ELSEVIER

Fisheries Research 31 (1997) 73–82

FISHERIES RESEARCH

Suitability of motorized under-ice seining in selective mass removal of coarse fish

Timo Turunen [a,*], Ilkka Sammalkorpi [b], Petri Suuronen [c]

[a] *Finnish Game and Fisheries Research Institute, Saimaa Fisheries Research, FIN-58175 Enonkoski, Finland*
[b] *Lahti Research and Training Centre, PO Box 12, 00014 University of Helsinki, Finland*
[c] *Finnish Game and Fisheries Research Institute, PO Box 202, FIN-00151 Helsinki, Finland*

Accepted 23 January 1997

Abstract

The efficiency of modern, fully motorized under-ice winter seining technique was studied in the selective mass removal of coarse fish in the eutrophicated Lake Vesijärvi, southern Finland in 1992–1994. The total catch in 57 seine hauls was 69 000 kg and the average catch per haul 1210 kg (250–6500 kg). The average biomass removed from the fishing area per haul was 120 kg ha^{-1} (SD 116) in the deepest basins (depth > 15 m), where smelt (*Osmerus eperlanus* L.) dominated the catches. The corresponding catch was 192 kg ha^{-1} (SD 187) in a shallower basin (< 15 m) where the catch comprised mainly cyprinids, all age classes of bream (*Abramis brama* L.) and bleak (*Alburnus alburnus* L.) and juveniles (1 + and 2 +) of roach (*Rutilus rutilus* L.) and bleak. The catches were composed of aggregated fish since there was no correlation between the length of the haul and weight of the catch and the biomass removed from the fishing area was high. The under-ice pelagic schooling pattern of fish distribution was confirmed by scanning sonar monitoring which was effectively utilized in fishing. Winter seining is a suitable method for selective fish removal both in fisheries management and in biomanipulation of temperate lakes which are ice-covered for several months during a year. © 1997 Elsevier Science B.V.

Keywords: Under-ice seining; Mass removal; Biomanipulation; Cyprinids; Smelt; Behaviour

1. Introduction

It is well established that the species composition of fish communities changes dramatically and fish biomass increases due to the eutrophication of lakes (Svärdson, 1976; Leach et al., 1977; Persson et al., 1988). Dense populations of cyprinid fish, in particular roach and bream, often play an important role in maintaining the internal phosphorous loading after a reduction of the external nutrient load (Andersson et al., 1978; Keto and Sammalkorpi, 1988; Brabrand et al., 1990; Horppila and Kairesalo, 1990; Hamrin, 1993). A drastic reduction of these fish improves the composition of fish stocks (Miller, 1947; Healey, 1980; Amundsen, 1988; Barthelmes, 1994). It also improves water quality (Hrbacek et al., 1961; Straskraba, 1965; Stenson et al., 1978; Reinertsen and Olsen, 1984). The term 'biomanipulation' includes different kinds of manipulations of the biota of lakes and their habitats (Shapiro, 1990). However, the point of manipulation of fish populations is to reduce the density of planktivorous and benthivorous fish.

* Tel: +358-15 345 500; fax: +358-15 345 5059; e-mail: timo.turunen@rktl.fi.

PII S0165-7836(97)00018-0

Our aim was to study whether effective exploitation of diverse coarse fish could be carried out by winter seining. Mass removals and reductions of coarse fish (fish with low economic value) have been carried out mainly by means of capturing, poison treatment, introduction of and catch restrictions of piscivorous fish, and habitat modifications (reviewed by Shapiro, 1990). Trawl, seine, pound-net and other fishing gear have recently been used in biomanipulation projects (e.g. Søndergaard et al., 1990; Backx and Grimm, 1994; Hamrin, 1993; Horppila and Peltonen, 1994).

There has been a rapid development in commercial winter seining technique of vendace, *Coregonus albula* (L.) in Finland since the end of the 1980s (Tuunainen and Tuunainen, 1990; Salmi and Husko, 1995). This paper describes how the technique used in fully motorized under-ice winter seining was developed for selective mass removal of coarse fish, and makes a preliminary assessment of the ecological and economical merits and limitations of this method. Also the usefulness of scanning sonar location of under-ice fish schools was evaluated. The under-ice seining is compared with pelagic trawling as described by Peltonen and Horppila (1992) and Horppila and Peltonen (1994) as well as with winter-seine fishing in Lake Wolderwijd, the Netherlands (Backx and Grimm, 1994). No previous studies exist on under-ice seining of coarse fish with modern methods in lake biomanipulation.

