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MARK-RECAPTURE ESTIMATE OF THE STOCK ABUNDANCE OF ATLANTIC SALMON DONE DURING CATCH-AND-RELEASE FISHING ON THE PONOI RIVER, KOLA PENINSULA, RUSSIA

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ABSTRACT

In the beginning of the 90s recreational fishing based on catch-and-release began to develop on the Kola peninsula, this led to a reduction of quotas in commercial fishery for salmon at barrier fences and even further to a closure of commercial fishery on a number of rivers. A reduction of commercial harvesting of Atlantic salmon primarily with the purpose of conserving the stocks left the researchers with no handy way to assess reliably the abundance of salmon.

On the Ponoi river, one of the largest rivers on the Kola peninsula (annual returns 25 000 – 30 000 salmon), mark-recapture estimate has been applied for stock assessment since 1994 after closure of commercial fishery at the barrier fence. Every year about 1500 salmon were tagged in recreational fishery based on catch-and-release. The exploitation rate varied from 12% to 19%. During the fishing season 5-8% of tagged salmon were recaptured which enabled to conduct separate estimates for summer and autumn run salmon. Application of the mark-recapture estimate during recreational fishing on salmon rivers may be restrained by the length of the fishing season, catch size and migrations of salmon within the river system.

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INTRODUCTION

The fishery for salmon on the Ponoi river dates as far back as the 16th century. As fishing gears fixed and floating gill nets and trap nets were used which were operated both in the river and along the sea coast in the vicinity of the river mouth. From the end of the 19th century and until 1929 a solid barrier fence was used to block the river to fish the salmon gathered at it with nets and traps in-built in the fence. Some spawning tributaries were also occasionally blocked with fences. In addition, salmon were fished with nets and trap nets over the entire river length where bottom relief and current made it possible to use these fishing gears (Grinyuk, 1977). As such a fishing pattern could lead to overfishing of Atlantic salmon and impact adversely on the status of its stock, in 1964 as a conservation measure (Azbelev et al., 1958) concentrated fishing at a barrier fence that blocked the river completely in its mouth was implemented on the Ponoi river. The barrier fence was operated in such a manner that no less than 50% of salmon entering the river were let escape through it to reach the spawning areas. This was achieved by alternating one day of fishing with one day of escapement.

In the beginning of the 90s the recreational fishing based on catch-and-release began to develop on the Kola peninsula having 79 salmon rivers (43 flowing to the Barents Sea and 36 to the White Sea), their length varying from 9 km (Kolvitsa river) to 426 km (Ponoi river) (Zubchenko, Zelentsov, 1998). In 1991 catch-and-release fishing was initiated on the Ponoi river. In connection with the development of this type of fishery for Atlantic salmon, new in Russia, a fishing effort in the fishery at the barrier fence on the river was considerably reduced in 1992 and in 1994 this fishery was closed.

With barrier fence it was possible to assess the abundance of returning salmon with a rather high accuracy, therefore after its removal a problem arose of how to assess the stock and acquire data relating to its biological structure. Therefore in 1994 the Polar Research Institute of Marine Fisheries and Oceanography (PINRO) and the Atlantic Salmon Federation (ASF) with the financial support from the "Ponoi River Company" launched a scientific project (Whoriskey et al., 1996), which main objective was to assess the abundance of returning Atlantic salmon by using mark-recapture method.

MATERIAL AND METHODS

The Ponoi river is the largest salmon river on the Kola peninsula. It flows latitudinally and has the length of 426 km, its width varies from 45 to 250 m, catchment area is 15467 km^2, mean yearly water flow 164 m^3/s. In almost two thirds of its length the Ponoi flows on a flat country and only in the downstream it turns into a mountain river (Anon, 1970).

