Fish migration from two large regulated lakes to outcoming rivers monitored by hydroacoustics.

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Teppo Vehanen
Natural Resources Institute Finland (Luke)

Pekka Hyvaerinen
Natural Resources Institute Finland (Luke)

FISH MIGRATION FROM TWO REGULATED LAKES TO OUTCOMING RIVERS MONITORED BY HYDROACOUSTICS

Teppo Vehanen, Pekka Hyvärinen and Aki Mäki-Petäys
Finnish Game and Fisheries Research Institute, Kainuu Fisheries Research and Aquaculture
Manamansalontie 90, FIN-88 300 Paltamo
Finland
kainuun.kvl@rktl.fi

ABSTRACT

Fish migration from two large northern Finnish lakes, Lake Oulujärvi and Lake Inarijärvi, to their outcoming rivers were studied by echo-sounding, exploratory fishing and fish marking. Both lakes are regulated for hydroelectric purposes. The area of Lake Oulujärvi is 928 km^2. The mean depth of the lake is 7.6 m, and the average annual amplitude of the water level regulation is 1.9 m. The mean flow (MQ) in the outcoming River Oulujoki is 229 m^3/s. The surface of Lake Inarijärvi is 1071 km^2. The mean depth of the lake is 14 m. The annual mean amplitude of water level fluctuation is 1.48 m. The mean flow (MQ) in the outcoming River Paatsjoki is 157 m^3/s. In both rivers two sonar stations with stationary up- and down-looking transducers were used in data collecting for one year. Exploratory fishing was done for species identification. Fluorescent pigment marking was done to separate the stocked and naturally reproducing brown trout in Lake Inarijärvi.

The fish migration rate in the River Oulujoki was larger than in the River Paatsjoki. In the River Oulujoki the fish migrated mainly downstream and in the River Paatsjoki both down- and upstream. In the River Paatsjoki, large fish showed active migration in the spring and autumn, whereas in the River Oulujoki the increase in the migration occurred simultaneously in all the size groups. The different species composition and the different nature of the lakes together with the different regulation practises was proposed to result in the varying migration and behavioral patterns.The importance of downstream migration was greater for the fish community in Lake Oulujärvi, whereas in Lake Inarijärvi the importance of the migration in the River Paatsjoki can have a positive effect through the spawning and feeding areas in the river. We conclude that no barriers to prevent fish migration are needed in these rivers.

KEY-WORDS: Hydroacoustics/Exploratory fishing/Fish marking/Fish migration/Migration rate/Lake regulation/Fish community/Stocking/Whitefish/Brown trout

INTRODUCTION

Many lakes in northern Finland are regulated for hydropower production. Due to the decrease in natural fish reproduction in those lakes fish stocking is carried out as a compensatory process. The most important species stocked are whitefish (*Coregonus lavaretus* L. sl.) fingerlings and brown trout (*Salmo trutta* (L.) m. *lacustris*) smolts. The results from the stocking have been widely varying. One possible reason for these variations is the descending of stocked fish from the regulated lakes to the rivers (e.g. Heikinheimo-Schmid and Huusko, 1988). In order to prevent the migrations, demands have been made to establish physical barriers in the outlets of several rivers.

The application of hydroacoustics theory is currently accepted in fisheries research (Forbes and Nakken, 1972; Johannesson and Mitson, 1983; Thorne, 1983; Bodholt, 1990). With hydroacoustics it is possible to conduct absolute *in situ* measurements of fish abundance. The major disadvantage of the method is the lack of biological samples.

Portable hydroacoustic instruments have been used to detect pelagic fish abundance in marine environment and in lakes. The riverine conditions are often shallow and acoustically very noisy. Stationary transducers improve signal to noise characteristics and eliminate the problem of resolution near the boundaries (Thorne, 1983). Several single beam transducers can produce information of fish behaviour eg. the direction of migration. Stationary transducers have been used in studies solving problems related to fish migrations in hydroelectric dams (Johnston *et al.*, 1993), but they have also been used in studying the trout distribution in a lake environment (Stables and Thomas, 1992).

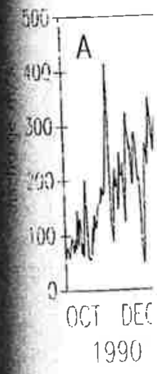
Fish migrations from two large regulated lakes in northern Finland to their outcoming rivers were studied with hydroacoustics using stationary transducers in 1990-1991 and 1993-1994. The purpose of the study was to evaluate the need for any physical barriers to prevent the fish migration.

MATERIAL AND METHODS

Study area

The area of Lake Oulujärvi is 928 km^2 (Fig 1). The mean depth of the lake is 7.6 m, and the maximum is 36 m. The lake has been regulated since 1951. The average annual amplitude of the water level regulation has been 1.9 m during 1959-89. This exceeds the preregulation average with 0.8-0.9 m. High water level has been decreased by 60 cm from the natural. In spring the water level of the lake is rapidly lowered to collect the meltwater. This is why the water level in April is about 1 m lower than in the unregulated lake. In the outcoming River Oulujoki, which flows into the Gulf of Bothnia, the flow varies greatly due to the regulation (Fig. 2A). The first power plant is situated in the outlet of the River Oulujoki and followed by six more in the main basin of the river. Two sonar stations were placed into the river in 1990-1991.

