Comparison and development of assessment methods for pelagic fish stocks in northern great lakes.

Final report

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1. Introduction

At the moment, hydro-acoustics is the most important fish stock assessment method not depending on catches or reconstruction from other historical data. The precision of the method is found to be fairly good (Bagenal *& al.*, 1982). Assessment of pelagic fish stocks for research and management purposes is one of the most important practices of hydro-acoustics in Finnish lakes. For more than ten years hydro-acoustics has been the only method used to monitor the pelagic fish-stock in the three largest Swedish lakes. In Norway, the method is used in many lakes both for monitoring and research purposes. In Russia, hydro-acoustics has proved to be almost the only available stock assessment method because the availability of statistics collapsed with the centralised fishery in the beginning of 1990's. Our intention was to undertake an inter-calibration to evaluate the ways hydro-acoustics is used in the four countries.

Vertical beaming is common in acoustic fish stock assessment. However, for technical reasons the downward facing transducer leaves the uppermost *ca.* 5 metres poorly sampled. *E.g.* young coregonids often live in the first metres beyond the surface. Vertical hydro-acoustic stock assessments will thus under-estimate the stock size if there are young fish in the lake (Auvinen & Jurvelius, 1994). Horizontal and up-looking echo-soundings can partly solve this problem (Jurvelius & al., 1996; Trevorrow, 2001; Knudsen & Saegrov, 2001). We tried to assess the amount of under-estimation in echo surveys done with vertical beaming by comparing survey in all three directions.

It is probable that the vessel towing the echo sounder frighten fish from its path. So the acoustic survey might underestimate the density of these fish. Our intention was to study the fish avoidance in relation to the swimming speed and direction of escaping fish.

Hydro-acoustics will provide *e.g.* estimates of fish density per hectare and size distribution of surveyed fish but it gives no information about their species composition. Hence it is necessary to take fish-samples. These samples are most often caught by trawl. Beside different designs there are also differences in the employment of the trawls, for example, one or two boats can be used in towing. In one-boat trawling the route of the trawl is much the same as that of the hauling vessel. In two-boat trawling the route is between the hauling vessels. If the fish in the surface layers avoid the vessels this biases the sampling. We tried to estimate the effect of one and two boat trawling on fish sampling.

Hydro-acoustic data can be processed using different methods and different analysis software. The question is if the end result will be the same. We compared the echo survey results of diverse equipment to estimate the previous and future compatibility of hydro acoustics results in participating countries.

Our intention was (i) to compare the results of diverse echo sounding equipment, (ii) to study stock assessment with vertical, horizontal and up-looking beams, (iii) to compare one- and two-boat hauling, (iv) to study the catchability of trawls and (v) to study the boat avoidance of surveyed fish.

The project "*Comparison and development of assessment methods for pelagic fish stocks in northern great lakes*" was planned to fulfil the task. A project application was made to the Nordic Council of Ministers. The application was accepted in 2001.

Finnish Game and Fisheries Research Institute coordinated the project planned for 2002. The study was carried out in September and a workshop meeting in November 2002.

Scientists that have contributed to this project are Dr. Heikki Auvinen (Finnish Game and Fisheries Research Institute, FGFRI), Eva Bergstrand (Fiskeriverket, Sweden), Dr. Andrei Degtev (Northern Fisheries Research Institute, Russia), Dr. Olof Enderlein (Fiskeriverket, Sweden), Dr. Juha Jurvelius (FGFRI), Dr. Frank Knudsen (Department of fisheries research, Simrad AS, Norway), Dr. Heikki Peltonen (Finnish Environmental Institute), Juha Lilja (University of Jyväskylä, Finland), Timo J. Marjomäki (University of Jyväskylä, Finland), Dr. Torfinn Lindem (University of Oslo, Norway).

Trawl fishing was carried out by Esa Hirvonen (FGFRI), Tauno Nurmio (FGFRI), Raimo Riikonen (FGFRI), Matti Jalkanen (R/V Muikku) and Jukka Kettunen (R/V Muikku). Maija Hyttinen (FGFRI) assisted in fish sampling. Echo surveys and trawl fishing was done with R/V Muikku owned by the Environmental Research Center for South-Savo. In 2-boat hauling a 11 m commercial trawler skippered by Ari Partanen assisted R/V Muikku.

2. Material and methods

2.1. Study area

Echo-sounding and trawling were done *ca.* 5 km south from town Savonlinna in the northern part of Lake Pihlajavesi between September 10th and 13th in 2002 (Fig.1). This is in the central part of Saimaa lake system in south-east Finland. Experiments were done in a deep basin of *ca.* 6x2 km area with a maximum depth of 63 m. They were carried out in areas deeper than 25 m.

Water colour was *ca.* 30 Pt mgl^{-1} in the study area, water temperature was 18 C^o between surface and 13 m depth and 6 C^o near the bottom (Fig. 2). Thermocline was between 13 and 18 metres, and oxygen concentration was high. At noon, darkness began in *ca.* 8 m depth. Sunset was at 19:39 and sunrise at 06:20 o'clock. Day-length was thus *ca.* 13h 30 min.

In September 2002, the pelagic areas of Lake Pihlajavesi had a dense vendace (*Coregonus albula*) stock. Commercial vendace catch from the study area was *ca.* 25 t (20 $kgha^{-1}$) in 2001. No commercial trawling took place in the area during our experiment. Smelt (*Osmerus eperlanus*) is the other abundant species in the pelagic fish community. It has no commercial value.