2. Material and methods

2.1. Study area

Lake Vesijärvi (10 800 ha) consists of five major basins. Three of them were included in this study; the Enonselkä Basin, Paimelanlahti Basin and Kajaanselkä Basin (Fig. 1). The basic characteristics of

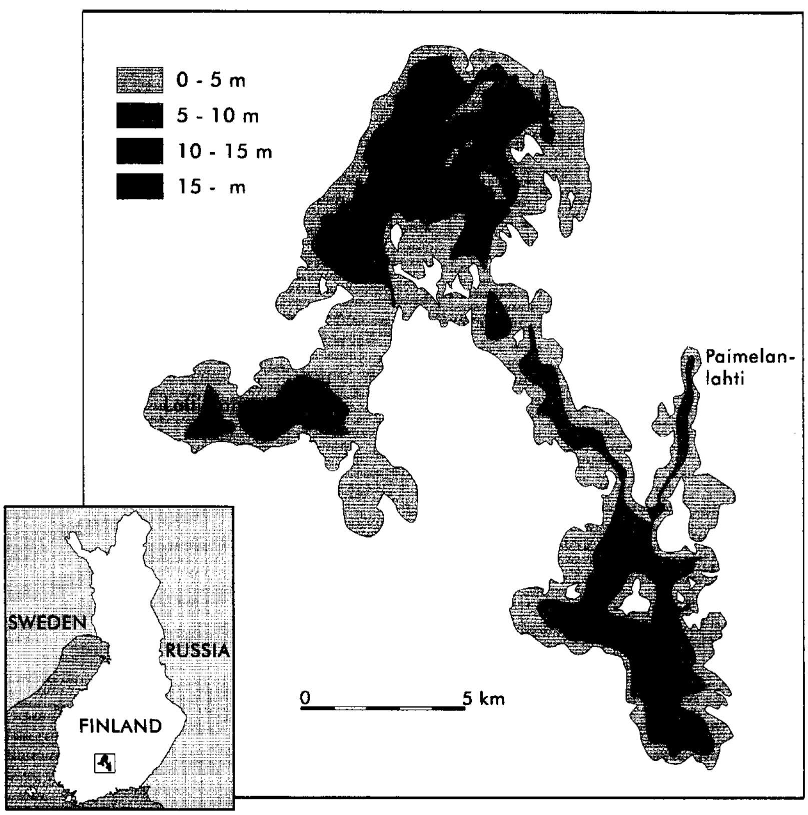

Fig. 1. Lake Vesijärvi. Areas deeper than 10 m are shaded.

Table 1
Basic information about the three main basins of Lake Vesijärvi (Keto, 1982; Keto and Sammalkorpi, 1988)

	Enonselkä	Paimelanlahti	Kajaanselkä
Area (ha)	2600	390	4400
Mean depth (m)	6.8	3.5	6.8
Max. depth (m)	33	15	42
Total phosphorous (g l^{-1}) (1990s)	33	40	20
Transparency (m) (1994)	4–5	2.5–3	5–6

these basins are summarized in Table 1. During the 1960s, Lake Vesijärvi became the largest heavily eutrophicated large lake in Finland (Keto, 1982). In particular, the Enonselkä Basin (2600 ha) was strongly loaded with municipal sewage from Lahti city. In 1976, the sewage load was completely diverted. The lake started to recover: the phosphorus concentration in March in Enonselkä Basin declined within 2 years (1975–1977) from 150 $\mu g\ l^{-1}$ to 50 $\mu g\ l^{-1}$ (Keto, 1982). However, summer blooms of blue-green algae still remained in the 1980s in spite of the gradual improvement in chemical water quality due to internal phosphorous loading in summer (Keto and Sammalkorpi, 1988; Horppila and Kairesalo, 1990).

The fish community and fishing have suffered heavily from eutrophication in Lake Vesijärvi in the latest decades. There were occasional fish deaths, and taste and odour problems have been frequent during the 1960s and 1970s (Keto, 1982). Coregonid fish disappeared, and the cyprinid species became dominant (Keto and Sammalkorpi, 1988). A quantitative echosounding study in the Enonselkä Basin in 1984 revealed a very high density of fish, on average 25 000 individuals ha^{-1} (Jurvelius and Sammalkorpi, 1995). Food chain studies suggested and enclosure experiments verified that the continuation of poor water quality was catalyzed by the dense coarse fish populations (Keto and Sammalkorpi, 1988; Horppila and Kairesalo, 1990).

The catch taken by trawl from the Enonselkä Basin was on average 84 kg ha^{-1} per year, and during the 5 year fishing period (1989–1993) about 1.1 million kg in total (Horppila and Peltonen, 1994). The biomass of roach decreased from 172 kg ha^{-1} to about 50 kg ha^{-1}. However, whilst pelagic adult roach was effectively removed, the two or three youngest age groups were not captured. Horppila and Peltonen (1994) estimated that when effective exploitation was ceased after 1993, roach biomass would double after the trawling phase in 3 years, but a constant fishing mortality rate of 0.3 per year (yearly catches 45 000–50 000 kg) for one-year-old and older roach would prevent the recovery of the stock. This exploitation was studied using under-ice winter seine.

