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Migratory behaviour of cultured Atlantic salmon smolts released during day or night

by

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Abstract

Within the framework of a large-scale sea ranching programme (PUSH; Programme for Encouragement of Sea Ranching), 55000 smolts, 1st generation offspring of wild parents from three regional rivers, were released in groups (5-7000 individuals) during day and night. The releases were carried out between 24 May and 13 June from net pens in a small marine bay on the west coast of the Sotra Island, SW-Norway. The day and night releases were surveyed by a Simrad EK echo sounder with a horizontally mounted transducer and divers. During the daytime releases, the smolts left the bay rapidly. Fast migrating schools were observed. The migration out of the bay was slower during night releases, 5-9 hours, and the smolts was more loosely organised. The migration in the sea therefore seem to be faster during daytime when the smolts school. The change in behaviour from day to night is similar to that of several other pelagic species.

Introduction

Atlantic salmon has developed a variety of behavioural adaptations enabling it to adapt to both the freshwater and the open sea environment. In the river, there are relatively few other species, and intra specific competition for the resources (Symons 1971). When leaving the river, there is a change from individual aggressive behaviour to schooling behaviour (Gibson, 1983, Bakshtanskiy et al. 1988). The transition from a fresh- to a seawater adapted fish has encouraged a large scientific effort, especially concerning the physiological smoltification process of cultured salmon. While the osmotic adjustments during seawater transfer has been described in a high number of papers, our knowledge on the change in behaviour after seawater entry of wild and released smolts is less known.

In release experiments, monitoring of the behaviour of the smolts in the release area may be important for evaluation and improvement of the release methods (Skilbrei et al. 1994*a,b*). Such studies are difficult to perform, because of the large water volumes to be surveyed. Hydroacoustic tagging may be use to follow single fish, but then information on the behaviour of groups of fishes will be lacking. This study reports an attempt to study the post-release behaviour of smolts in the sea by applying echo sounder technique. The fish were released during day- or night time to see whether the migratory behaviour changed during the day - night cycle.

Materials and Methods

The fish released in the experiments were 1+ smolts descending from wild parents caught in the regional rivers Vosso, Loneelv and Dale. During late winter 1990 yolk sac fry were transferred to the Selstø hatchery in the immediate vicinity of the release area. In addition, fry from a cultured strain were included. The fish were raised according to standard fish farming practices. However, due to genetic considerations, the family groups were kept separated in 1 x 1 m tanks until the fish were large enough to be adipose fin-clipped. Then groups were united two and two and transferred to outdoor cylindrical 5-7 m diameter tanks.

In April - May three release groups were set up by mixing the offspring of the different groups, and a fourth group consisted of the cultured strain. At various dates, the fish were transferred to and released from net pens in the Selstø Bay (see Table 1 for details). The Selstø Bay is located close to open sea at the western coast of Norway (Fig. 1). The salinity at 0.1 m depth was around 32 ‰. The fish were released at or just before high tide.

