulting from the decrease in abundance of the population has been a factor which has reduced migration to the sea, and consequently that increase in abundance (overpopulation) will lead to increase in migration. Thus downstream migration to the sea serves as a regulator of abundance of the salmonid population of the river" (Barach, 1952).

Consequently I consider that the departure to sea of a part of the salmonid population is necessary, in the usual sense of that word, and is governed by the fact that the food supply of the river is insufficient for the whole population. In the river there remain only as many as it can provide food for. The individuals which remain in the river do not attain the size which the seaward migrants do, but in the third year of life they too mature and begin to reproduce. A part of those which have once been sexually mature, also, can swim out to sea and transform into anadromous kumzha.

The already well-known fact that sexually mature trout can migrate to sea and transform into anadromous kumzha made it possible for Dahl to speak of replenishment of the kumzha stock in the sea by river trout. Accepting the relevance of the facts outlined, I suggest that for the most part the recruitment of trout to the salmonid stocks in the Black Sea is determined by the [degree of] seaward migration of the young fish which are the common stock of recruits for both the salmon and the trout populations associated with any given river.

SPAWNING MIGRATION OF THE ANADROMOUS KUMZHA

In view of the scarcity and rather low fecundity of the females in the freshwater population and the incomparably greater fecundity of the females of the anadromous kumzha, we must consider that the natural reproduction of the salmon and trout populations is maintained mainly by females of the anadromous form.

The approach of kumzha to the Abkhazii͡a coast begins at the end of February; at this time scattered individuals appear, which are not yet entering the river. Throughout March and April there is an accumulation of anadromous kumzha in the region just off the mouths of the rivers, and in April their entry into the river begins. Toward the end of May the approach of new masses of kumzha to the coasts of Abkhazii͡a falls off and in June it ends, and the catches in the sea fall off abruptly. Toward the middle of July the main bulk of the anadromous salmon are in the rivers-- in the sea there are none (possibly occasional examples escape enumeration).

As regards the sex composition of the Black Sea anadromous kumzha it is typical, as mentioned above, to have invariably an excess of females over males--often quite markedly developed: [page 238] in the Chernai͡a River stock the females comprised on the average 88% (in different years from 76 to 100%), in the Kodor River stock they amounted to 65% (from 53 to 77%), and in the Bzyb River 63% (from 53 to 71%).

The Black Sea kumzha attain sexual maturity and go up to spawn for the most part in their third year (age 2+), after one (frequently incomplete) year of life in the sea. Only a few individuals from among the late-leaving young, after remaining in the river longer and moving to sea during the winter or spring at the start of their third year of life, become sexually mature and go up to spawn for the most part at the beginning of their fourth year, at age 3+.

The composition of the spawning stocks is indicated in the following table [see next page].

It is characteristic of Black Sea salmon to have early sexual maturity and to spawn annually. Among first-spawning individuals, more than 80% are third year fish (2+) and about 20% are individuals at the start of their fourth year of life (3+). Yearly repetition of spawning is associated apparently with short migration routes, which do not require a great expenditure of energy and permit the kelts to return quickly to the sea after spawning, and easily and rapidly recuperate their strength for a new spawning.

The functional fecundity of the females of the Chernaia͡ River stock, on the average for 5 years (1947-1950), was 8,500 eggs per female; the average number varied in different years from 7,500 to 10,500, individual variation was from 2,500 to 15,500 eggs. Two exceptional examples which I observed were a female 81 cm long with 23,200 eggs, and one 79 cm long with 19,400 eggs.

The magnitude of the functional fecundity of the Chernaia͡ River females is very close to their absolute fecundity, since the eggs in these years were obtained by opening females caught alive before the eggs were loose.

The average functional fecundity of the Bzyb and Kodor River females, taken by spear after the eggs were running, that is, when there had been some loss of eggs, was lower, namely 6,300 and 7,400 eggs. Their absolute fecundity naturally was no less than that of the Chernaia͡ River fish.

GROWTH OF THE YOUNG BLACK SEA KUMZHA AND THEIR DOWNSTREAM MIGRATION

The hatching of the fry from the eggs, which takes place in the Chernaia͡ River at a temperature of 9-10°, occurs during December and January and lasts sometimes into the first days of February. Up to 70% of the fry hatch at the middle [page 239] of January, the remainder in the second half of January. Eggs develop under the same temperature conditions in the greater part of the spawning grounds of the Bzyb and Kodor Rivers. The

Groups, according to number of sexual cycles	Percentage in the composition of the stock	Age	Fork length in cm		
			Range	Mean	Principal range
Individuals spawning for the first time	31-32	2+(3+)	35-90	60.7	50-70 (71%)
Individuals with one previous spawning	44-45	3+(2+-4+)	50-100	80.9	70-90 (74%)
Individuals with two previous spawnings	14-15	4+(3-5)	70-110	89.8	90-100 (55%)
Individuals with three previous spawnings	6-7	4+, 5+	70-110	95.0	90-110 (75%)
Individuals with four previous spawnings	1-2	5+	90-120	100	110-120 (67%)

beginning of free [individualnaia] life in the Black Sea kumzha in the rivers of the Abkhaziia coast occurs at the start of the year.