2.2. Fishing gear, methods and operations

There has been a rapid development in commercial winter seining technique (targeted on vendace) since the end of the 1980s. The modern under-ice winter seining is made as follows: holes in the ice (thickness usually 40–60 cm) are made with chainsaw and motorized drills (Fig. 2). Hauling ropes are drawn under the ice by a rope-steered, battery-powered device. This buoyant apparatus is equipped with two wheels with sharp pins which firmly bit on the under-surface of the ice. Hauling ropes are then attached to the floating spreaders fixed to the wingtips of the seine. With the assistance of sharp skates, the spreaders slide under the ice during the haul. The special mechanism of the spreaders forces the seine to form a typical sphere during the haul. The seine ropes are reeled in by the small motorized (combustation engine) winches fixed behind the heaving hole (Fig. 2). With the help of this new technique only two men (instead of 4–6) are now needed to operate a winter-seine. Two or even three hauls can be carried out during a short winter day.

Seining experiments using this method were conducted in February–April 1992–1994. The total number of hauls was 57 (15 in 1992; 22 in 1993 and 20 in 1994). The depth of the seining area varied from 6 to 25 m (Fig. 1). Experiments were carried out with three seines (Fig. 3). The largest one, used

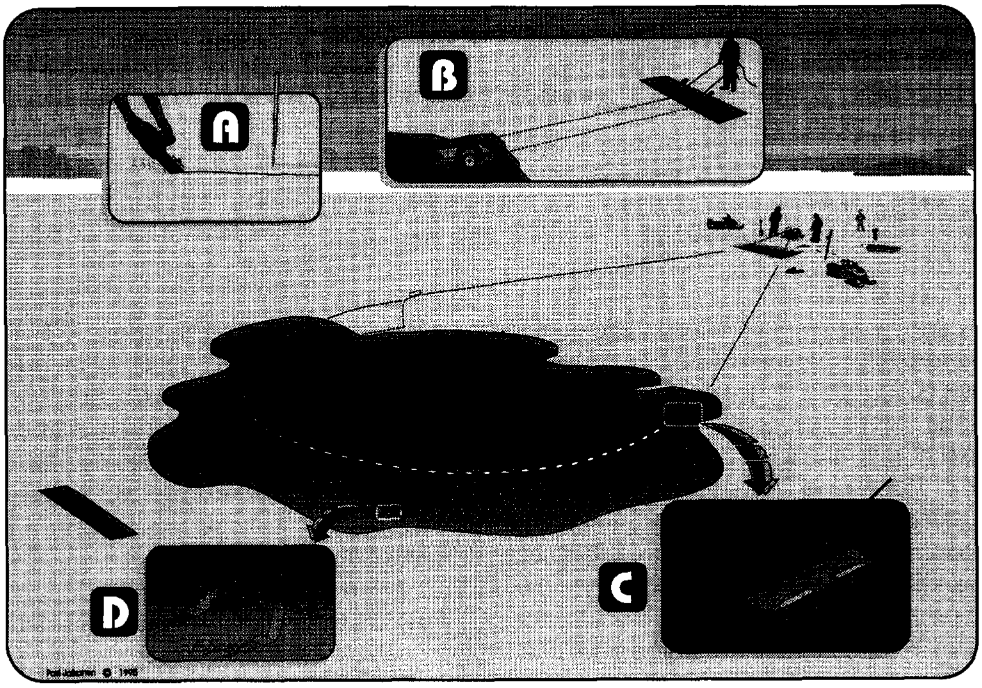

Fig. 2. Schematic representation of the modern winter seining procedure: (A) Holes in the ice are made with a chainsaw. (B) The hauling ropes are drawn under the ice with a rope-controlled, battery-powered device. (C) Spreaders force the seine to form the seine sphere. (D) Weighted flexible plastic strips keep the seine in contact with the bottom without sticking on obstructions.

only in 1992 in the areas deeper than 15 m, was 20 m high (when stretched). The smaller seines, which were used in shallower areas (< 15 m), were 11 m and 7 m high. The total length of the seines were 330, 310 and 280 m, respectively. They were made of white knotless nylon (PA 210/6 and 210/9) with a mesh size of 8–40 mm (bar length) in the wings and 5 mm in the codend (bag). The meshes of the seines were denser than those used in commercial vendace fishery.

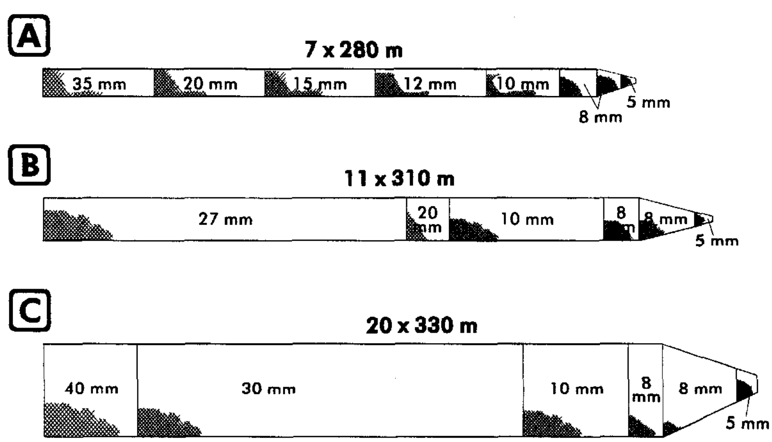

Fig. 3. Seining experiments were carried out with three different sized seines (A–C; height × circumference in metres).