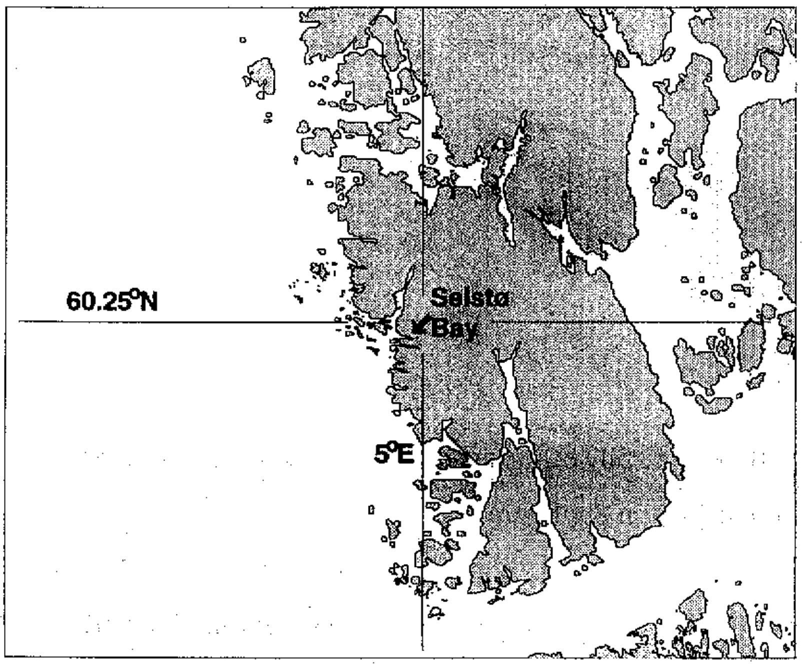

Figure 1. Location of the Selstø Bay in western Norway.

The tidal forces in the area are relatively weak; with a maximum difference of between low and high tide of approximately 0.9 m. Due to a of combination of the Norwegian coastal current pressing the water inwards in the small fjords, the prevailing winds and the tidal forces, the predominant current pattern in the Selstø bay was an ingoing surface current on the south side and an outgoing surface current on the north side. The sea temperature at 1 m depth was 8.2° C during the first releases (24 - 28 May), rising to 11° C during the last release (14 June).

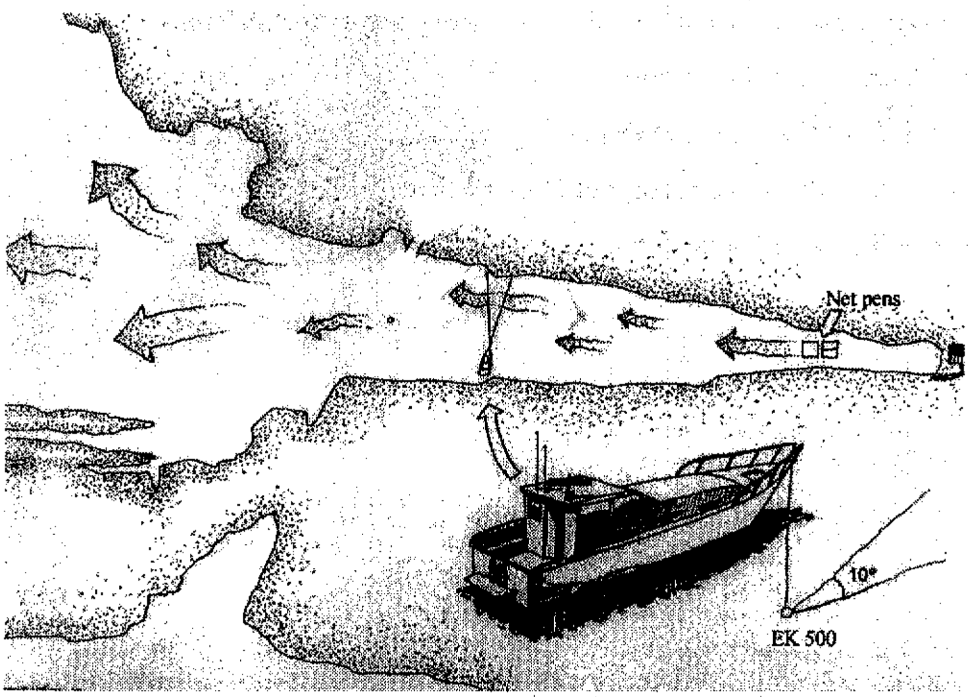

Fig 2. Location of the boat equipped with the EK-500 echo sounder and of the net pens in the Selstø Bay. The hatchery is indicated to the right in the figure.

Table 1: Dates for transfer to net pens in the sea, dates and time for releases and number and origin of fish where W=offspring from wild and C=offspring from cultured parents.