The surface of Lake Inarijärvi is 1071 km^2 (Fig. 1). The mean depth of the lake is 14 m and the maximum 96 m. The lake has been regulated since the 1940's. According to average values (from 1959 to 1989) the annual mean amplitude of water level fluctuation has been 1.48 m, which is 0.30-0.35 m more than in the unregulated lake. Compared to the natural situation the upper high water is on average 52 cm higher and the low water about 18 cm higher than in the unregulated lake. The outcoming River Paatsjoki, drains into the Barent Sea. Because of smothering regulation the variations in the flow of the River Paatsjoki are smaller than those in the River Oulujoki (Fig. 2B). There are seven power plants in the river. The first is situated five kilometres from the river's outlet. Two sonar stations were placed in the River Paatsjoki and they collected data from 1993 to 1994.



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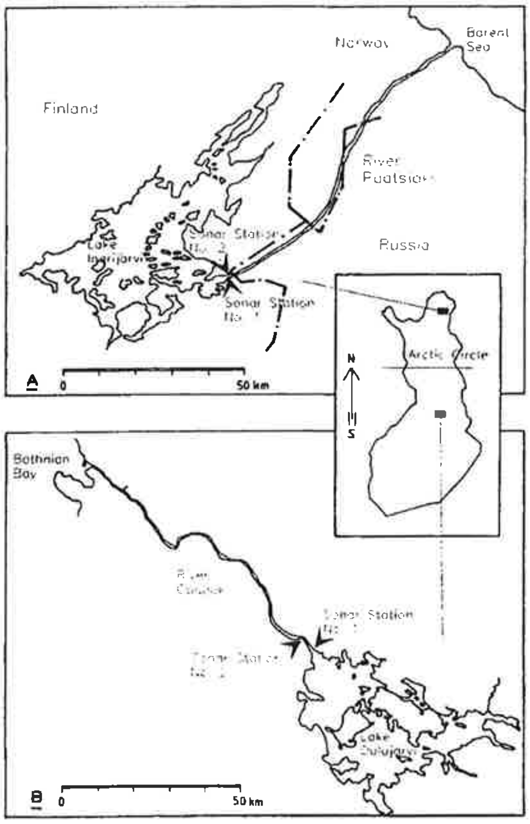


Figure 1: Location of the study areas and the sonar stations.

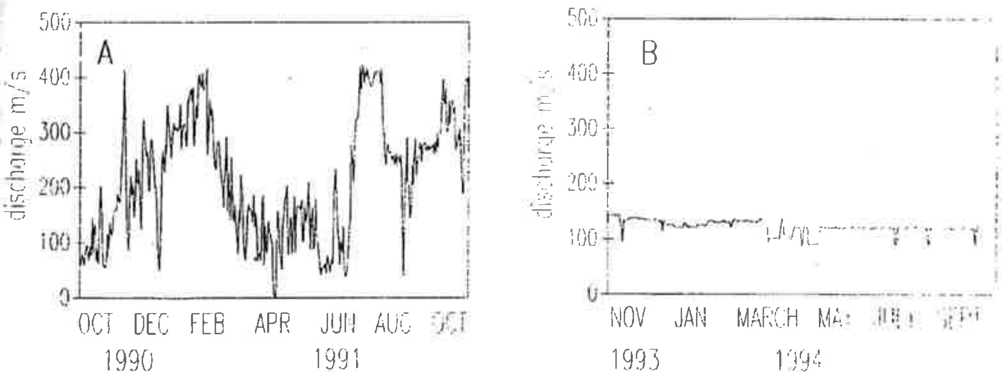


Figure 2. The mean daily discharge of the River Oulujoki (A) during the study from Oct 10,1990 to Oct 18, 1991, and the mean daily discharge of the River Paatsjoki (B) during the study from Nov 12, 1993 to Oct 24, 1994.

The greatest difference in the fish community between the lakes is the presence of smelt and a variety of cyprinid species in Lake Oulujärvi. Lake Inarijärvi is a typical subarctic lake, where salmonid stocks are strong and the cyprinids are not precent, with the exception of minnow. Stocking of whitefish fingerlings and brown trout smolts is carried out intensively in both lakes.

Hydroacustic sampling

The hydroacoustic sampling was conducted by a River Sonar Station (RSS) equipped with stationary down- and up-looking transducers (Echo Research Co. 1990) and controlled by specific program (HAS, Henk Co. 1993). The system was especially designed for hydroacoustic surveys in rivers less than 30 m deep. It was based on independent 192 kHz echo sounding units with 400W transmitters which were both located in waterproof container. The time varied gain (TVG) was 40lgR and the dynamic range was 120 dB. 4-10 pings per second were transmitted according to the depth of the site. Lowrance THS-1992-20 transducers were used, the beam angles were 20° (-3db), and the tilted 10 degrees against the river flow (up-looking transducers) or along the flow (down-looking transducers).