The river has two distinct salmon runs. The summer run fish enter the river in June-July and spawn that autumn. Salmon from the autumn run show a different pattern, they start to arrive in the beginning of August and continue ascending the river until it freezes. They do not spawn in the year they arrive. Instead, they overwinter either in the mid- and downstream of the river or estuary, oversummer in the river and spawn in the autumn the following year. In spring after the ice drift a catadromous migration of kelts starts. It continues until August, however, the majority of them migrate to the

sea in late May – early June. The dynamics of salmon run has normally a steady pattern, and variations in the timing of run of any particular biological group are associated with variations of hydrometeorological conditions. A long-term proportion between summer run and autumn run salmon is 24% and 76% (Neklyudov, Egorova, 1993).

Catch-and-release fishing for Atlantic salmon on the Ponoi river begins after the ice drift in late May and continues until late September. The fishing is conducted on the stretch of about 70 km in the downstream of the river. On this stretch anglers are allowed to use only fly rods with single or double barbless hook.

The recreational fishing is based on four groups of salmon: kelts, salmon from the previous year's autumn run, summer run salmon and fresh autumn salmon. Most of the seasonal catch is composed of autumn salmon from the previous year's run. They are dominant in number over the entire fishing season compared to other groups. The proportion of these salmon in catch in the beginning of the fishing season can be as much as 90% and declines to 10% in the end, when fresh autumn fish arrive. Kelts begin to occur in catch with the opening of the season and in the first few weeks of angling they sometimes account for about 40% of the catch (usually about 10%). In the season their proportion declines rapidly and by the end of June only a few of them are found in catch. The time when summer run salmon begin to occur in catch is related to the water temperature and level in the river and may vary from mid-June to mid-July. A peak of catch of summer salmon falls on mid- to late July. From the beginning of August fresh autumn run salmon gradually replace in catch the salmon that spawn that year.

The abundance of Atlantic salmon was assessed by applying the mark-recapture method (Ricker, 1975) using the data on adults marked with external tags during catch and release. The fish were tagged non-stop throughout the entire fishing season by guides assisting anglers (over 1000 salmon per year). Salmon were marked with Floy spaghetti tag attached beneath the dorsal fin. The whole procedure – from removing a hook to releasing tagged fish back into the river – took less than one minute. In addition, guides recorded tagging date and site, biological group, to which the salmon belonged, sex and weight, where possible scale samples were collected and length measured. The tag number, date and site, sex and size of recaptured fish were recorded.

To estimate the abundance the fishing season was broken up into three periods: marking period, period when tagged fish mixed in with untagged fish, recapture period. The marking period continued the first three-four weeks of the fishing season. It was exactly at that time when most of the salmon were tagged (up to 1000 fish) in the hope to get as many recaptures as possible later in the season. Then a period of mixing followed which took place during two weeks (Whoriskey, 1996). The recapture period usually continued four weeks until fresh autumn fish began entering the river.

Calculation was done by the formula:

$$N = (M+1)*(C+1)/(R+1)$$ (Ricker, 1975), where:

N – the estimated population
M – the number of fish tagged in the marking period
C – the number of fish caught in the recapture period
R – the number of fish tagged in the marking period and retaken in the recapture period.

95% confidence limits for the abundance estimates were established according to Ricker (1975).

By this formula the total number of autumn salmon from previous year's run and summer salmon from that year's run was estimated, i.e. the abundance of the spawning stock. It was possible to conduct a separate Petersen estimate only for the autumn salmon, because recapture data for summer salmon were scarce. This was due to that massive run of summer salmon into the river began in late June – early July when the marking period had been completed. Therefore, in estimating the number of autumn salmon **C** was taken to denote the number of autumn salmon in catch in those weeks of the recapture period when the autumn fish were getting dark and summer fish were easily identified by their silver colour. **R** was taken to denote the number of recaptures in the same weeks, while **M** denoted the same as in the total estimate. The number of summer run salmon was determined as the difference between the total estimate and the number of autumn run salmon. Exploitation rate was calculated from the proportion of salmon catch before the fresh autumn fish run to estimated number of salmon that spawned that year.