Release group	Transfer date	Release date	Release time	Origin	Number
1	15.05	24.05	22:45	W	8000
2	16.05	27.05	10:00	W	8000
3	27.05	28.05	10:00	W	5000
4	07.06	14.06	24:10	C	10000

During the releases, the fish behaviour in the inner part of the bay, and in the vicinity of the net pens, was observed by divers with underwater video-equipment. Further out in the bay, the fish were acoustically observed from a boatl anchored close to the southern side of the bay. The boat was equiped with an EK-500 split beam echo sounder connected to a 120 kHz transducer on the bow of the boat (Fig. 2). The acoustic beam was oriented horizontally along the surface across the bay with an opening of 10°.

Using a ping rate of about 4 s^{-1}, the individual smolts passing the beam could be detected repeatedly at moderate swimming speeds. The echo trace data telegrams of the split beam echo sounder were logged over serial line to a portable PC and Target Tracking software (Ona & Hansen 1991). Individual tracks were counted in time blocks from the echogram output and the approximate size of schools passing were estimated from the integrator output on schools and individual fish.

Results

The divers reported that the fish left the net pens rapidly after release, but the migration out of the bay was substantial faster when the smolts were released during daytime. After the daytime releases (release time 10:00 and 11:00) must of the smolts passing the echo beam were registered during the first hour after release (Fig. 3 and 4). However, on May 28, there is a delay of several hours before the last part of the smolts passed the echo transducer. This may be due to a gasoline generator placed on a raft between the EK 500 monitoring point and the net pens. The generator was erroneously switched on to power video equipment during this release. When it was turned off, the fish started to pass the echo beam.

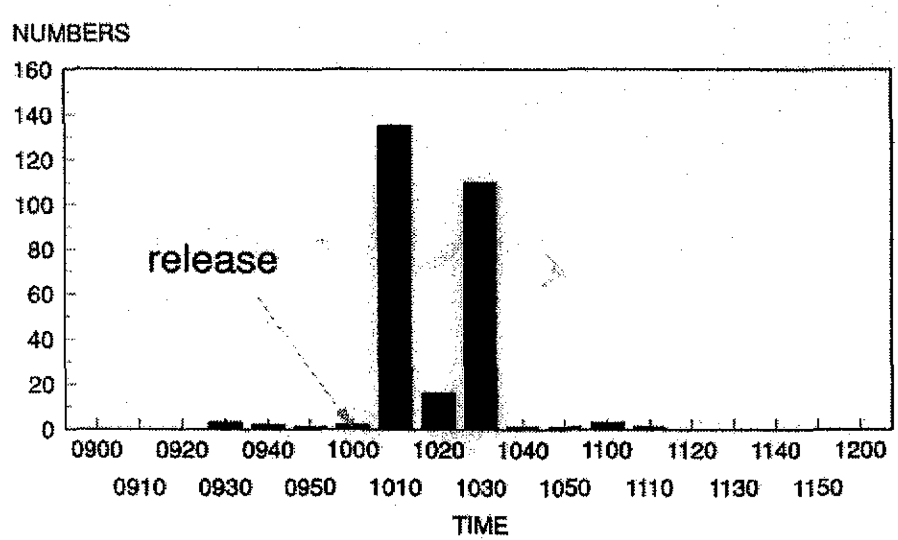

Figure 3. Number of smolts passing the echo beam during day-time release on May 27.