The calibration of the system was done twice in both locations with a standard copper sphere (Foote, 1982). The first calibration took place after deployment, and the second after a period of six months' continuous activity. The calibration was done separately to each sonar.

The hardware equipment used obtained echo strength (ES) instead of target strength (TS), which are known to differ in directivity:

(1) $$TS = ES - 20\log(D),$$

where: D = transducer directivity towards the target. To compensate for the lack of directivity information a precise modification of the Craig and Forbes (1969) method (Forbes and Nakken, 1972) was applied to provide an estimate of the target strength (TS). The detection of fish echoes begun 1 m from the transducer. The fish lengths (L) were calculated from the target strength (Lindem, 1983; Jurvelius, 1991):

(2) $$\log L = (TS + 67)/20$$

The equation was originally developed for smelt and whitefish, but in this study all fish species were expected to reflect the same target strength with respect to the length of the specimens. Only fish larger than 7 cm (-49.5 dB) were taken into consideration, because of a lack of biological samples from smaller fish and also the impurities in the acoustic data (gas bubbles, leaves etc.).

The direction of fish movement was calculated from the entrance and exit ranges of the targets as they passed through the beam. The transducers were placed at an angle of 10 degrees upstream or downstream. Target tracking technique (Johnston, 1985; Johnston and Hopelain 1987) was applied to all detected single targets on every sonars range to estimate angle aspects of moving targets towards transducer:

(3) $$a = \arctan\frac{R1 * \cos(\theta/2) - R2 * \cos(\theta/2)}{R1 * \sin(\theta/2) + R2 * \sin(\theta/2)},$$

where: a = angle of fish passage, R1 = entrance range of target, R2 = exit range of target and θ = transducer beam width at -3 dB.

Two sonar stations were constructed in the River Oulujoki and also in the River Paatsjoki (Fig 1., Table 1). The up-looking sonars were anchored on the bottom and the down-looking sonars were installed on a cable stretched across the river. The sonar units in the River Paatsjoki were installed in the same manner as in the River Oulujoki with the exception that the units located at the surface were anchored to a small metal bridge built across the river.

Table 1: Information of the two sonar stations constructed in the River Oulujoki and the River Paatsjoki to detect the number of fish passing the stations.

River	Sonar station	Data collection time	River width (m)	Depth of sonar locations (m)	Distance between sonars (m)	Number of down-looking sonars	Number of up-looking sonars	Coverage of the cross section by sonar beams %
Oulujoki	No.1	10.10.1990-18.10.1991*	140	3-8	5-15*	16*	6*	40*
	No.2	10.10.1990-18.10.1991	40	3-12	5-6	6	2	50
Paatsjoki	No.1	12.11.1993-24.10.1994	380	4-12	12-27	24**	0	15
	No.2	12.11.1993-24.10.1994	375	4-12	12-27	0	16**	12

*Ice floe broke the parts at the surface and from April 9, 1991 to April 25, 1991 the station did not collect data. After repairs station consisted of eight up-looking transducers covering 15 % of the rivers cross-section.
**One unit located at the surface and one at the bottom were shut down during the whole survey, because of the reflections causing noisiness in the other sonars.

To detect the possible noise of the data, visual echogram monitoring for each sonar was conducted on at least five days per month, and twice a week for minor instances of monitoring. Noisy data was excluded from the analysis by the monitoring program. The control program filtered out hydroacoustic noise resulting from strong echoes from stable obstacles. The data sometimes showed sporadic noise which may have been due to some non-predictable or occasional factors such as strong wind, rain or snowfall. These echoes clearly differed from fish echoes, and they were filtered from the data.

Each sonar collected daily data for 24 hours, and the data was stored on a hard disk. The daily numbers of upstream and downstream migrants in each size group were stored on disk. Only single fish targets were observed. Only few multiple (less than 3 % of targets) echoes were observed in both rivers. The direction of migration for multiple echoes could not be calculated, and they were left out of the calculations.The data from the sonars was expanded to cover the entire cross-section of the river.

Exploratory fishing

Gill net, fyke net and purse seine were used in the exploratory fishing in both rivers to identify the fish species which migrated through the acoustic beams. The fish caught were identified and their total length was measured. In the Oulujoki River the fishing was carried out in the area first above Station No.1, second in the area between the two stations and third in the area about one kilometer downstream from Station No.2. Monofilament gill nets with variable mesh sizes (30 x 1.8 m, 12-75 mm stretched mesh) were used. The nets were lifted daily and there were altogether 2448 net-days during the study. The trap nets were also lifted daily, the total effort being 418 fyke-days. Altogether 482 hauls were carried out with purse seine during the study.