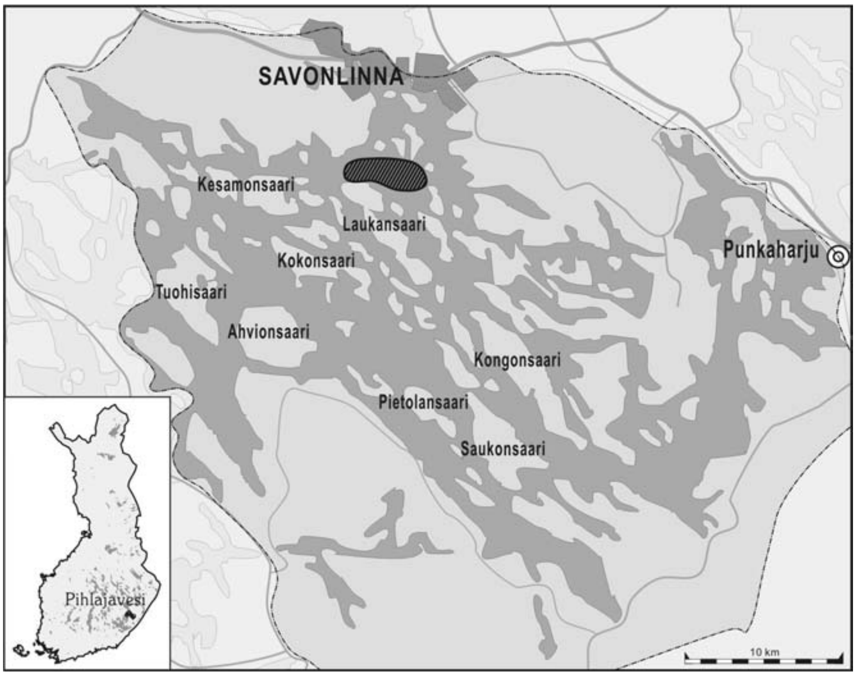


Fig. 1. Map of Lake Pihlajavesi. The study area is rasterized.

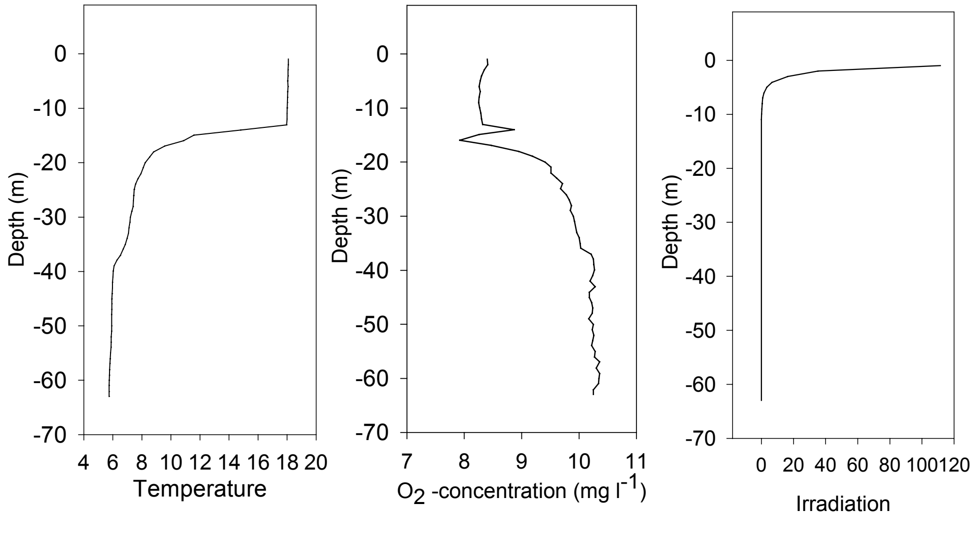


Fig. 2. Temperature, oxygen concentration and light intensity profiles in Lake Pihlajavesi, September 10, 2002 at 11.30 a.m.

2.2. Trawling

Altogether 14 trawl hauls were done (Table 1). The hauls were conducted during daylight, dusk and darkness. One-boat trawling was done with the 27 m long R/V Muikku. In addition to this, a commercial 10 metre-trawler was used in two-boat trawling. Hauling speed was 2 knots.

The 3-storey trawl consisted of three identical parts each 10 m high and 13 m wide. The width of the 700 feet trawl was 37.5 m its height being 15 m. Both trawls had an extra 5 mm bag on the cod end.

Table 1. Trawling and echo sounding in Lake Pihlajavesi in September 10-12, 2002.

				Simrad	Simrad	Simrad	Simrad	High Tech.Inc.		ASKOR
HAUL	START TIME	TRAWL	BOATS	ey500	ey500	ey500	ey-m	Model 243	ASKOR	ey-m
				38 khz	120khz	70khz	70khz	200khz	200khz	70KHZ
1	12:20	3-st	1	x		x		x		
2	13:39	3-st	2	x		x		x		
3	14:45	3-st	2	x		x				
4	15:55	3-st	1	x			x			
5	17:09	3-st	1	x		x			x	
6	19:39	3-st	2	x		x				
7	20:44	3-st	2	x		x			x	
8	21:35	3-st	2	x		x		x		
9	21:54	3-st	2		x	x				
10	23:00	3-st	2		x	x				x
11	0:02	3-st	1				x	x		
12	1:08	3-st	1		x	x			x	
13	21:24	700 ft.	1							
14	22:33	700 ft.	1				x			

2.3. Catch sampling

Catches from each trawl haul and cod end were sorted to species. The number of fish in each species was counted up to 100 individuals. Total weight of each species was recorded. In case the fish number exceeded 100 individuals, a sub-sample of 50 fish was taken. The average weight was used to estimate total numbers of the species. Length of the sampled fish was measured into 5 mm classes.