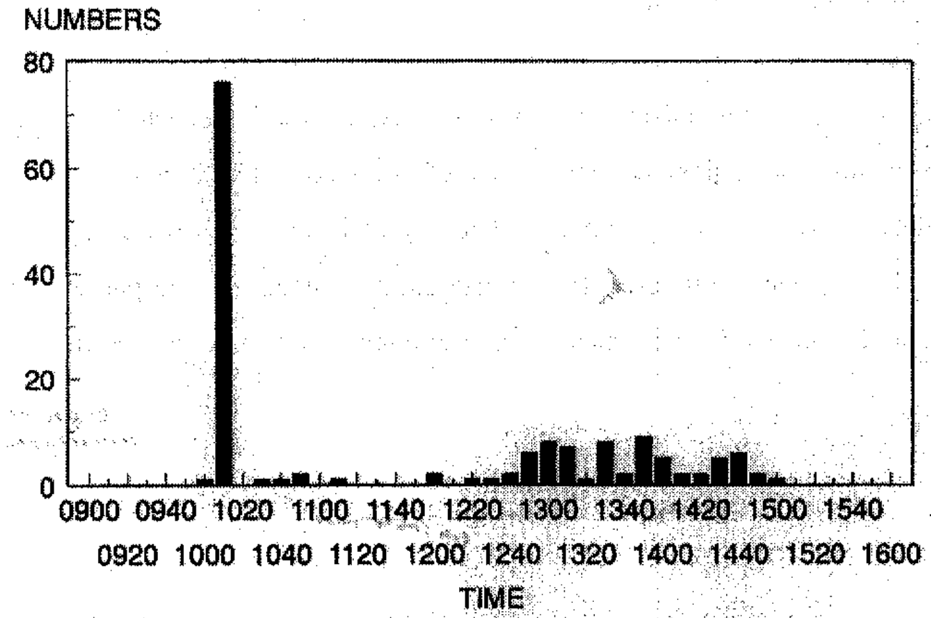

Figure 4. Number of smolts passing the echo beam during day-time release on May 28.

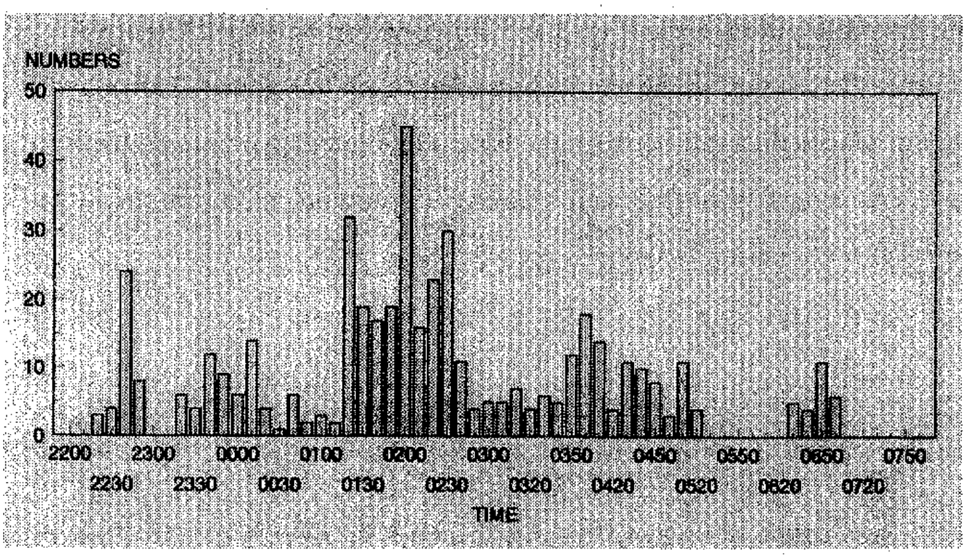

Figure 5. Number of smolts passing the echo beam during night-time release on May 24.