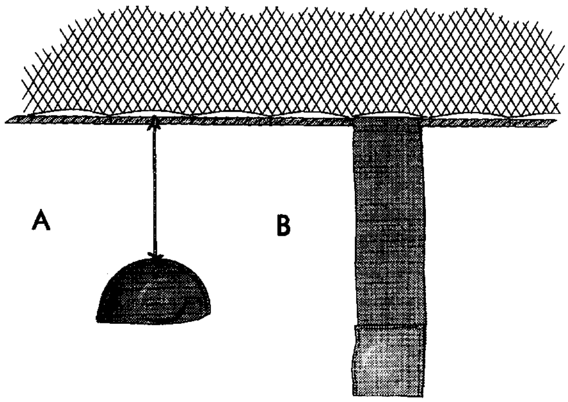

Fig. 4. Traditional, rubber-covered stone weights (A) are replaced in modern seines with flexible, lead-filled plastic strip weights (B). The weight of each strip in our experiments varied from 25 to 100 g, and the total weighting in the footrope varied from 200 g m^{-1} in the wings to 250 g m^{-1} in the rear part of the seine.

Seines were weighted by a new method where flat, flexible plastic strips (10 × 40 cm) with a lead-filled 'pocket' in the lowest part of each strip were attached to the floating footrope (Fig. 4). The distance between the strips was 50 cm in the wings, but in the rear part of the seine they were placed strip-to-strip so that they formed a 'wall' without space between. According to under-water video observations, weight strips kept good contact with the bottom at a hauling speed of 4 m min^{-1}. The bulky rubber-covered stone weight with a thin rope may easily stick, for example between stones on the bottom. On the other hand, the wide, flat plastic strip slides over the obstructions. Moreover, the total mass of the new weighting system is divided more evenly along the footrope than that of the conventional.

The average length of seine hauls was about 500 m (280–760 m) in 1992 and 1993. In 1994, the length was standardized to 400 m in the Paimelanlahti Basin and 600 m in the Enonselkä Basin. Seining was conducted only in areas where fish schools were observed by sonar. The hauling speed was 3–4 m min^{-1}; hence a haul of 400–600 m took 2–3.5 h. Due to the weighting method, seines did not stick on small obstructions on the bottom.

The area (ha) covered by each haul (A) can be described as: $A = 0.02x - 1.8$, where x is the length of the haul (m). The shortest hauls (length 280–300 m) covered an area of 3–4 ha and the longest hauls (length 680–760 m) 12–13 ha. The biomass removed from the fishing area by each haul as well as the biomass removed from the total fishing area (i.e. lake area where experiments were carried out) was calculated. The fishing effort was also estimated in man-hours. The species and size composition of the catch in each haul was estimated from samples ranging from 4 to 20 kg.

A scanning sonar (Furuno CH-18) was used for the evaluation of bottom topography, and for the monitoring of fish location and behaviour during seining. The display of sonar was videotaped (Hi8 format) for later analysis. Fish behaviour and the performance of the gear during hauling was occasionally monitored using an underwater low-light camera (Osprey OE 1232 SIT) mounted on a stick that was operated manually via a hole in the ice. Observations were recorded on video tape (S-VHS format). The selection of seining areas was based on preliminary sonar surveys before the seining periods and on observations of qualitative echo sounder surveys made in autumn before freezing.

3. Results

3.1. Catch size, composition and fish distribution

The total seine catch was 17730 kg (on average 1182 kg $haul^{-1}$; SD 1525) in 1992, 22960 kg (on average 1044 kg $haul^{-1}$; SD 1756) in 1993, and 28310 kg (on average 1416 kg $haul^{-1}$; SD 1331) in 1994. In general, the most common catch category was 500–1000 kg per haul (Fig. 5). The catch and the catch composition was examined separately for

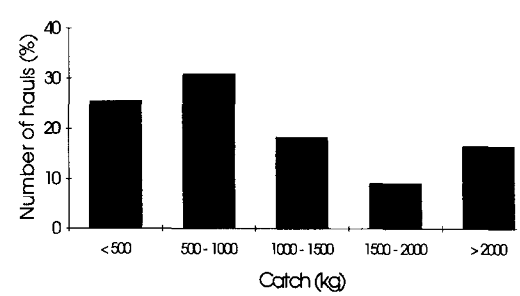

Fig. 5. The distribution of seine catches into the catch categories of 500 kg intervals.