In a few occasions, the total weight of a mixed catch was recorded, and a sample of *ca.* 150 individuals was taken. The weight proportions of vendace and smelt were used to estimate the total weight per species. This was used to calculate total number of specimens in each species. In large catches 0+ fish were treated as separate species in the sampling procedure.

2.4. Echo-sounding

Echo-sounders were calibrated either before or during the experiment. Echo-sounding was done during every trawl haul. Altogether 7 transducers were installed on R/V Muikku (Table 2). Transducer depth was *ca.* 1 m from the surface. Transducers that had acoustic interference were not used simultaneously.

Table 2. Specifications of the echo sounders used in Lake Pihlajavesi.

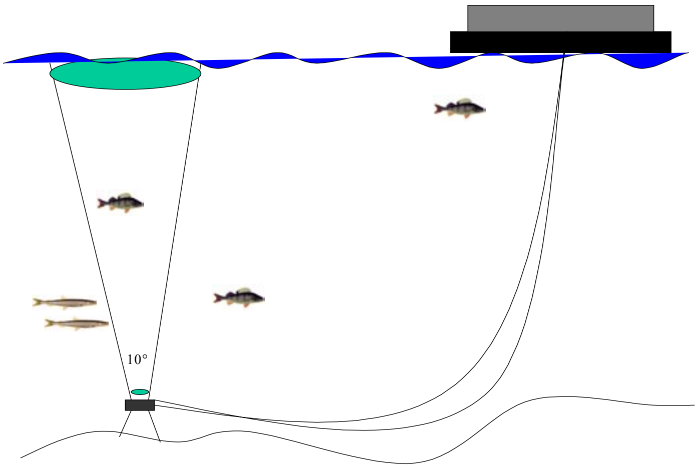
Type	kHz	beamwidth (degrees)	split beam	single beam	pulse length (ms)	ping rate (pulse/s)	vert	horiz	post-processing program	areas of main use
EY500	38	12x12	x		1		x		EP500	Baltic Sea and Saimaa
EY500	120	7x7	x		0,3	2,5	x		EP500	Finnish lakes
EY500	120	2,5x10	x		0,3	2,5		x	EP500	Finnish lakes
EY500	70	11x11		x	0,6	3,3	x		EP500	Vänern, Vettern and Hjälmaren
HTI	200	4x10	x		1,25	5		x		In rivers and small Finnish lakes
Furuno	200	14x14		x	0,4	4,5	x		Askor	Onega, Baikal and Kaspian Sea
Furuno	50	43x43		x	0,4	4,5	x		Askor	Onega, Baikal and Kaspian Sea
EY-M	70	11x11		x	0,6	3	x		Hadas	Finnish lakes

Estimates of fish density and fish TS-distributions were based on vertical soundings only. Swimming speed variations of fish caused by a small echo-survey boat was studied while the engines on the floating research vessel were turned off. The boat (length 8 m) passed the research vessel at noted times. Fish swimming speed was estimated with a Simrad EY500 echo-sounder beaming vertically with one circular transducer (38 kHz) and a HTI Model 243 echo-sounder with two horizontally aimed oval transducers (200 kHz) installed on R/V Muikku.

Mobile horizontal survey was done with one EY500 transducer (120khz) and two transducers (200 khz) of Model 243 installed onboard R/V Muikku into *ca.* 1 m depth. One transducer pointed to the left and the other to the right.

Fish density and swimming speed estimations in the uppermost 2 m depth layer was done with an up-looking transducer (2.5^{o}x10^{o}, 120 kHz) of EY500 in Lake Jyväsjärvi in 2-3.10.2002 (Fig 3.). Depth in the study site was 15 m and the wind speed varied from 1 to *ca.* 10 ms^{-1}. The work was included into a hydro acoustic course in University of Jyväskylä.

Fig. 3. Layout of the echo-sounding with up-looking beam.



2.5. Counting of the results

To facilitate comparisons with size distribution of fish in trawl catches, the analyses of TS distributions concentrate on the water layers where the trawl hauls were made. Fish density (fish ha^{-1}) comparisons between the sounders were based on the results obtained with the software of the equipment.

The measured fish lengths were transformed to acoustic estimates assuming for all species a TS-length dependence $TS=20 \log L - 67$ (Lindem 1983), where L is fish length in cm (mid-point of a length class). The TS-values were classified into 3 dB classes. In the transformation explained above, the influence of the transmitting frequency of the acoustic equipment is not taken into account. The equation of Love (1971) considers the dependence of TS on acoustic frequency of the echo sounder. However, the TS estimates would be *ca.* 0.5 dB larger with a 38 kHz than with a 120 kHz transducer, and therefore it is of minor importance to include operation frequency in these length-TS transformations.