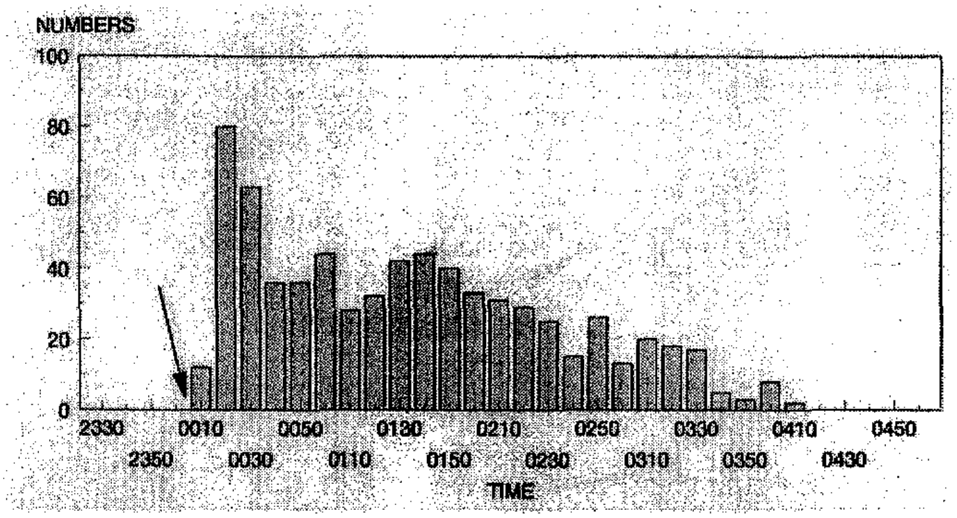

Figure 6. Number of smolts passing the echo beam during night-time release on June 14

After the night releases, fish were crossing the beam of the echo transducer for 4-8 h after releases, and were roughly evenly distributed with time during these periods (Fig. 5 and 6).

The smolts migrating rapidly out of the during daytime were frequently observed in small, dense schools. An example is shown in Figure 7, showing a school of approximately 102 individuals on May 27 at 10:35, i.e. within a half our after release. For comparison, detection of approximately 30 individuals on May 25, at 01.56, three hours after release, show that these fish were more loosely organised, and that each individual used a longer time to pass the echo beam making the overall picture more noisy (Fig. 8). However, some schools were observed after night releases. Within the first 10 min after the release on June 14, three distinct schools of approx. 20 individuals each were spotted (Fig. 9). Individual fish swimming more slowly, and therefore targeted by a greater number of pings typical of the night releases, are also visible on the echo diagram as longer strings (Fig. 9).