Table 2
The average under-ice winter seining catch of Lake Vesijärvi (E: Enononselkä; K: Kajaanselkä; P: Paimelanlahti)

Year	Area/depth	Catch (kg haul^{-1})	SD	Number of hauls
1992	Tot.	1182	1525	15
1993	Tot.	1044	1756	22
1994	Tot.	1416	1331	20
1992	E Basin/ > 15 m	644	412	8
1992	K Basin/ > 15 m	1797	2098	7
1993	K Basin/ > 15 m	1900	153	3
1993	E Basin/ < 15 m	233	132	3
1993	P Basin/ < 15 m	1035	807	16
1994	E Basin/ < 15 m)	1318	861	9
1994	P Basin/ < 15 m	1536	1296	11

deep (> 15 m) and shallow (< 15 m) areas (Table 2).

3.2. Deep areas (> 15 m)

In winter, 1992 the average catch per haul was 644 kg (SD 412) in eight hauls in the pelagial of the Enonselkä Basin, and 1797 kg (*SD* 2098) in seven hauls in the Kajaanselkä Basin. The average biomass removed from the fishing area was 120 kg ha^{-1} (SD 116). More than 99% of the weight of the seine catches in deep areas consisted of smelt. The size of smelt individuals was small (7.5–10 cm) in both basins.

3.3. Shallow areas (< 15 m)

In the Paimelanlahti Basin (mean depth 3.5 m, max depth 15 m), the average catch per haul was 1035 kg (SD 807) in 1993 and 1536 kg (SD 1269) in 1994. The average biomass removed from the fishing area was 192 kg ha^{-1} (SD 187). The catch was composed almost entirely of cyprinids, mainly bream, bleak and small roach. There were peaks in the length distribution of roach at 4.5–6 cm and 8–9 cm representing 1 and 2 year old fish, respectively. Bream was the only cyprinid species that was caught in adult form in large numbers in the Paimelanlahti Basin.

In the shallower areas of the eastern and western parts of the Enonselkä Basin sonar observations did not show fish aggregations in 1993. This was confirmed by low catches (700 kg in three hauls; SD 132). In the northeastern part more aggregated, but not densely schooling fish were found in 1994. The catch per haul averaged 1318 kg (SD 861) in 1994. The roach were mainly adults as in the trawl catch in the previous summer.

The length of the haul had little effect on the catch (Fig. 6). In the Paimelanlahti Basin two high catches (2100 and 2300 kg) were caught with hauls of only 300 m, which is a short length in under-ice seining. The length of haul was shortened to 400 m in the Paimelanlahti Basin in 1994. Although 20 236 kg had been fished in the Paimelanlahti Basin in 1993 after the winter, the average catch was higher in 1994. We interpret that this was caused by improved knowledge of local conditions and 'learning' of the skills of fishing cyprinids. The length of haul was ca. 600 m in the Enonselkä Basin since the schooling tendency of the older roach was weaker than was found for young cyprinids in the Paimelanlahti Basin.

3.4. Fish behaviour

Schools of smelt were large (diameter up to 50 m) and dense in January–March in the Kajaanselkä Basin and Enonselkä Basin. In March 1993 and 1994 schools of cyprinids were also in the pelagial zone of Paimelanlahti Basin just below the ice cover. In April schools became more scattered, and that caused seine catches to decrease. Perch and adult roach stayed in the shallower areas, below 5–8 m (confirmed by angling catches of local fishermen), and were never caught by seines in large numbers.

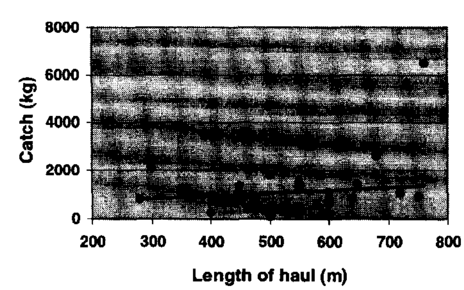

Fig. 6. The relation between the length of the seine haul and the catch. According to the linear equation, $y = 2.23x - 122.5$ ($r^2 = 0.053$; $P > 0.05$; $n = 43$) the haul length (x; in m) explained only about 5% of the catch weight (y; in kg).