In stationary up-looking survey the trace tracking program of EP500 (vers.5.3) was used. Length, size and swimming direction of all traces registered were analysed by sight to accept a fish trace in each of the 18 study periods 2 h each. Swimming speed estimates were counted only for accepted fish traces.

In boat avoidance studies data was recorded with a Simrad EY500 echo sounder equipped with a vertically aimed ES38-12 circular transducer on board the research vessel. Echoes from single targets in the recorded sonar data were detected with Sonar5's Cross-filter detector. The tracks were first evaluated in a visual test without and afterwards with knowledge of the boat passing times. The results were compared. Fish echoes were then tracked in two classes; one from periods of boat passages and another from periods without boat passages. Swimming statistic were calculated from the tracks in the two classes and compared.

The swept area of the trawl were estimated from the width and towing speed of the trawl. Number of specimens caught divided by the trawl swept area gave an estimate of the fish density *i.e.* catch per swept area (CSA). An index of catchability (q) of the trawls was CSA of ≥ 8 cm long fish (mostly vendace) divided by the echo density estimate of fish with TS $\geq$-51 dB.

3. Results and discussion

3.1. Comparison of hydro-acoustic equipment

3.1.1. Fish TS-distributions

In daylight low fish density together with small sampling volumes in near-surface layers produced large variations in TS-distributions (Table 3). Particularly, the single-beam system needs many single targets for successful application of the Craig-Forbes algorithm. In deep water layers or night transects, the analyses rely on a large number of single targets and therefore, the target strength distributions were more consistent with different equipments. Obviously, random variations could occur also in deeper layers, for example, a small schools detected with one echo sounder but not with another may have produce differences in the fish density estimates between echo sounding systems.

Table 3. Compatibility of TS-frequencies of the echo sounders in Lake Pihlajavesi in 10-12.9.2002. green colour and normal font = compatible, red colour and italics= mismatched.

haul nr.		1	2	3	4	5	6	7	8	9	10	12	14
hauling started		12:20	13:39	14:46	15:56	17:09	19:41	20:47	21:37	21:57	23:02	1:09	22:33
Pair													
EY500 38 - EY500 70		*37,4; 12*	*97,1; 13,4*	*78,2; 13,4*		8,8; 10,6	7,5; 10,6	6,2; 9,2	8,2; 9,2				
EY500 38 - EY-M					*43,7; 14,7*								*14,0; 10,6*
EY500 38 - ASKOR						6,3; 10,6		7,7; 10,6					
EY500 70 - ASKOR						*9,9; 9,2*		*11,0; 9,2*				10,4; 12,0	
EY500 120 - EY500 70										11,3; 12,0	*16,2; 12,0*	7,8; 13,4	
EY500 120 - ASKOR												3,3; 12,0	

The night-time TS distributions with EY500 with 38 (split beam) and 70 kHz (single beam) are compatible. At day there was a big difference between the TS distributions. The split beam EY500 with 120 kHz frequency seem to produce TS-distributions with more small and fewer large fish than the same system equipped with a 70 kHz single beam transducer. However, the compatibility of TS distributions was fairly good in night surveys. Also in the TS distribution with the EY-M, somewhat more targets fall into the small TS-classes than with the 38 kHz EY500. TS-distributions with ASKOR system seem to be in concordance with the distributions from split beam equipments.

The differences in TS-distributions may be partly explained by the complex reflection of sound from fish and the dependence of reflectivity on the frequency of the acoustic. For example, it is known that side lobes arising when a sound beam reflects from a large fish may be detected and interpreted as reflections from a smaller acoustic target. Additionally, there are usually errors in detecting single targets. In acoustic systems, selection against small targets have been observed, and large ones are more easily accepted. It is possible that the split beam 120 kHz system equipped with a narrow-beam transducer was better suited to detect small targets than the other acoustic instruments.

The acoustic TS-distributions were less peaked than the distributions derived with the TS-length dependence equation from the fish length measurement data. Not only fish length but also factors such as fish species, variable tilt angles of fish, swimming motions, physiological state etc. produce both systematic and random variations in TS-length relationship.

In daytime there were almost exclusively small targets, and these transects produced acoustics TS-distributions consisting of scattered peaks. The acoustic TS distributions did not appear to have distinctive patterns though modal values lie in the smallest TS-classes as could be expected from the transformed length frequencies. The fit of the modal values in the transformed length frequencies and in acoustic TS-data seemed to be better in night-time and deeper transects, than in those made at day and in shallow depth layers. The daytime trawl catches mainly consisted of small fish, which were difficult to separate from other acoustic objects. In the deeper transects the modes in TS-distributions and in transformed length data often fell in the same TS-classes. However, there was some indication that in case there were large fishes in a trawl catch, acoustics gave higher TS than could be expected from the catch. On the other hand in case the catches consisted of small fish, the acoustic TS-distributions suggested that even smaller fish could occur. These problems may have risen from trawl selectivity *e.g.* the largest fish could avoid, at least, the smaller 3-storey trawl.