RESULTS

1997 population estimate

In 1997 in the marking period from 1 to 20 June 617 salmon and 16 kelts were tagged. A recapture period started on 6 July and continued until 2 August. Over that time 1427 salmon were angled of those 26 were recaptures. According to these data the total estimate of summer salmon and previous year's autumn run salmon was 32 685 fish. In the last three weeks of the recapture period (13.07-01.08) when it was possible to reliably distinguish summer salmon from autumn salmon, the catch of the latter was 900 fish of which 21 were recaptures. So, the abundance of autumn salmon were estimated at 25 310 fish and summer salmon 7 375 fish. Before the fresh autumn salmon run, in the period from 1 June to 1 August 6 070 salmon were angled or 18.6% of the estimated abundance.

1998 population estimate

In the marking period which continued four weeks from 31 May to 26 June 742 salmon and 86 kelts were tagged. After a two-week's break required for mixing of tagged and untagged fish a recapture period began, which lasted until 8 August. Over that period 24 salmon and 1 kelt tagged in the marking period were angled. The total catch in four weeks of the recapture period was 1 405 fish. These data enabled to estimate the total abundance of summer salmon and previous year's autumn run salmon at 41 786 fish. In the last three weeks of the recapture period when summer salmon could be easily distinguished by their silver colour from previous year's autumn run salmon which already began getting dark 610 autumn salmon were angled

of which 14 had tags. Based on these data the abundance of 1997 autumn run salmon was estimated at 30 265 fish. The abundance of summer salmon estimated as the difference between total estimate and estimate derived for autumn salmon was 11 521 fish. Exploitation rate of summer and autumn salmon in the period from 31 May to 7 August when 5 778 fish were angled was 13.8%.

1999 population estimate

From 30 May to 25 June 761 salmon from 1998 autumn run, 126 kelts and 8 summer salmon were tagged. In the marking period from 11 July to 7 August 17 autumn salmon tagged in the marking period were recaptured. The total catch in the recapture period was 743 salmon, of which 558 fish belonged to 1998 autumn run. On the basis of these data abundance of the spawning stock in 1999 was estimated at 31 741 fish, including 22 888 salmon of the 1998 autumn run and 8 853 summer salmon from the 1999 run. Before the run of fresh autumn fish began 3 786 salmon from various biological groups were angled and exploitation rate was 11.9%.

Table 1. Salmon abundance estimates by mark-recapture method and their 95% confidence limits (CL)

Biological group	*N*	95% CL
1997		
Autumn 1996	25310	39773-16873
Summer 1997	7375	11063-5106
1998		
Autumn 1997	30265	52181-18530
Summer 1998	11521	17563-7869
1999		
Autumn 1998	22887	37797-14609
Summer 1999	8853	14620-5650

Recapture patterns of tagged fish in 1997

In the 1997 fishing season 1 738 salmon from various biological groups were tagged (Table 2). During the season 158 tagged fish were recaptured. Five of the salmon tagged in 1997 were recaptured a second time after tagging. Of all recaptured fish 142 were tagged in 1997, 9 were tagged during 1996 and 2 in 1995.

For salmon tagged in 1997 time between marking and recapture averaged 37.0 days(SD=26.9, Median=32.5, N=142). The longest time to the second capture was 112 days, whereas four salmon were caught a second time on the day of marking. 34 salmon were recaptured within the same beat, 49 moved upstream after marking and 59 downstream. The time between marking and recapture was less (Mann-Whitney U, $P<0.001$) for fish captured twice within the same beat (Mean-23.8, SD=25.4, Median=11.5, N=34). The period between marking and recapture was the same for

salmon moved upstream (Mean=41.6, SD=24.6, Median=37.0, N=49) and those moved downstream (Mean=40.8, SD=27.5, Median=40.0, N=59).

Recapture patterns of tagged fish in 1998

Of 1 614 salmon marked in 1998 116 fish were recaptured during the fishing season (7 fish twice after marking) (Table 2). Besides, recaptured were 14 salmon from the previous year's autumn run marked in autumn 1997, five kelts marked in 1997 and one kelt marked in 1994, in addition three fish which returned for a second spawning two of which were marked in 1996 and one in 1997.