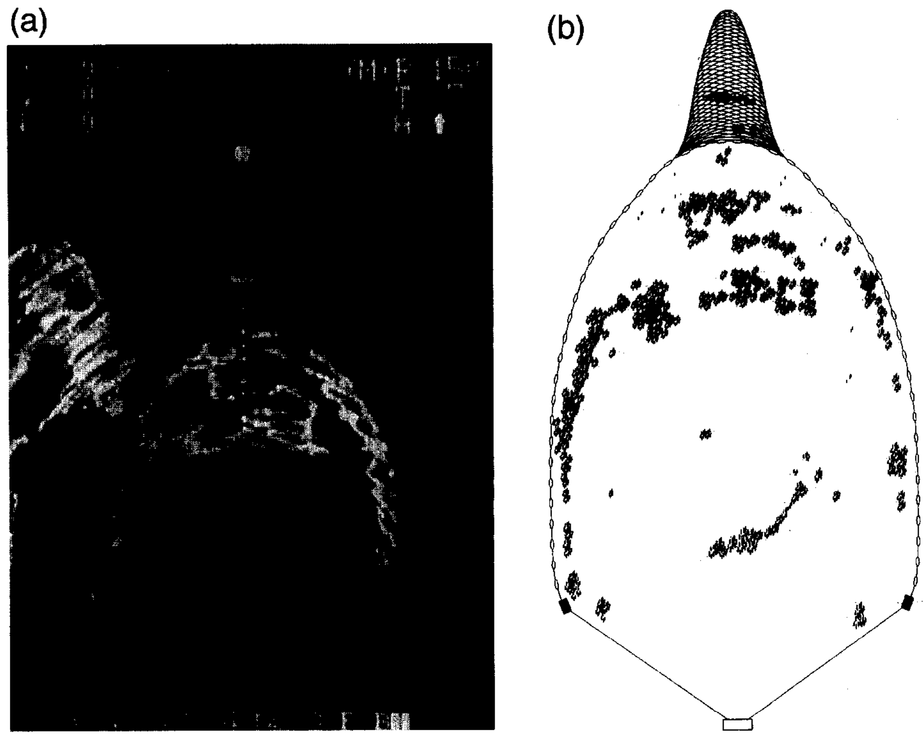

Fig. 7. The formation of actively swimming cyprinid schools in under-ice winter-seine (mainly roach) recorded by the scanning sonar via a hole in the ice (photo on left). The illustration (on right) shows simplified forms of fish schools as well as the seine, seine spreaders and the lifting hole in the ice.

Fish schools did not usually react to the seine until the seine-wall was close to the fish. Schools usually entered into the the rear part of the seine and swam slowly until the heaving started. However, the cyprinids often began to swim actively in a loose 'circle' formation (Fig. 7). In several cases, roach and bleak were found being gilled as head-first in the meshes apparently indicating escape attempts. The behaviour of smelt was less agitated. Even in the largest smelt catch of 6500 kg in a haul on March 1992, all fish stayed calm near the codend during the heaving.

Escape was usually attempted when free swimming space became smaller inside the seine. The mesh size of the seine-nets, except in the most extreme parts of the wings, was so small that escape was difficult. However, video-camera monitoring showed the smallest cyprinids (1 and 2 year old roach and bleak) pushing through 8 mm meshes during the heaving. The densest meshes (5 mm) in the codend prevented escape in the lifting phase. In most cases the seine haul covered the water column from the bottom to the ice, and hence free escape avenues were mainly closed. The new weighting system prevented better the escape below the footrope.

4. Discussion

Under-ice winter seining proved to be a potentially effective method in removal of coarse fish. It is possible to get selective seine catches by utilizing the habitat segregation ('wintering strategies') of different species and their age groups. In particular, the catching of young cyprinids was successful with winter-seines in the shallower areas. With the exception of Backx and Grimm (1994) no earlier data exists of large catches of juvenile cyprinids removed from biomanipulation lakes. A very selective fishing of smelt was routine in the deeper areas.

Clearly, winter seining has many advantages as a selective mass removal method of coarse fish in temperate lakes. Seine-fishing appears especially suitable for biomanipulation of typical eutrophic Finnish lakes which are small, shallow and morphologically split up by islands and peninsulas. Handling and preservation of catches in the cold season do not cause similar problems as during summer. Seine-fishing also demands lower investments and operation costs than for instance trawling. In Lake Vesijärvi the calculated price for trawled fish was 1.5–2 times higher than that of winter-seined fish. Moreover since trawls are targeted mainly on adult fish (Horppila and Peltonen, 1994; Horppila et al., 1996) and the fish caught in winter are mainly juveniles, the weight unit removed in winter by seine-fishing includes many times as many fish individuals as that of summer trawling. We anticipate that the yearly exploitation required to prevent the recovery of the roach stock in Lake Vesijärvi (Horppila and Peltonen, 1994) could be reached by extensive winter seining.

When the winter seining catches were compared with the trawling catches in the Enonselkä Basin (Peltonen and Horppila, 1992; Horppila and Peltonen, 1994) the following observations were made:

1. Large individuals (> 15 cm) of roach, which dominated the trawl catch in summer, were not found in the seining areas in winter. The angling, trap net and gillnet catches of local fishermen revealed that adult roach—and the majority of perch as well—were found in areas shallower than 6–8 m.

2. Young roach and bleak, which stay mainly in the littoral in summer and were practically absent from the pelagic trawl catches, were dominant in pelagic winter-seine catches in Paimelanlahti Basin.

3. Smelt was concentrated in winter as well as in summer in areas deeper than 15 m, and were effectively seined in winter as well as trawled in summer.