In the River Paatsjoki the fishing took place above the sonar station only because no fishing was allowed downstream from the sonar stations due to vicinity of the Russian border. Gill nets with stretched mesh sizes of 12, 15, 20, 25, 35, 45, 60 and 75 mm and lengths of both 10 m and 30 were used. The height of the net panel was 1.8 m. Also some 3.0 m high panels were used. Altogether 5109 net-days were fished. Altogether 304 hauls were carried out with purse seine nets during the study. Fishing with fyke-nets was rather difficult in the River Paatsjoki conditions and only 114 fyke-net days were fished.

Hydroacoustic results were converted to fish species according to the exploratory fishing. The conversion was done on a monthly basis in the River Oulujoki. In the River Paatsjoki the conversion was based on a two-month catch. Six different length groups were used in both rivers: 7-11 cm, 11-15 cm, 15-21 cm, 21-30 cm, 30-42 cm, and over 42 cm fish.

The following conversion equation was used:

(4) $$Aij = (Cij/(TOT(Ci)j))*(Xjx)$$

where Aij = the total number of i-species and its j-size group fish migrating upstream or downstream. Cij = the number of i-species and its j-size group fish in the catch, TOT(Ci)j = the number of j-size group fish of all the species in the catch and Xjx = the number of j-size group fish during a period of one month (the River Oulujoki) or two months (the River Paatsjoki) migrating either downstream or upstream according to hydroacoustic sampling.

<u>Fish marking</u>

In order to estimate the number of stocked and natural brown trout, a fluorescent pigment marking (Jackson 1959, Strange and Kennedy, 1982) was used in Lake Inarijärvi in a mass-marking of stocked brown trout smolts. Altogether 39300 were marked (see also Table 4). The marked fish were kept at a hatchery for nine months, after which the marks were checked and the fish were released to Lake Inarijärvi. All the captured brown trout in the River Paatsjoki were checked for possible fluorescent pigment marks under a UV-light.

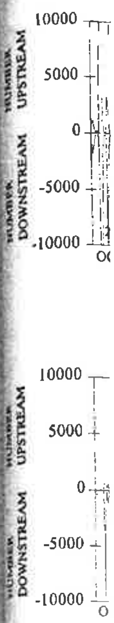
RESULTS

The number of fish detected in Station No.1 in the River Oulujoki was 438334 fish and at Station No.2 it was 265357 fish. The majority of the fish at Station No.1, (84.5 %), and No.2, (91.7 %), were migrating downstream.

In the River Paatsjoki the fish numbers detected by the sonar were smaller than in the River Oulujoki. At Station No.1 152522 fish were estimated to have passed the station, while the number at Station No.2 was 128438 fish. The direction of the migration in the River Paatsjoki was more evenly divided between the upstream and downstream movement from the division detected in the River Oulujoki. At Station No.1 70106 (46 %) fish were discovererd to be swimming downstream, whereas the corresponding figure at Station No.2 was 69300 (54 %).

In addition to the larger number of fish migrating downstream in the River Oulujoki, also the variations in the daily numbers of the fish observed at the sonar stations were distinguishably greater in the River Oulujoki in comparison with the numbers obtained from the River Paatsjoki (Fig. 3). However, a somewhat similar timing in the migration rate was found, so that a period of a relatively low migration rate of fish from November to March was found at both sites. In the spring a period indicating a slightly higher migration rate was found in the River Oulujoki in March and in April-May in the River Paatsjoki with a more northern location. After a period of a relatively low migration rate the numbers of the fish observed by the sonar stations began to increase and a relatively high migration rate was reached in October in both rivers. The cycle of the migration rate between the size groups did not differ noticeably in the River Oulujoki, the visible difference being the small amount of large fish (>35 cm long) migrating compared to the fish in the smaller size groups (Fig. 4A). The increase in the migration rate occurred simultaneously in all the size groups. In the River Paatsjoki the cycle of the migration rate varied between the different size groups (Fig. 4B).

The total number of the fish caught by the exploratory fishing was 33461 fish in the River Oulujoki and 4533 fish in the River Paatsjoki. On the basis of the species and size distribution in the catches of the sample fishing (see equation 3) the results of the hydroacoustic sampling were converted into species composition (Table 2 and 3). In the River Oulujoki the most abundant species migrating were perch, whitefish, roach, ruffe, burbot, brown trout, vendace, and dace. In the River Paatsjoki whitefish was the most abundant species, which constituted more than a half of the estimated number of the migrating fishes. At both stations in the River Paatsjoki both the downstream and upstream migrating fish were observed quite evenly.