3.1.2. Fish density (fish ha^{-1})

In spite of some discrepancies in fish density estimates, all the echo sounders gave clear differences between the transects with low and high fish density (Fig. 4). The EY500 with 70 kHz single beam produced on average *ca.* 8% higher density estimates than a similar echo sounder with a 38 kHz split beam transducer (Fig. 5). However, in transect 5 the 38 kHz system produced a higher estimate. This exceptional high value was obviously produced by a school that gave higher backscattering with the 38 kHz than with the 70 kHz sounder. This value also strongly influenced the linear regression if the depth layer down to 50 m were analysed. This comparison indicated that the 38 kHz sounder gave *ca.* 20 % higher fish density estimates. But in case this 5 m layer in haul 5 was rejected from the analysis, the 70 kHz sounder produced almost 20 % higher densities. Rejection of this value increased the coefficient of determination from 53% to 83% (Fig. 6). This analysis indicates the sensitivity of comparisons of equipments even when several transects are recorded and compared with two systems.

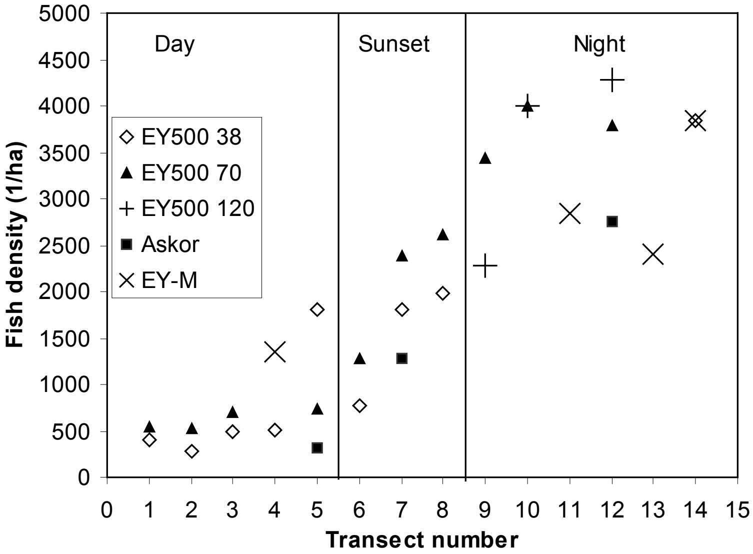


Fig. 4. Fish density (ha^{-1}) estimated with different equipments in transects 1-14. Estimates were made in 5 m layers in depths 5-50 m (with some exceptions with Askor, see text). Minimum TS was -58 with Askor, - 57 dB with EY500 and –56 with EY-M.

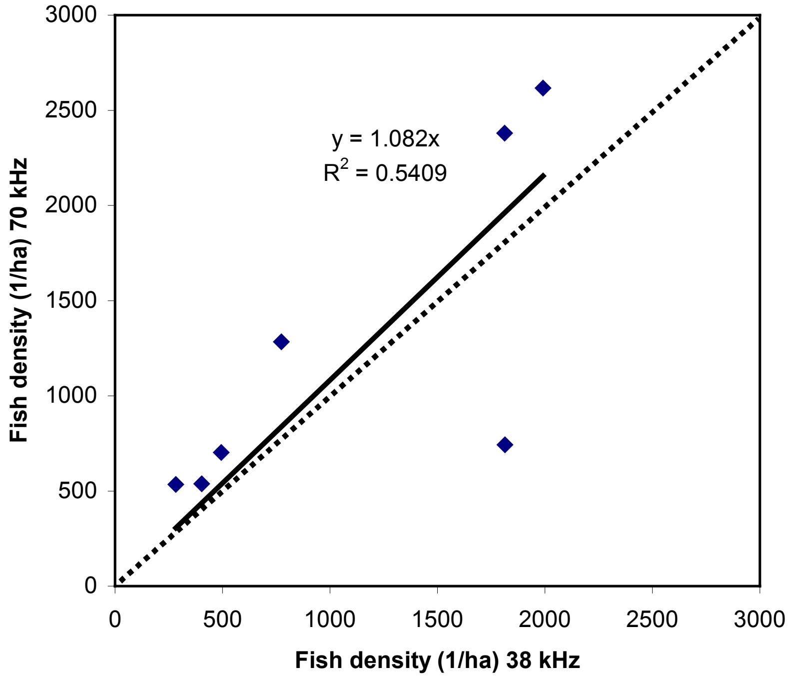


Fig. 5. Fish density (ha^{-1}) with EY500 38 and 70 kHz. Linear regression (intercept set to zero) and the coefficient of determination. Transects 1-3 and 5-8. Estimates in 5 m layers in depths 5-50 m.