The shortest time between marking and recapture was 2 days, the longest 80 days. The average time between marking and recapture was 31.0 days (SD=19.5, Median=25.0, N=116). 32 salmon were recaptured on the same beat, 37 further upstream and 46 further downstream. The period between marking and recapture was shorter for the salmon captured twice on the same beat (Mann-Whitney test, $P<0.05$), than for salmon which moved upstream after marking. The time before recapture of salmon which moved downstream after marking was the same as for salmon recaptured further upstream (Mann-Whitney test, $P>0.20$).

Recapture patterns of tagged fish in 1999

In 1999 1 218 salmon were tagged of which 66 were recaptured during recreational fishing (Table 2). Besides, recaptured were 9 kelts, 6 of which were tagged in 1998 and the other three in 1997 with one of them already recaptured and released in 1998. In addition, there were recaptured four salmon which returned for a second spawning and were initially tagged in 1997 as salmon of the 1996 autumn run, and six salmon of the 1998 autumn run tagged in 1998.

Of 66 salmon marked and then recaptured in 1999 18 were recaptured on the same beats where they had been marked, 22 further upstream and 26 moved downstream after marking. The time between marking and recapture averaged 32.9 days (SD=21.44, Median=30.0, N=66). The longest time was 100 days and the shortest 2 days. The time between marking and recapture of salmon on the beats located upstream of the marking site was the same as for salmon recaptured on the beats located further downstream (Mann-Whitney test, $P<0.01$). There were no second recaptures of tagged salmon in 1999.

Table 2. Details of salmon marking in 1995-1999 (data for 1995-1996 have been borrowed from Whoriskey & Prusov, 1997)

	1995	1996	1997	1998	1999
Number of marked salmon	1201	1143	1738	1614	1218
Number of recaptures	60	96	142	116	66
% of marked fish recaptured	5.00	8.40	8.17	7.18	5.42
Number of fish recaptured twice	1	5	5	7	0
% of marked fish recaptured twice	0.08	0.44	0.29	0.43	0

DISCUSSION

From the end of the 50s a concentrated fishery for salmon at barrier fences that completely blocked rivers in the mouth (Azbelev et al., 1958) was implemented on the Kola Peninsula with the main objective of conserving Atlantic salmon stocks. Concentration of the in-river fisheries at barrier fences enabled to avoid the risk of overfishing the salmon stock in any individual river, which was achieved through applying the "one day fishing – one day escapement" regime. On those rivers where the status of stocks was defined as unsatisfactory an additional number of spawners were let escape through the barrier fence to reach the spawning grounds (Zunchenko, Zeletsov, 1998). Besides, operation of barrier fences enabled to assess the numbers of salmon migrating into the river with a rather high accuracy and collect representative data on the biological structure of stocks (Azbelev et al., 1958). From 1958 to 1977 barrier fences at different times were operated on a total of 36 rivers on the Kola Peninsula and their greatest number (23) was operated in 1978 (Zubchenko, Zelentsov, 1998). A development of recreational fisheries from early 90s led to re-allocation of quotas between commercial and recreational fisheries and closure of commercial fisheries for Atlantic salmon on a number of rivers. In 1998 the commercial fisheries were conducted at 5 barrier fences only by contrast to two previous years when they were 7 (10 in 1995) (Prusov et al., 1999). And though such a reduction of commercial fishery for Atlantic salmon was primarily meant to ensure conservation of the stocks, as was said before, it left researchers with no convenient tool to assess the status of salmon stocks. So, in these circumstances a mark-recapture method fairly broadly applied for stock assessment (Anon, 1999) could become one of the alternative ways of estimating the abundance of salmon on the Kola Peninsula.