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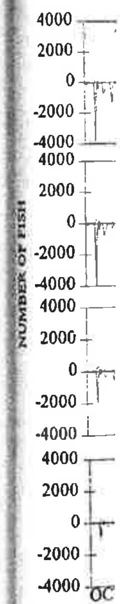

Figure 4
Sonar

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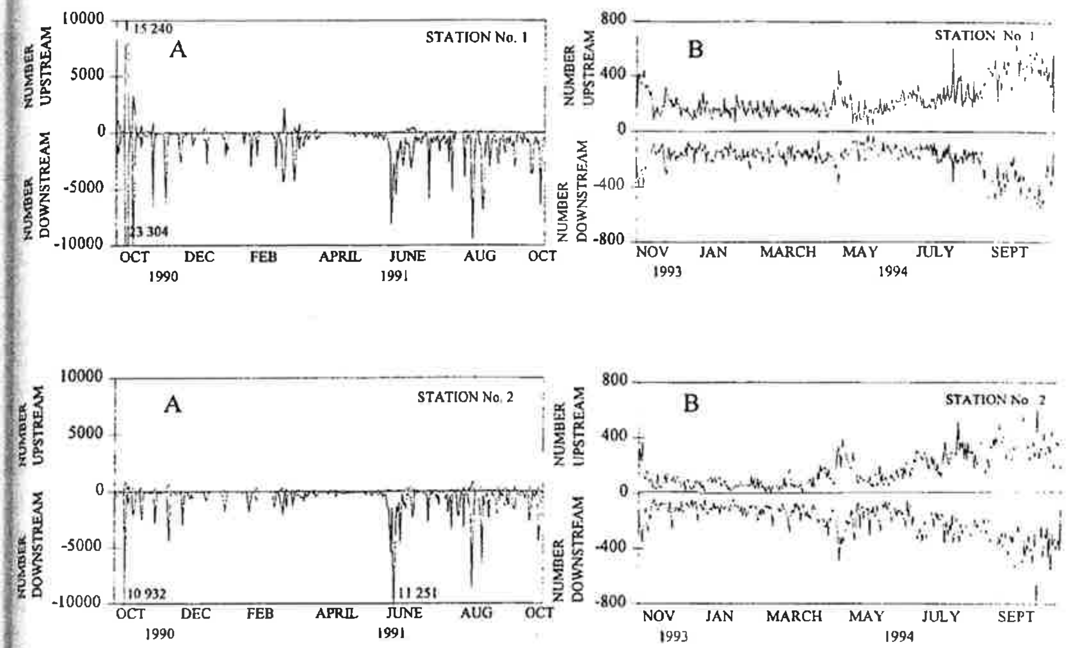

Figure 3. The daily numbers of the fish migrating in the River Oulujoki (A) and the daily numbers of the fish migrating in the River Paatsjoki (B). Notice different scales.

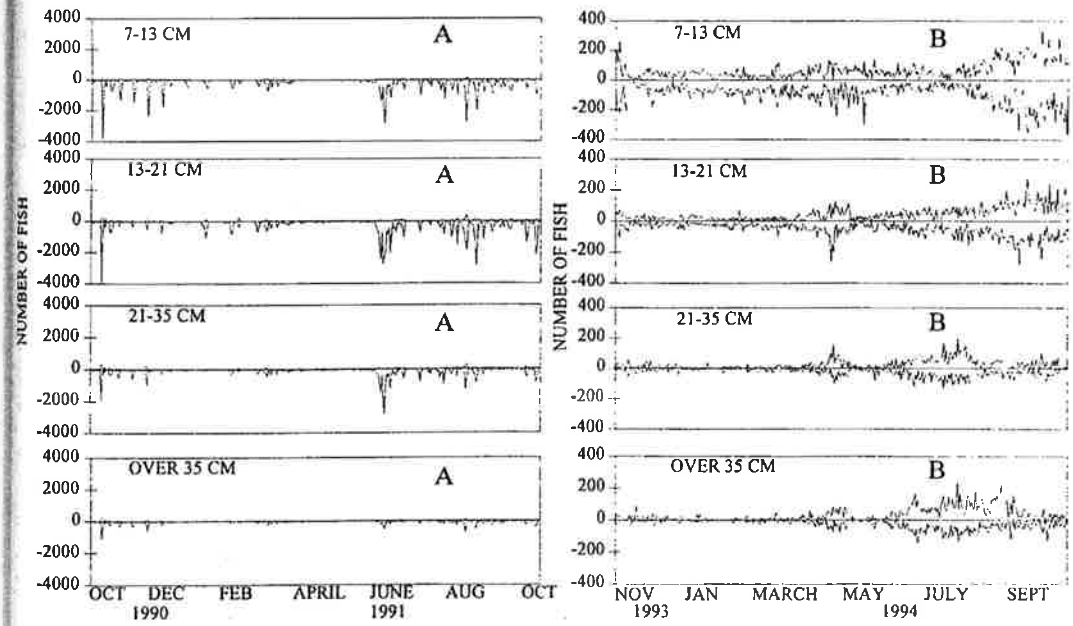

Figure 4. The daily numbers of the fish migrating in the River Oulujoki divided into four size groups at Sonar Station No.2 (A) and in the River Paatsjoki at Sonar Station No.2 (B). Notice different scales.