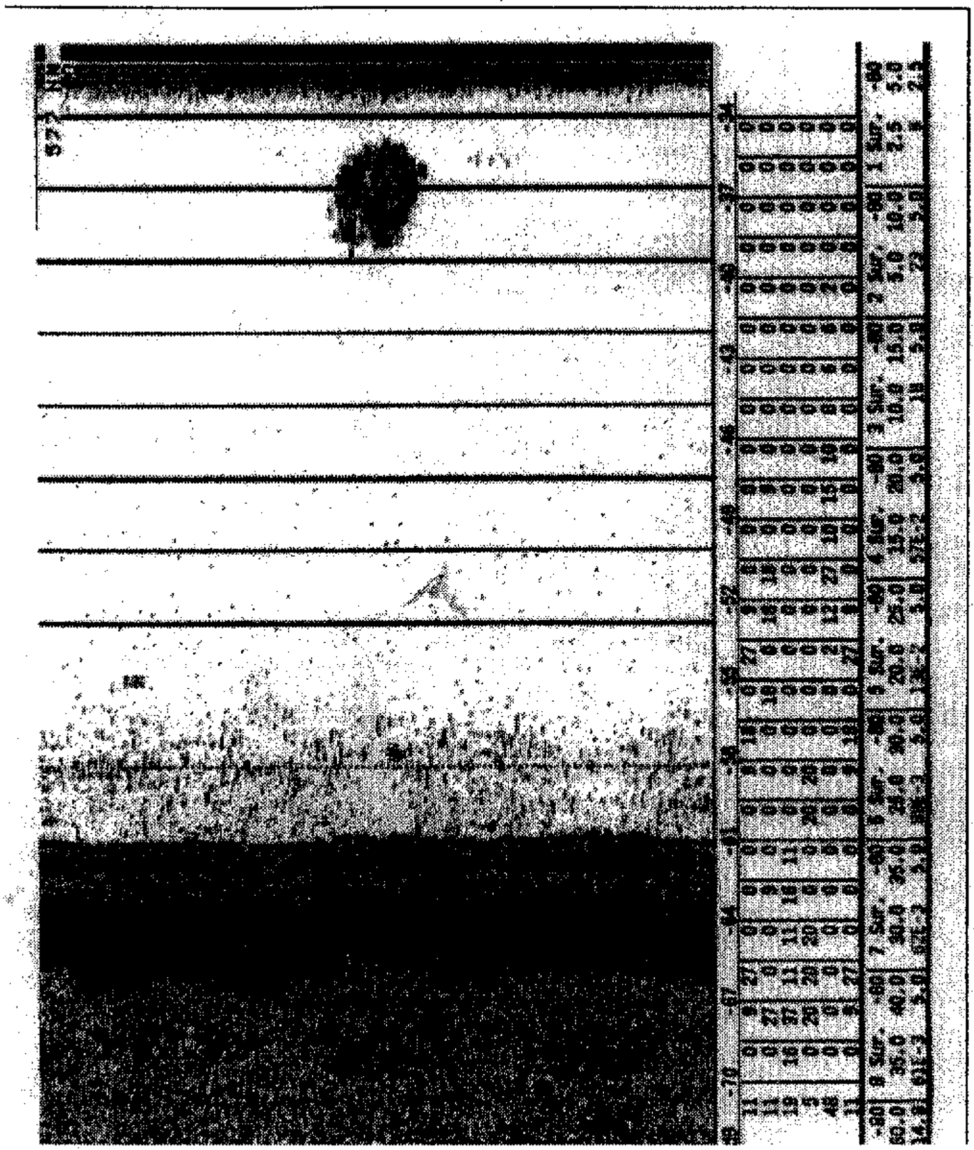

Fig. 7. Echogram showing the passing of a school of calculated to 102 individuals swimming of approx. 3 body lengths s^{-1}