Toward the end of the year the fingerlings have attained a fork length [po Smitu] from 9 to 13 (12.8) cm (av. 10.4 cm) and a weight of 15 to 35 g (av. 25 g). The growth in length of the salmon (trout) fingerlings in the Chernaia River is characteristically rapid and uniform.

At the beginning of their second summer the yearlings have attained, by direct measurement, 9.0-16.6 cm (av. 12.1 cm); by back calculation from the scales of downstream migrants caught in the Chernaia River their length varies from 8.7 to 15.9 cm (av. 11.5 cm).

The increase during the winter of their first year and spring of their second is about 30-35%. The average length of the body of yearlings (1+) in April and May varies from 14.5 to 20.0 cm (av. 17.1 cm) (to the fork of the tail). On the scales there can be distinguished an internal ring with a number of sclerites from 16 to 20 (av. 18) corresponding to the complete first year including the winter, and an external spring ring of the second year, in which up to April there are 5-7 sclerites in all.

The transformation of Chernaia River parr to the migratory stage begins in the spring of their second year. Among the smolts in spring there are encountered individuals with a body length of 14 cm, a majority have a length from 17 to 21 cm. In October the yearlings (smolts) have reached a fork length of 17.4-25.1 cm (av. 20.7 cm) and a weight of 60-160 g (av. 90.3 g). Among the downstream migrants sampled [uchtennye] in 1951 in the Chernaia River, those of April and May comprise 21%, those in July were 18% and in October 61%. The length of all the sampled migrants was from 14 to 26 cm (av. 19.3 cm); among them 77% were between 16 to 22 cm. The length of the smolts caught during May and June in the sea was from 14 to 30 cm (av. 20.6 cm). By back calculation from the catches of migrating salmon we obtained the same average [smolt] length: 20.2 cm (from 9 to 40 cm, of which 75% are from 16 to 26 cm).

The downstream migration of the young of the Black Sea kumzha begins in the spring and lasts throughout the summer and autumn. Towards winter apparently all the smolts have left for the sea.

All of the Black Sea anadromous kumzha--the salmon--end their river life during their second year, and migrate to sea at age 1+. So short a period of river life in this form is associated with the rapid rate of growth, which in turn is related to the temperature conditions and, apparently, good feeding conditions in the nursery rivers.

NATURAL AND ARTIFICIAL PRODUCTION OF THE STOCKS

Production of stocks of Black Sea kumzha is favoured by the following factors: 1) large extent of the spawning area, in which must be included the places of reproduction of the trout, including small rivers that salmon cannot enter, but from which migration to the sea may occur; 2) rapid rate of growth of the young, which reach smolt size in 12-20 months; 3) early maturity of the kumzha and its habit of spawning every year; 4) the relatively high fecundity of the anadromous form. In spite of the favourable circumstances just mentioned, neither the natural production nor the management procedures adopted up to now have been able to increase the abundance of the stock of salmon in the Black Sea, which remains at a very low level. I believe the cause of this is primarily the year-round fishery for trout; because of this, not only is the general [page 240] breeding stock decreased, but also the number of young fish which reach the sea is reduced, because along with the trout smolts are caught, which have already begun to swim to sea. Another very unfavourable circumstance for production is the poaching that occurs on the Abkhaziîâ rivers, both prior to spawning and also in the spawning period (spearing on the redds). Increased protection for the salmonids in the spawning rivers, elimination of poaching, and regulation of the trout fishing industry, will gradually improve the situation; but all of this cannot bring the stocks up to the level at which salmon in the Black Sea will become of commercial importance.

The hatchery of the Chernaîâ River Station is supposed to take 400,000 eggs yearly for incubation, and to release all of the product, among which young fish of migrant size should number 82,000 pieces. Commercial returns are expected to the number of 25%, that is, about 20,500 pieces or 800-1000 centners of salmon. However for fish cultural work on such a scale the size of the rearing facilities of the hatchery are insufficient.

Reviewing the results of rearing young salmon in ponds on natural foods, B. I. Cherfas came to the conclusion that "with correct choice of ponds and the provision of measures which permit the rearing of a food fauna for the young, the productive output can be taken as 100-120 kg per hectare" (Cherfas, 1950, p. 224).

In our establishment there is only 0.76 hectare of ponds, which are far from being well adapted to introducing an intensified cultural program. At the rate of production mentioned by Cherfas, we could anticipate obtaining from the existing pond area 91.2 kg of product. At the usual average weight of migrant young Black Sea salmon (at the beginning of the spring of its second year) this will give 1800 fish in place of the anticipated 82,000.