Table 2. The estimated numbers of the eight most abundant species migrating downstream or upstream at the two sonar stations in the River Oulujoki.

	Station 1.			Station 2.		
Species	Upstream	Downstream	Difference	Upstream	Downstream	Difference
Perch	8743	95357	-86614	2453	45234	-42781
Whitefish	28389	129637	-101248	3355	30653	-27298
Roach	5715	28259	-22544	9374	113418	-104044
Ruffe	4921	61213	-56292	630	18009	-17379
Vendace	6328	12929	-6601	69	871	-802
Burbot	6951	13583	-6632	3540	18469	-14929
Brown trout	2478	6457	-3979	240	3840	-3600
Dace	418	10446	-10028	59	947	-888

Table 3. The estimated numbers of the eight most abundant species migrating downstream or upstream at the two sonar stations in the River Paatsjoki.

	Station 1.			Station 2.		
Species	Upstream	Downstream	Difference	Upstream	Downstream	Difference
Whitefish	42933	37106	5827	32532	39665	-7133
Burbot	15142	14774	367	9189	11284	-2094
Grayling	14086	10272	3814	9915	9809	106
Perch	3540	3009	531	2306	3079	-773
Brown trout	3022	2055	968	2802	2426	376
Pike	2481	1841	639	2355	1964	391
Vendace	499	620	-121	767	678	88
Arctic char	423	424	-2	391	355	57

In the River Oulujoki the species composition at the upper (Station 1) and lower (Station 2) sonar stations was quite different (Fig. 5). Different species showed clear migrating periods. The majority of the brown trout migration in the River Oulujoki occurred in June-July. However, according to the results of the exploratory fishing, the peak in the brown trout migration took place during a very short period from the end of June to the beginning of July, when the brown trout catch of the test fishing was high. Because the numbers of the fish migrating were calculated on the basis of the monthly figures of the migrating fish, a migration peak of such sorts can lead to an underestimation of the migrating brown trout.

Whitefish was the most abundant species throughout the year in both stations in the River Paatsjoki, the estimated period of abundance being September-October (Fig. 6). Migrating periods of different species were also found in the River Paatsjoki.

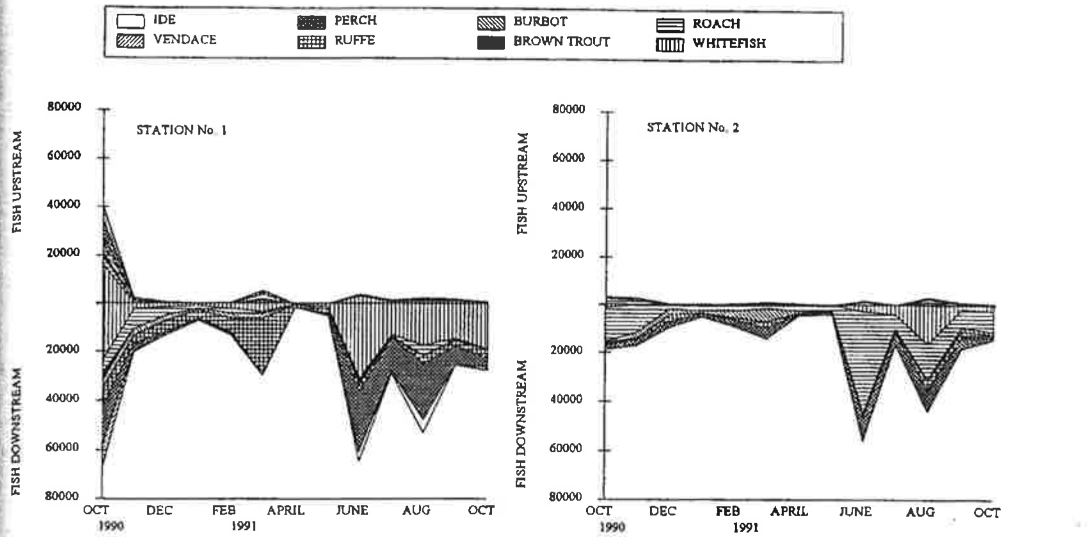

Figure 5. The results of the hydroacoustic sampling converted into various fish species on the basis of the sample fishing in the River Oulujoki. The eight most abundant species are shown.