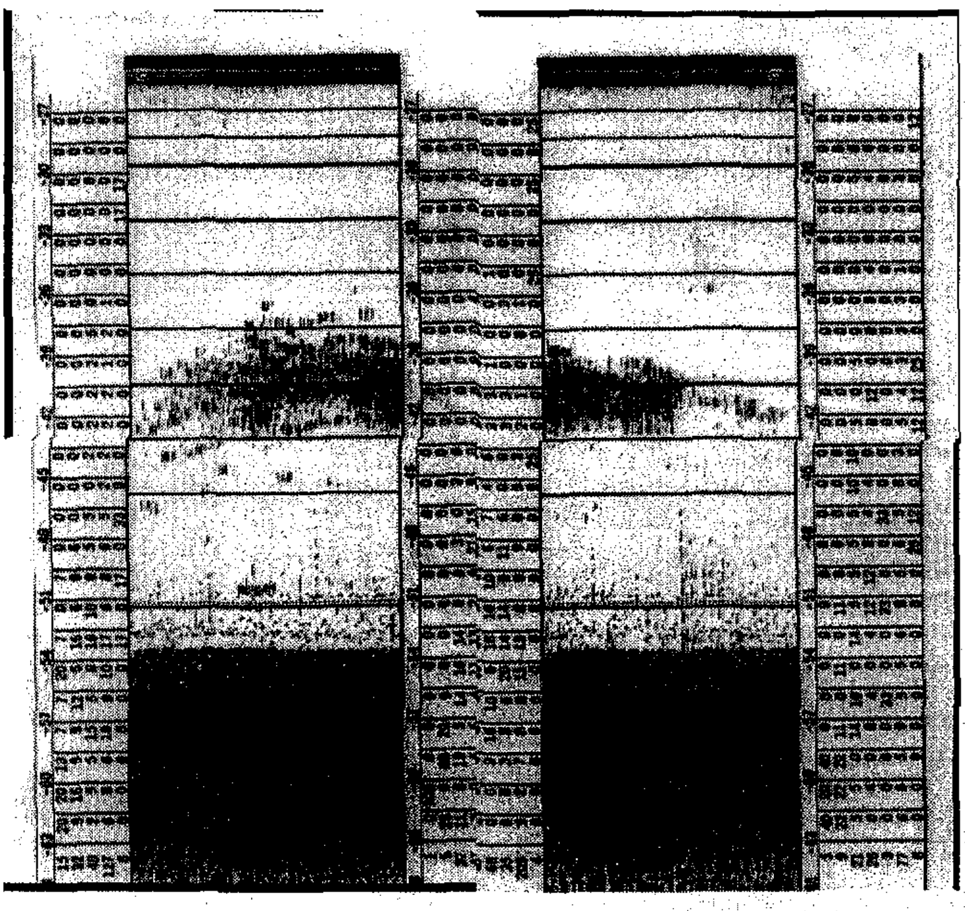

Fig. 8. A group of 30 individuals passing the echo beam at appr. 1 body length s^{-1} after night-time release on May 25 01:55.

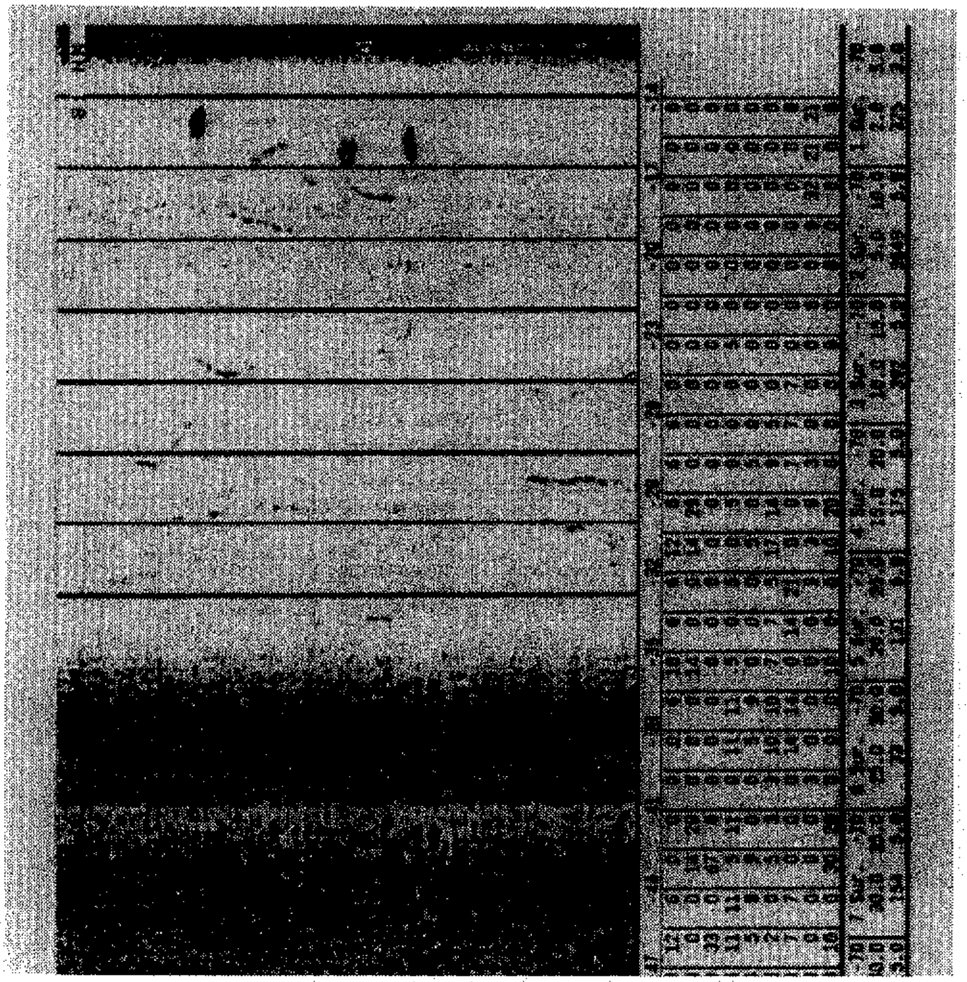

Fig 9. Fish passing the echo beam within the first 10 minutes after the night-time release on June 14. Three schools containing approx. 60 in sum is seen in the upper part of the figure. In addition, there are 9 individual tracks.