4. The number of large predatory fish (pike, pikeperch) in winter-seine catches were very low, as in the trawl catch. Both gear were suitable for selective removal of coarse fish in this respect.

It was necessary to locate aggregated fish before the seining: without sonar-prelocation (randomly provided) seining would apparently have produced significantly smaller catches than with the help of sonar monitoring. In general, fish schools were found in the Paimelanlahti Basin after 1–2 h of searching since seining crew learned potential areas for fish concentrations. It was possible to determine on the basis of sonar display if the fish schools were large enough for seining. At the same time the suitability of the bottom topography for seining operation was evaluated.

Our winter-seine catches and their locally high efficiency agree with the results of Backx and Grimm (1994) from the large scale biomanipulation of Lake Wolderwijd (2700 ha) although their fishing was conducted during ice-free winter months. Large catches of small roach (< 14 cm) were caught in Lake Wolderwijd particularly in winter when roach aggregated. The average catch was 459 kg ha^{-1} calculated for the eventual fishing area of Lake Wolderwijd (Table 3). In the Paimelanlahti Basin, the catch per fishing area (about 30–40 ha) was slightly over 400 kg ha^{-1} in 1993 and 550 kg ha^{-1} in 1994. This is good evidence of the intensive aggregation of cyprinids in winter. Also the observation that the length of the seine haul did not affect the amount of the catch emphasizes the tendency of fish to aggregate in winter. This was the reason why the prelocation of schools was considered necessary

Table 3
The winter seining catch in shallow Paimelanlahti Basin of Lake Vesijärvi (under-ice seine fishing, seine length 280 m) in comparison to the catch in Lake Wolderwijd (open water seine fishing, seine length 180 m; Backx and Grimm, 1994)

	Paimelanlahti Basin (1993)	Paimela Basin (1994)	Lake Wolderwijd (1991)
Number of fishing days	8	8	61
Fishing area (ha)	30	40	142
Catch (kg)	16550	16500	65182
-kg per fishing area (ha)	552	413	459
-kg per day	2069	2063	1086
-kg per man-hour	61	98	38

both in Lake Wolderwijd and in Lake Vesijärvi. Presnyakov and Borisenko (1993) reported that under-ice fish schools moved gradually throughout the day (see also Pavlov et al., 1986). In Paimelanlahti Basin, schools also tended to move about erratically, so their prelocation was always necessary for a good seining result.

The catch per day was higher in the Paimelanlahti Basin than in Lake Wolderwijd. This was apparently partly due to the shorter fishing period and a consequent lack of decline in the unit catches. The catch per man-hour was 61 kg in 1993 and 98 kg in 1994 in the Paimelanlahti Basin, compared with 38 kg in Lake Wolderwijd in March 1991. The shorter fishing period in Paimelanlahti Basin and the use of a larger seine partly explained the differences between catch rates. Also the smaller need for man-power of the modernized winter-seine (a crew of two men) must have contributed to the difference in catch per man-hour.

Acknowledgements

We owe special thanks to the seining crew, Keijo Kilponen, Kari Kinnunen and Veikko Nevala, for their valuable technical assistance during the experiments. J. Kaalikoski, R. Niittyviita and P. Savola participated in the field work and sample processing. Thanks for developing the new weighting method for the seine as well as other seining gear goes to Veikko Nevala. We also thank the City of Lahti and Uusimaa Regional Environment Centre for providing funding and other necessary resources for this study. We would like to express our thanks to Stellan F. Hamrin for his pre-examination of the manuscript.

References

Amundsen, P.-A., 1988. Effects of an intensive fishing programme on age structure, growth, and parasite infection of stunted whitefish (*Coregonus lavaretus* L. s.l.) in Lake Stuorajavri, northern Norway. Finnish Fish. Res., 9: 425–434.

Andersson, G., Berggren, H., Cronberg, G. and Gelin, C., 1978. Effect of planktivorous and benthivorous fish on organism and water chemistry in eutrophic lakes. Hydrobiol., 59: 9–15.

Backx, J.J.G.M. and Grimm, M.P., 1994. Mass removal of fish from Lake Wolderwijd, The Netherlands. Part II: Implementation phase. In: I.G. Cowx (Editor). Rehabilition of Freshwater Fisheries. Fishing News Books, Oxford, pp. 401–414.

Barthelmes, D., 1994. Impact of intensive fishing pressure on fish populations in lakes of Eastern Germany. In: I.G. Cowx (Editor). Rehabilition of Freshwater Fisheries. Fishing News Books, Oxford, pp. 69–76.

Brabrand, Å., Faafeng, B. and Nilssen, J.P.M., 1990. Relative importance of phosphorous supply to phytoplankton production: fish excretion versus external nutrient loading. Can. J. Fish. Aquat. Sci., 47: 364–372.

Hamrin, S.F., 1993. Lake restoration by cyprinid control in Sätofta bay (Lake Ringesjön). Verh. Internat. Verein. Limnol., 25: 487–493.