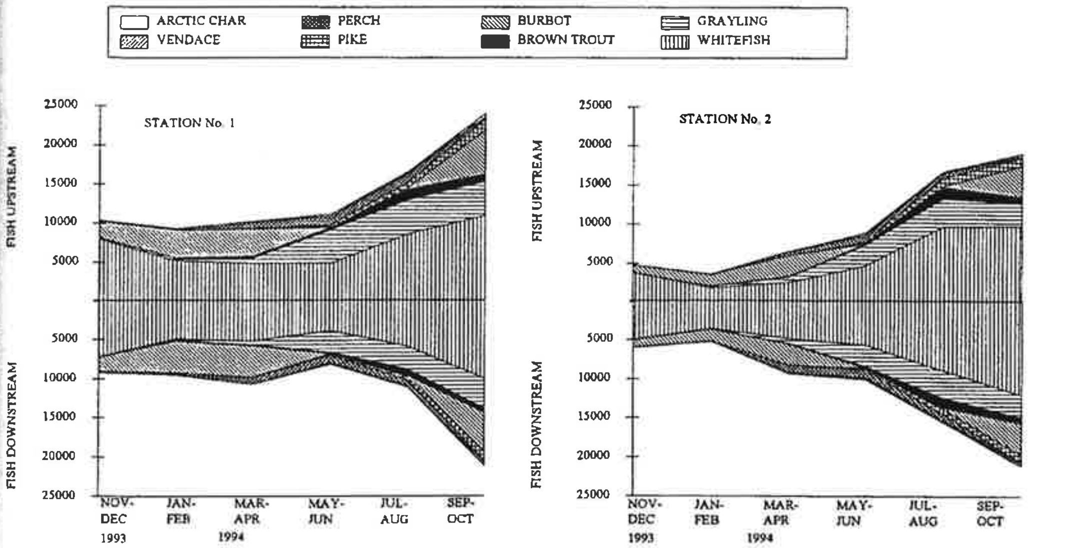

Figure 6. The results of the hydroacoustic sampling converted into various fish species on the basis of the sample fishing in the River Paatsjoki. The eight most abundant species are shown.

In the River Oulujoki 2145 whitefish were randomly sampled in order to measure the proportion of the stocked densely rakered whitefish from the naturally reproducing whitefish forms in the lake. According to the gillraker frequency, 41.2 % of the whitefish obtained migrating from the River Oulujoki were densely-rakered whitefish and thus they originated from stockings. In Lake Oulujärvi the brown trout catch is based on the stocking. On the basis of the age and size distribution the majority of the migrating brown trout in the River Oulujoki, 93 % (altogether

744 brown trout were sampled), were from the stocking made during the study in 1991. This would mean that 3571-6005 of the brown trout stocked in 1991 were migrating downstream. The number of the ascending brown trout was 6.1-10.3 % of the annual number stocked in 1991 (58 066 fish were stocked in 1991)

In the River Paatsjoki altogether 176 brown trout were caught during the study and out of them 145 were 2-4 years old, possibly originating from the stockings (2-4 year-old brown trout were stocked in 1994). Out of these 145 brown trout 25 were marked with fluorescent pigment (Table 4). The assumption was that the relation between marked and unmarked stocked fish was the same in the River Paatsjoki as it was in Lake Inarijärvi (34005 brown trout marked/116120 brown trout stocked). According to this relation more than a half (85 fish, 58.9 %) of the 2-4 year old brown trout detected in the River Paatsjoki were from stockings. On the basis of these figures the estimated numbers of the brown trout stocked in Lake Inarijärvi in 1994 and observed in the River Paatsjoki were 986-1451, suggesting that the total amount of the stocked brown trout in the River Paatsjoki was very small in respect to the total amount stocked in 1994.

Table 4. Results of brown trout groups marked with fluorescent pigment, stocked to Lake Inarijärvi and catched from River Paatsjoki. Tag retention was checked after nine months in a hatchery.

Tag-group	Age	Date of stocking	Number marked	Tag retention %	Marked fish stocked	Mean size of fish mm	Tagged fish catched
3	4	June 9-15,1994	10900	77,4	8437	266	1
4	4	June 24-29, 1994	14570	94,8	13812	264	20
5	3	June 20-22, 1994	13830	85	11756	238	4
TOTAL			39300		34004		25

DISCUSSION

Two largely different migration rates and also clear differences in the direction of travel between the lakes studied were found. The migration from Lake Oulujärvi to the River Oulujoki was larger and more varying when compared to the movement from Lake Inarijärvi to the River Paatsjoki. Also the direction of travel was clearly downstream migration in the River Oulujoki, whereas in the River Paatsjoki the direction of travel was almost equally both upstream and downstream. The direction of travel of each fish was measured according to the assumption that fish swim parallel to the bottom or the surface. This was obviously true in the majority of the cases, and the difference between the two rivers monitored by the same method was clear.

The possible reasons for the differences in the magnitude and direction of travel between the lakes can be attributed, besides the possible effect of the difference in the species composition, to the dissimilarities in the nature of the lakes. Lake Oulujärvi is the central lake in the Oulujoki water system. Two large water courses flow into the lake and drain via the River Oulujoki into the Bothnian Bay, Lake Oulujärvi being a typical water course lake. Although many rivers flow into Lake Inarijärvi, none of them are large ones and Lake Inarijärvi is not as typically a part of a water course as Lake Oulujärvi. Another difference between the lakes studied are the dissimilar regulation practices carried out in the lakes. Due to heavier regulation the variations in the water level of Lake Oulujärvi, and especially the variations in the flow of the River Oulujoki, are larger when compared to those in Lake Inarijärvi and the River Paatsjoki. Also the shallowness of Lake Oulujärvi increases the effect of the water level regulation on the physical environment of the lake in comparison with the deeper Lake Inarijärvi. All this can be the contribute to the larger and more varying amount of fish migrating downstream from Lake Oulujärvi.