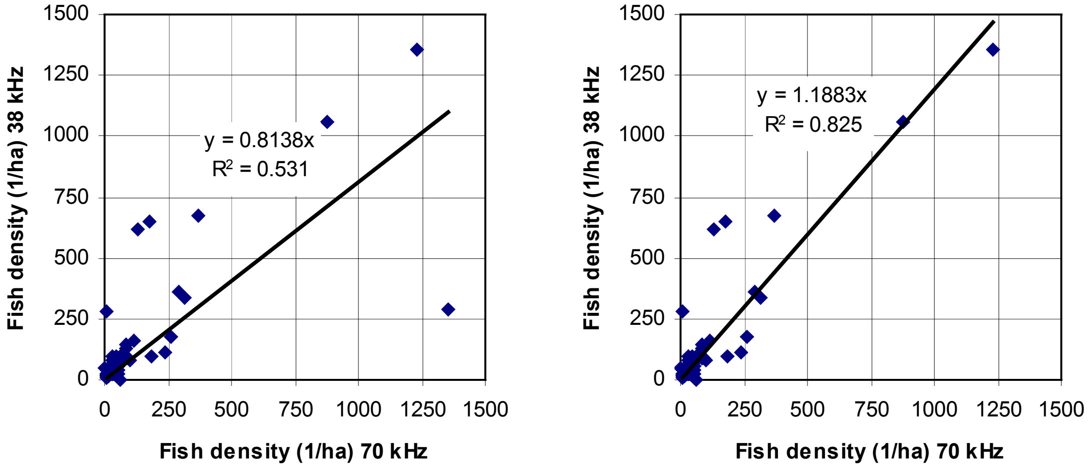


Fig. 6. Dependence of fish density estimates with the 38 and 120 kHz echo sounders. Each point represents a 5 m deep water layer in a transect. Otherwise, the two graphs are made on the same data, but on the right hand side graph one observation from the lower right corner is assumed to be an outlier and it has been rejected.

The EY500 120 kHz system gave on average *ca.* 10 % higher fish density estimates than EY500 70 kHz (Fig. 7). However, the variation between estimates was relatively high producing a low R^2-value. With the 120 kHz system some parts of transects were omitted from the analyses due to noise problems. This may produce some bias in the results if fish density was higher or lower in the omitted than in the analysed areas.

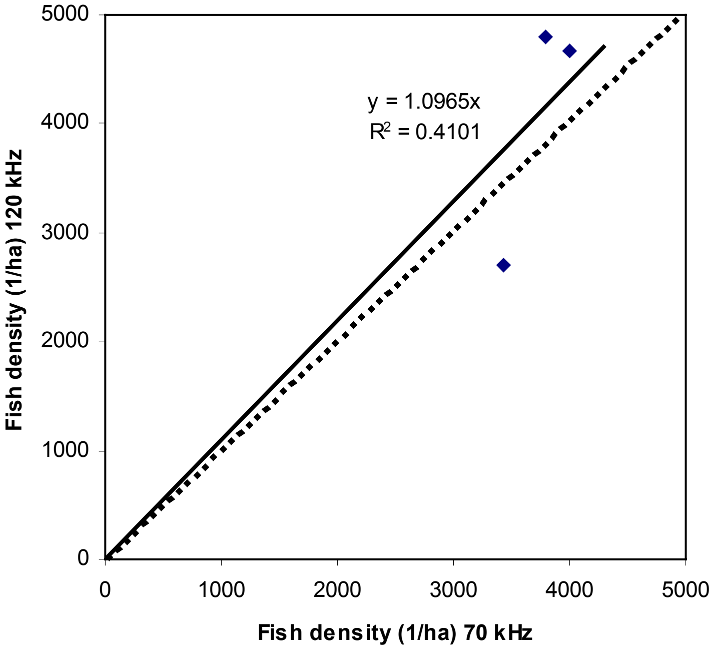


Fig. 7. Fish density (ha^{-1}) with EY500 70 and 120 kHz. Linear regression (intercept set to zero) and the coefficient of determination. Transects 9, 10 and 12.

The ASKOR produced on average lower density estimates than the other systems. The lower estimates may be due to that not enough single target detections for applying C-F-algorithm were obtained in all water layers, and some layers were excluded. The wide beam angle of the echo sounder connected to this device may result in a low number of single targets, because when using a wide beam, it is likely that several vertically overlapping echoes are received from a certain depth. With the available techniques it is impossible to resolve overlapping echoes and to define the TS of the objects. If we do not know the average TS we are not able to derive the fish densities from areal back-scattering strength estimates.

On the other hand, ASKOR accepted somewhat smaller targets (minimum TS -61 dB) than the other systems (min. TS -60 or -58 dB) which should enlarge the fish density estimates made with ASKOR.

3.1.3. Mobile horizontal survey

Noise and reflections from the lake surface made great difficulties in analysing the data in this experiment. Also the number of fish traces found was very low.

Our mobile horizontal survey did not succeed, and other techniques must be taken into consideration when fish stock assessment in the uppermost 5 m is concerned. At the moment, the most reliable way of doing hydro-acoustic stock assessment is while few fish occur in the surface layers.

3.1.4. Stationary up-looking survey

Fish density (fish traces/study period) in 0-2 m depth was lowest at night (Fig. 8). At the same time, the density in 2-15 m depth was at its highest. Speed of the analysed traces varied from 0.03 to 1.59 ms^{-1}, and no statistically significant ($p>0.05$) difference was found between the study periods in this respect.

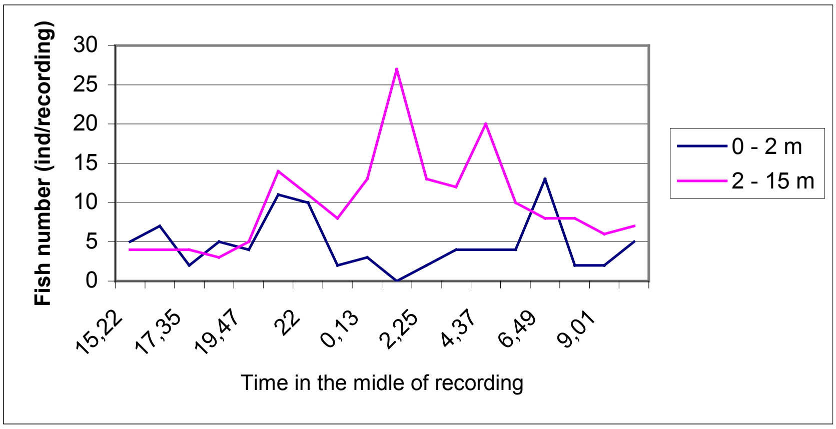


Fig. 8. Effect of the time of day on fish echoes in the up-looking beam echo soundings.