However, there is a number of difficulties associated with application of the mark-recapture method for stock assessment during recreational fishing. In the first place this refers to the need to mark a rather large number of salmon so that the accuracy of estimates could be acceptable to managers. For example, for such big stocks of Atalantic salmon as the Ponoi stock is (about 30 000 salmon return to the river for spawning every year) no less than 1000 salmon need to be marked yearly (Ricker, 1975). This could be a constraint for the application of mark-recapture method on those rivers where the catch during a recreational fishing season is known to be less

than the number of salmon required to be marked to derive estimates of acceptable accuracy. Besides, a fishing season should be of sufficient length so that it could include a marking period, a period of mixing of tagged and untagged fish and a recapture period. There are also certain difficulties with conducting separate estimates for different biological groups of salmon due to different run timing.

It does not appear possible to apply the mark-recapture method to estimate the numbers of kelts during recreational fishing because they migrate quite rapidly down to the sea. Every year in the beginning of the fishing season on the Ponoi river up to 100 kelts were marked, however, only one kelt was recaptured once during its migration to the sea in the year when it had been marked. Besides, an estimate for the fresh autumn run salmon can be conducted only the following year because salmon continue to arrive in the river well after the fishing has closed. And although, salmon from this biological group overwinter primarily in the downstream and/or estuary of the river, a part of them move upstream beyond the river stretch where catch-and-release takes place before the fishing season starts. Therefore, the population size could be underestimated.

When it comes to estimating a fish population size, the mark-recapture method is more applicable to populations which live in locked waters which excludes migrations of fish out from the area where assessment is undertaken while migrations within the area contribute to good mixing of tagged and untagged fish and ensure reliable estimates. As to estimating the population size of Atlantic salmon in such large rivers as Ponoi by mark-recapture method, migrations of fish in the river should be taken into account as well as timing of the run of different biological groups into the river. Ideally, for conducting such estimates salmon should be marked in the river mouth with data collected in the mid- and upstream of the river and its tributaries.

REFERENCES

ANON. 1970. Resources of surface waters in the USSR. V.1, Kola peninsula, Leningrad, Hydrometeoizdat Publishing Office, 316 p. (in Russian)

ANON. 1999. Report of the Working Group on North Atlantic Salmon // ICES CM 1999/Assess:14, 288 p.

AZBELEV V.V., GROMOV G.D., LAGUNOV I.I. 1958. Experience with assessment of salmon in the rivers on the Kola peninsula // Fisheries J., No.2, pp. 96-101 (in Russian)

GRINYUK I.N. 1977. Fisheries, production and projection of abundance of the salmon spawning stock in the Ponoi river// PINRO Selected Papers, Vyp. 32, pp. 156-182 (in Russian)

NEKLYUDOV M.N., EGOROVA I.A. 1993. Biological characteristics of the Ponoi river salmon // Materials to the Annual Meeting of PINRO on results of scientific research in 1992. Murmansk, pp. 249-258 (in Russian)

PRUSOV S.V., PRISCHEPA B.F., KRYLOVA S.S., ANTONOVA V.V., BUGAEV V.F. Fisheries, Status of Stocks and Management of Atlantic Salmon in Russia in 1998. // ICES CM 1999/S:02.

RICKER, W.E. Computation and interpretation of biological statistics of fish population. // Bulletin of the Fisheries Research Board of Canada. - 1975.- 191. - 382 pp.

WHORISKEY, F. Initial report on the 1995 Ponoi scientific programm, prepared for the summit meeting in Saint John, New Brunswick. - Atlantic Salmon Federation, 1996.

WHORISKEY, F.G., KUZMIN, 0. & GOODHART, D. Monitoring of sports fishing catches of Atlantic Salmon *(Salmon salar L.)* of the Ponoi River, Russia to document population characteristics. // Polish Archives of Hydrobiology - 1996. - 43. – P. 167-177.

WHORISKEY, F., PRUSOV S. Atlantic salmon of the Ponoi River, Russia. // ICES working paper, 1997/24.

ZUBCHENKO, A. V., ZELETSOV. A. V. Salmon rivers of the Kola peninsula. Precautionary approach and management of Atlantic salmon in rivers of the Kola peninsula. // ICES CM 1998/T:5.