Discussion

Due to the small angle of the echo beam only a small part of the smolts were detected when passing the beam. It is therefore uncertain if these fish are representative for the different release groups. However, the demonstration of the basic behavioural patterns, to swim rapidly in a school or to prolong the stay in the release area in less organised shoals or as individuals spread over an area, probably reflect a change in behaviour during the day and night cycle. During the two consecutive years all smolts were released from the net pens during daytime. The clear tendency of the smolts to leave the bay within a short time interval and also the formation of rapidly migrating schools were observed repeatedly, although smolt size and the date of release also influenced the migration motivation (Skilbrei et al., 1994*a,b*). In the present study the acclimatisation period differed between the releases. The duration of acclimatisation period had a relatively small influence on the migratory behaviour in the consecutive years, at least when 3 and 7 days were compared (Skilbrei et al. 1994*b*). A change in behaviour from day to night was also observed by Holm et al (1984) in a study tracking ultrasonic tagged cultured smolts. The migrating smolt stayed closer to surface during night hours, and the repeated diving activity seen during daytime was reduced or absent during dark hours.

Assuming that the present results show a general trend of seaward migrating smolts to change behaviour according to the day/night cycle, then possible explanations may be related to feeding, migratory behaviour and/or prey-predator interactions. Prey-predator interactions are strongly influenced by light intensity (Hobson 1978). Several marine species stay close to the surface during night, and decrease the risk of predation during daytime by moving to greater depth and/or by schooling (Tricas 1979). Fish in groups generally spend more time to search for and consume prey and use less time for to recognise and escape predators than single individuals (Pitcher 1986).

In the release area, most predated smolts have been found in the stomachs of pollack (P. *pollachius*) (unpublished data). Fish predators are surely a danger for the smolts in the marine environment, and additionally, avian predation has been demonstrated for salmon smolts (Reitan et al. 1987, Kennedy and Greer 1988). The seagulls are active during daytime and may represent a serious threat for fish staying close to surface. As it is assumed that salmon migrate in the upper water column (Holm et al. 1982; 1984), the change in behaviour between day and night may also reflect adaptations to minimise the total predatory risk from both fish and avian predators. According to Litvak (1993) shoaling fish may change school structure due to avian attacks.

The schooling behaviour and increased migration speed during daytime may also be a functional aspect of orientation and migration of salmonids. According to Dodson (1988) salmon may use sun compass during migration, and schooling is commonly observed for long distance migrators (Ovchinnikov 1986). Recapture rates have been increased by releasing smolts into shoals of wild smolts (Hvidsten et al. 1993). The distance from Norwegian salmon rivers to the ocean feeding areas (in the northern Norwegian Sea) may be 2000 kilometres. The migratory, antipredator and feeding behaviour of the young salmon must necessarily be a result of evolutionary mechanisms enabling fish survival.. The present study does not explain the mechanisms for the observed changes in behaviour from day to night, but points to similarities between our results and general behaviour of marine species. Although the study was performed with cultured smolts, the differential response of the smolts to the new environment according to the time of the day probably indicate an inherent adaptability of salmon when migrating from a freshwater ecosystem into open sea. The use of EK-500 with a horizontally mounted transducer proved to be a valuable aid to monitor undisturbed migratory behaviour of groups of smolts. Although the volume covered in this study with only one single transducer was relatively limited, it would be possible to cover a substantially larger area by using several transducers or a scanner.

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