Our results were parallel to the general findings that fish ascend from the bottom during night. Furthermore the results point out that sunset and sunrise may be problematic times in down-looking vertical echo-surveys.

3.1.5. Boat avoidance

From the visual study of the echograms and from the statistical tests based on 441 tracked fish, no change in fish behaviour could be detected when the small boat was passing the research vessel. Because of the low fish density boat avoidance could not be studied in the up-looking sonar experiment. In future, a hydrophone should be used to map the noise level in the study area of boat avoidance of fish.

3.2. Trawl-catches

3.2.1. Vertical distribution and fish lengths

3.2.1.1. *3-storey trawl*
In daytime, surface (0-15 m) hauls, the catch in the uppermost cod-end (0-5 m) consisted entirely of small vendace less than 120 mm in length (Table 4). Along with small vendace, less than 70 mm long smelt was caught in the mid (5-10 m) and more regularly in the lowermost cod-end. The catches from 15-30 m included also larger vendace and smelt. The mean length of smelt increased with the depth of cod-end.

No clear changes in species composition or fish length distribution were detected during the sunset hours. Smelt seemed to ascend faster than vendace to the uppermost 5 m depth layer. The proportion of vendace was highest in the two latest night hauls (Table 4-5). In respect to depth, the proportion of small smelt was highest in the uppermost cod-end (10-15 m) and the proportion of large vendace highest in the lowermost cod-end.

3.2.1.2. *700 feet trawl*
In the surface (0-15 m) the catch comprised mostly of small vendace and smelt. Whereas the catch from 15-30 m depth consisted of higher proportion of larger vendace compared to the surface haul and, furthermore, only a few large smelt.

According to trawling there was species- and length group segregation among the echo-surveyed pelagic fish. Information of this segregation can be utilized in species-specific hydro-acoustic stock assessment of pelagic fish in lakes.

3.2.2. Catch per swept area (CSA)

In daytime surface hauls the CSA of vendace was lowest in the uppermost cod-end and highest in the lowermost (Table 4-5). Below that in 15-30 m in haul 5 the CSA was very low.

During sunset, the CSA was highest in the first haul, the maximum being in 5-10 m layer.

During night, the CSA in the first two hauls (9 and 10) was clearly highest in the lowermost cod-end 20-25 m. However, in the last two hauls it was lowest there, and highest in the middlemost cod-end and rather high in the uppermost cod end. The total CSA was higher in the later two hauls (11, 12) than in the first two.

The CSA of 700 ft trawl was low in comparison to 3-storey trawl.

In daytime surface hauls the CSA of smelt was lowest in the uppermost cod-end and highest in the lowermost (Table 4-5). Below that in 15-30 in haul 5 the CSA was very low. Thus the results resembled very much those of vendace.

As for vendace, the CSA was highest during the sunset in the first haul and in 5-10 m layer.

Contrary to vendace, the total CSA during night was higher in the first two hauls (9 and 10) than in the later two. Also contrary to vendace, the CSA of 700 ft trawl was higher in 0-15 m than in 15-30 m.

Table 4. Vendace catch per trawl swept area in Lake Pihlajavesi in 10-12.9.2002.

HAUL	START TIME	TRAWL	BOATS	CATCH PER SWEPT AREA IN DEPTH LAYER, ind./ha								
				0-5 m	5-10 m	10-15 m	15-20 m	20-25 m	25-30 m	0-15 m	15-30 m	TOTAL
1	12:20	3-st	1	2	7	98						107
2	13:39	3-st	2	2	12	244						258
3	14:45	3-st	2	10	51	773						834
4	15:55	3-st	1	8	84	336						428
5	17:09	3-st	1				7	7	7			22
6	19:39	3-st	2	15	449	31						495
7	20:44	3-st	2	53	35	23						111
8	21:35	3-st	2	5	9	84						98
9	21:54	3-st	2			2	32	791	0	0	0	826
10	23:00	3-st	2			4	12	393	0	0	0	409
11	0:02	3-st	1			296	660	140	0	0	0	1095
12	1:08	3-st	1			404	893	154	0	0	0	1451
13	21:24	700 ft.	1							79		79
14	22:33	700 ft.	1								383	383

Table 5. Smelt catch per trawl swept area in Lake Pihlajavesi in 10-12.9.2002.