The more southern location of Lake Oulujärvi is seen in the species composition of the River Oulujoki in the larger numbers of cyprinid and percid fishes when they were compared with those in the River Paatsjoki. In both rivers the spawning period was apparent in the increased movement involving the majority of the species. However, when the different size groups in the River Oulujoki were observed, an increase in the migration rate was seen to take place simultaneously in all the size groups. In the River Paatsjoki a clear migration peak in the spring and late summer was seen in the larger fish. The free flowing section of the River Paatsjoki serves as a feeding site and also a spawning site for the naturally reproducing fish, such as grayling, whitefish and brown trout. The results suggest that in the River Paatsjoki the up- and downstream migration results partly from the spawning fish actively migrating to the river. Also feeding migrations are possible in the River Paatsjoki. In the River Oulujoki, where the first power station is situated in the outlet of the river, the migration can be more passive and a larger proportion of the migrating fish were small. However, feeding migrations are possible also in the upper part of the River Oulujoki, above the first power station. A clear difference in numbers and species of migrating fish was found between the two sonar stations in the River Oulujoki. This difference can partly be attributed to fish returning to Lake Oulujärvi before descending below the first power station into the river, fishing and also turbine loss. Local river reservoir fishes (eg. roach) were detected in greater numbers at the second sonar station.

The total catch in Lake Oulujärvi has varied between 350-700 tonnes with whitefish, vendace, pike, roach, burbot, and perch forming more than 90 % of the total catch. According to the data the total number of the whitefish descending from Lake Oulujärvi exceded 100000 fish at Station No.1 and some 30000 fish at Station No.2, about 40 % of the fish originating from the stockings of the densely-rakered whitefish. However, when compared to the size of the natural and stocked whitefish stocks in Lake Oulujärvi (which is estimated to 1500000 two-year old and older fish in 1989, Salojärvi (1991)) the number of the ascending fish was not large. In addition to this, a substantial part of the descending whitefish were small fish, 7-15 cm long. Because the relationship between the stock size and growth of the whitefish has been found to exist in Lake Oulujärvi, the descending of the whitefish can be compensated by the better growth of the whitefish. Nevertheless, the effect of the downstream migration on the whitefish catch is fairly small. The ascending trout, 6.1-10.3 % of the total amount of the annually stocked brown trout, does have some significance for the brown trout yield obtained from the lake. However, the annual brown trout yield in Lake Oulujärvi was in 1990, for example, 9600 kg, and the loss in the yield due to the descending of brown trout is not crucial. The majority of the other migratory fish (mainly vendace, perch, roach, ruffe, burbot, and dace) were small, 7-13 cm fish. Although the amount of these migrating fish was fairly large their influence to the total yield of the lake was small and migrating fish do not present any threat for the natural stocks in the lake.

In Lake Inarijärvi the annual total catch in 1987-1993 has varied between 160-560 tonnes. Vendace, which was introduced into the lake in the 1980s, has been the strongest factor behind the variation. The vendace catch was at its greatest in 1989, but since then it has rapidly decreased. Only few vendace were found to migrate to River Paatsjoki in this study. The other commercially important coregonid fish, whitefish, was migrating almost evenly both up- and downstream in the River Paatsjoki and the importance of the migrations to the Lake Inarijärvi fishery was very small. In fact, the significance of the free flowing section of the River Paatsjoki can be positive for whitefish, and also for grayling and brown trout, for it serves as a spawning and feeding area. Also brown trout were found migrating evenly both up- and downstream. Even if all the stocked brown trout detected in River Paatsjoki were assumed to be migrating downstream, the amount found in the river was, with respect to the annual stocking amount, so small that the downstream migration had no or very little effect on the brown trout yield in Lake Inarijärvi. Also the amount of burbot, grayling, perch and, pike were relatively small and the direction of travel both up- and downstream indicated that the importance of the migration for the yield is neglible.

Hydroacoustic employing stationary transducers together with intensive exploratory fishing and fish marking could, with a reasonable error rate, give answers to the questions conserning the amount, size, and species of migrating fish and also about the timing of the migration. The fact that the same relation between fish length and target strength was employed, does, due to the different backscattering properties of the different species, create an error rate of some extent in the species identification. Our assumption, however, is that the size grouping used in the study was accurate enough for the species identification relevant for the purposes of this study. Two largely different migration patterns were found between the two lakes studied. The importance of the downstream migration ranged from moderate in Lake Oulujärvi to almost zero in Lake Inarijärvi. In addition, on the basis of the results, the significance of the migrations in either lake was not large enough to make barriers preventing migration recommendable.

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