As far as I know, artificial rearing of salmonid young to the smolt stage is nowhere practised in our hatcheries. Even the rearing of fingerling salmon has not got beyond the stage of experimental work. In view of this the projected results of the Chernaîa River hatchery seem to me unreasonable. For the present the rearing of salmonid young can consist only of experimental efforts, divorced from production assignments. In any event, in the years immediately ahead the productive activity of the Chernaîa River hatchery can consist only of the release of young at the fry stage. But to improve the favourable effect of this it is necessary to increase the collection of eggs for incubation as much as possible.

Doubts exist concerning the usefulness of rearing salmon by release of the product in the fry stage. I believe that even this measure can be very much more effective than natural reproduction: with artificial fertilization and incubation the loss of eggs is many times less than with natural spawning. Therefore the favourable effect of releasing fry may be regarded as certain. The whole matter depends on the scale of the work--the number of eggs obtained for incubation.

There is one further consideration: the level of release of young into the river is limited by the food resources of the latter. The observations which I made earlier give reason for believing that the abundance of the salmonid population of the river is regulated by the degree of migration downstream to the sea, and that adding to the level of the population in the river will not lead to overpopulation but to an increase in downstream migration, and consequently to an increase in the abundance of the migratory stock at the expense of the freshwater stock. From the point of view of production of salmon stocks, this seems to me a favourable factor.

[page 241] However, I do not suggest limiting our efforts in producing salmon stocks solely to the release of the maximum number of fry in the Chernaîa River, leaving everything else as it is. Considering the river as a site for rearing the young fish to the age of migration, and the sea as a foraging water; and considering that some part of the young fish, after reaching this age, do not migrate to sea but remain in the river and constitute an unutilized reserve of potential salmon, we should make it our object to achieve the maximum departure of young to the sea for feeding. This objective can be achieved by an annual fishing-out of the river and transplanting the young fish to sea--the second-year salmon/trout--and also some of the sexually mature trout. Part of the sexually mature trout retained must be put in holding ponds for utilization as spawners (of this, more below), and the remainder can be used commercially. This annual fishing-out of the river will result in improved conditions for rearing the young fish and will increase their survival rate.

Thus, in fact, we do not object to rearing young fish to the age of migration, but we propose to do this under natural conditions in the Chernaîa River. Because of its rather short length (18-20 km), the Chernaîa River can be used as a rearing water for the Chernaîa River fish hatchery if the latter is provided with the necessary equipment for the proposed management measures. This will give better results than using rearing ponds at the hatchery, with less expenditure of labour and materials.

To increase the collection of eggs appears to me quite practical. The size of the salmonid spawning stocks of the Chernaîa, Bzyb and Kodor Rivers makes it possible to count on a considerably larger collection of eggs than at the present time. In addition, we may and we must use as spawners the non-anadromous trout-kumzha (the reason for this was given above). In any event, fertilization of salmon eggs by the milt of the male trout is not only permissible (and under our conditions unavoidable), but it is also desirable. We have in mind the studies of Darwin, as elaborated by I. V. Michurin, on the importance of crossing males and females (of a single species) which differ in respect to place and conditions of feeding, or origin. The recommended heterospermous fertilization is possible for us only by using male trout.

Thus at the present time a system of fish-cultural measures for increasing stocks of salmon for the fishery in the Black Sea must include, in my opinion, the following:

1) Collection and incubation of salmon and trout eggs in the largest numbers possible; 2) release into the Chernaîa River of their product at the fry stage, or as fingerlings 1-2 months old; 3) catching in the river and transportation to the sea of second-year salmon/trout and, to some extent, of mature trout. These measures must be continued for as long as the problem remains unsolved of rearing young fish in ponds and basins of the Chernaîa River hatchery to the downstream migrant stage, or at least to the [autumn] fingerling stage. But I believe it is very likely that rearing the young fish in the Chernaîa River, with yearly transportation of these young to the sea, will always be more economic.

The proposed basic plan for fish-cultural measures to increase the stocks of Black Sea kumzha gives high priority to the following scientific research work:

1) perfection of the biological techniques of holding spawners;

2) study of the embryonic development of kumzha under the conditions of incubation that prevail in the Chernaîa River hatchery;

[page 242] 3) a comparative study of the survival of eggs of salmon, trout, and their cross, and the hardiness of the young of these different origins;

4) study of the Chernaîa River as a nursery water for the hatchery, the life of the young fish in the river, and the dynamics of their downstream migration;

5) study of the marine migrations of kumzha, and their return as commercial-size stock.

LITERATURE

Barach, G.P. 1952. Significance of brook trout in the production of stocks of Black Sea salmon (kumzha). Zool. zhurn., Vol.31, No.6.
Cherfas, B.I. 1950. Fish culture in natural bodies of water. Pishchepromizdat.