HAUL	START TIME	TRAWL	BOATS	CATCH PER SWEPT AREA IN DEPTH LAYER, ind./ha								
				0-5 m	5-10 m	10-15 m	15-20 m	20-25 m	25-30 m	0-15 m	15-30 m	TOTAL
1	12:20	3-st	1	0	1	516						517
2	13:39	3-st	2	0	0	338						338
3	14:45	3-st	2	0	0	337						337
4	15:55	3-st	1	0	128	611						739
5	17:09	3-st	1				17	15	42			75
6	19:39	3-st	2	259	686	15						960
7	20:44	3-st	2	111	28	18						158
8	21:35	3-st	2	7	94	279						379
9	21:54	3-st	2			119	317	228				664
10	23:00	3-st	2			47	76	453				577
11	0:02	3-st	1			322	5	11				338
12	1:08	3-st	1			354	8	6				368
13	21:24	700 ft.	1							222		222
14	22:33	701 ft.	1								21	21

3.2.3. Comparison of one-boat and two-boat trawling

Either in case of smelt or vendace, no evidence for higher CSA in two-boat trawling was found. During the daytime the CSA of vendace did not seem to depend on the number of boats and the CSA of smelt in one boat trawling was even higher than that in two-boat trawling. During night the results for smelt were the opposite and the vendace CSA was higher in one boat trawling. Thus, the exploratory trawling results seemed to be independent of the towing method.

3.3. Catchability (q) of the trawls

During daytime, in hauls 2-4 the q-index was greater than 1. This means greater CSA than the hydro acoustic fish density estimate. It could be due to the fact that fish may stay during the daytime near the surface where vertical echo sounding cannot detect them. Fish may have dived to avoid the trawl as the CSA was highest in the lowermost cod-end. Another possible reason for a higher q than expected from hydro acoustic estimates is that the trawl may actually have fished from a wider area than its own width.

The catchability in haul 5 from deeper (15-30 m) layer was close to 1, as expected. Also in that case it was highest in the deepest cod-end, and this implies to diving of fish in front of the cod-end.

During night, q was typically less than 1 in mid-water trawling (hauls 9-12). The averages for 120 and 70 kHz EY-500 were 0.62 and 0.39, respectively. The catchability did not seem to depend on whether one or two boat towing was applied. However, during daytime the catchability in two-boat trawling seems to be higher than in one-boat trawling.

Table 6. Index of catchability (catch per trawl swept area of fish length > 8 cm/ , density of fish TS> -51 dB) in Lake Pihlajavesi., # = density 0, catch ability indefinable.

HAUL	START TIME	TRAWL	BOATS	ECHO-SOUNDER	INDEX OF CATCHABILITY IN DEPTH LAYER							
					5-10 m	10-15 m	15-20 m	20-25 m	25-30 m	0-15 m	15-30 m	TOTAL
1	12:20	3-st	1	EY-500/38	0,1	0,38						0,21
				EY-500/70	#	0,23						0,37
2	13:39	3-st	2	EY-500/38	#	12,82						13,58
				EY-500/70	0,27	16,24						4,23
3	14:45	3-st	2	EY-500/38	25,5	24,92						25,26
				EY-500/70	#	51,5						55,57
4	15:55	3-st	1	EY-500/38	6,49	5,69						5,94
				EY-M	0,56	2,1						1,37
5	17:09	3-st	1	EY-500/38			0,32	0,85	1,18			0,68
				EY-500/70			0,61	0,69	1,52			0,92
				ASKOR			1,83	1,09	2,31			1,73
6	19:39	3-st	2	EY-500/38	12,84	0,61						4,79
				EY-500/70	2,15	1,21						2,07
7	20:44	3-st	2	EY-500/38	1,46	0,12						0,52
				EY-500/70	1,4	0,08						0,36
				ASKOR	2,33	0,25						1,05
8	21:35	3-st	2	EY-500/38	0,45	1,18						1,07
				EY-500/70	0,59	0,33						0,35
9	21:54	3-st	2	EY-500/120		0,02	0,04	3,73				0,82
	23:00			EY-500/70		0,01	0,02	2,24				0,4
10	23:00	3-st	2	EY-500/120		0,04	0,01	1,27				0,23
				EY-500/70		0,01	0,01	1,19				0,17
11	0:02	3-st	1	EY-M		3,95	0,68	0,54				0,85
12	1:08	3-st	1	EY-500/120		1,76	0,83	0,32				0,82
				EY-500/70		1,31	0,51	0,45				0,61
				ASKOR		4,3	0,78	0,76				1,04
13	21:24	700 ft	1	ASKOR						0,39		0,39
				EY-M						3,15		3,15
14	22:33	700 ft	1	EY-500/38							0,13	0,13
				EY-M							0,19	0,19

4. Conclusions

(i). Hydro-acoustic stock estimations done with diverse equipment were in accordance.
(ii). Up-looking echo-survey seemed to be more promising in stock estimates than horizontal survey. However, another try would be done before abandoning horizontal surveying.
(iii). There was no difference in the catches between one-boat and two-boat trawling methods.
(iv). Night-hauling in mid-water depth layers was best suitable for estimation of trawl catchability.
(v). Results on boat avoidance of fish remained unreliable; hence the experiment should be repeated with somewhat modified design.
(vi). Night surveys are best suited for hydro-acoustic stock assessment, and sunset and sunrise should be avoided.
(vii). The comparison of hydro acoustic and 3-storey trawling showed that fish dive after the research vessel or/and before the trawl.
(viii). Working together is a good procedure to build up functioning networks between researches in various countries.

5. Plan for scientific publication

The research group plans to make several scientific publications based on the collected data. These include, for instance, following:
(i). Fish density and fish length estimates with diverse echo sounding systems and trawling.
(ii). Catchability of experimental trawling.
(iii). Why hydro acoustic and trawling estimates for fish density and fish lengths are unequal?
(iv). Boat avoidance of fish and hydro acoustic stock assessment (more data needed).

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