Healey, M.C., 1980. Growth and recruitment in experimentally exploited lake whitefish (*Coregous clupeaformis*) populations. Can. J. Fish. Aquat. Sci., 37: 255–267.

Horppila, J. and Kairesalo, T., 1990. A fading recovery: the role of roach (*Rutilus rutilus* L.) in maintaining high algal productivity and biomass in Lake Vesijärvi, southern Finland. Hydrobiol., 200/201: 153–165.

Horppila, J. and Peltonen, H., 1994. The fate of roach *Rutilus rutilus* (L.) stock under an extremely strong fishing pressure and its predicted development after the cessation of mass removal. J. Fish. Biol., 45: 777–786.

Horppila, J., Malinen, T. and Peltonen, H., 1996. Density and habitat shifts of a roach *Rutilus rutilus* (L.) stock assessed with one season by cohort analysis, depletion methods and echosounding. Fish. Res., 28: 151–161.

Hrbacek, J., Dvorakova, M., Korinek, V. and Prochakova, L., 1961. Demostration of the effect of fish stock on the composition of zooplankton and their intensity of metabolism of the whole planktonic association. Verh. Int. Ver. Limnol., 14: 192–195.

Jurvelius, J. and Sammalkorpi, I., 1995. Hyrdoacustic monitoring of the distribution, density and the mass-removal of pelagic fish in a eutrophic lake. Hydrobiol., 316: 33–41.

Keto, J., 1982. The recovery of Lake Vesijärvi after sewage diversion. Hydrobiol., 86: 195–199.

Keto, J. and Sammalkorpi, I., 1988. A fading recovery: A conceptual model for Lake Vesijärvi management and research. Aqua Fenn., 18 (2): 193–204.

Leach, J.H., Johnson, M.G., Kelso, J.R.M., Hartmann, J., Nümann, W. and Entz, B., 1977. Responses of percid fishes and their habitats to eutophication. J. Fish. Resh. Board Can., 34: 1964–1971.

Miller, R.B., 1947. The effects of different intensities of fishing on the whitefish populations of two Alberta lakes. J. Wildl. Manage., 11: 289–301.

Pavlov, D.S., Gusar, A.G., Pyanov, A.I. and Gorin, A.N., 1986. The results of hydroacustic observations on roach in Lake Glubokoe in winter. Hydrobiol., 141: 125–132.

Peltonen, H. and Horppila, J., 1992. The effects of mass removal on the roach *Rutilus rutilus* (L.) stock of Lake Vesijärvi estimated with VPA within one season. J. Fish. Biol., 40: 293–301.

Persson, L., Andersson, G., Hamrin, S.F. and Johansson, L., 1988. Predator regulation and primary production along the productivity gradient of temperate lake ecosystems. In: S.R. Carpenter (Editor). Complex Interactions in Lake Communities. Springer-Verlag, New York, pp. 45–65.

Presnyakov, V.V. and Borisenko, E.S., 1993. The study of fish behaviour under ice of Lake Glubokoe by means of scanning sonar. Fish. Res., 15: 323–329.

Reinertsen, H. and Olsen, Y., 1984. Effect of fish elimination on the phytoplankton community of a eutrophic lake. Verh. Int. Ver. Limnol., 22: 649–657.

Shapiro, J., 1990. Biomanipulation: the next phase—making it stable. Hydrobiol., 200/201: 13–27.

Stenson, J.A.E., Bohlin, T., Henrikson, L., Nilsson, B.I., Nyman, H.G., Oscarson, H.G. and Larsson, P., 1978. Effects of fish removal from a small lake. Verh. Int. Ver. Limnol., 20: 794–801.

Salmi, P. and Huusko, A., 1995. Vendace (*Coregonus albula* (L.)) winter seine fishing in the Kuusamo area, northern Finland, with implications on stock dynamics. Arch. Hydrobiol. Spec. Issues Advanc. Limnol., 46: 369–377.

Straskraba, M., 1965. The effect of fish on the number of invertebrates in ponds and streams. Mitt. Int. Ver. Limnol., 13: 106–127.

Søndergaard, M., Jeppsen, E., Mortensen, E., Dall, E., Kristensen, P. and Sortkjæ, O., 1990. Phytoplanton biomass reduction on a shallow, eutropic lake: a combined effect of reduced internal P-loading and increased zooplankton grazing. Hydrobiol., 200/201: 229–240.

Svärdson, G., 1976. Interspecific population dominance in fish communities of Scandinavian lakes. Rep. Inst. Freshwat. Drottningholm, 55: 144–171.

Tuunainen, P. and Tuunainen, A.-L., 1990. Vendace fisheries in Finnish lakes. In: W.L.T. van Densen, B. Steinmetz and R.H. Hughes (Editors). The Management of Freshwater Fisheries. Wageningen, Pudoc, pp. 145–150.