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THE USE OF TRANSPLANTATION-TAGGING-EXPERIMENTS IN STUDIES OF MIGRATORY DIVERSITY OF COD OFF NORWAY.

by

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ABSTRACT

Cod along the Norwegian coast show great variability in migration. Coastal Cod may be stationary for the whole life while mature Northeast Arctic Cod migrate long distances to reach the feeding areas in the Barents Sea and the spawning areas along the Norwegian coast.

In this paper migratory differences and possible mechanisms behind them are studied by transplanting the two types of cod to new locations and study their behaviour after release. Individual behaviour is examined by logging information from acoustic transmitters attached to the fish giving continuous data on position and depth. The data, although limited, show clear differences in migratory restlessness in Coastal Cod and Northeast Arctic Cod; the first showing a territorial behaviour compared to a more active and determined migration for the second, particularly in winter time. The use of low frequency noise from oceanic waves is suggested to be a possible navigation stimulus for Northeast Arctic Cod to find back to oceanic waters.

INTRODUCTION

Cod off the Norwegian coast are split into Coastal Cod (CC) living the whole life close to the coast, and Northeast Arctic Cod (NAC) with spawning grounds in Norwegian coastal areas and feeding areas in the Barents Sea - Svalbard region. The two types of cod represent extreme differences with respect to migratory activity (Godø 1984a). In contrast to the apparent territo-

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rial behaviour of CC in some areas, NAC may perform yearly spawning migrations equal to the distance from Bergen, Norway to Vigo, Spain and return. In addition, after the extremely long migration of NAC, the fish are apparently capable of returning to previously visited spawning grounds with high precision (Godø 1984b). The understanding of the difference between CC and NAC is made even more complex by the variable migratory tendency among CC from various areas.

This paper studies the possibility and potential of using transplantation - tagging experiments in studying migratory diversity of cod in Norwegian waters, and gives some results from initial trials.

MATERIAL AND METHODS

Three transplantation - tagging experiments were carried out, two in the Fanafjord (south western Norway) and one in the Ramfjord (northern Norway) (Fig. 1). Duration of the experimental cruises was from 7 to 10 days. Both acoustic transmitter tags and conventional tags were used, and the numbers of CC and NAC released in the different experiments are shown in Table 1. The conventional tags were of the Lea type attached in front of the first dorsal fin (ANON 1953). The acoustic tags were produced by VEMCO and transmitted at frequencies between 50 and 77 KHz. The tags were attached with nylon strings between first and second dorsal fins. The position of a fish was automatically recorded when tag remained within reach of a triangle of hydrophone buoys located at 400 m - 600 m distance. When outside the range of the buoy system, the fish were tracked by a manually operated directive hydrophone lowered from a small vessel. The signals from the tagged fish were coded for depth information, and, hence, simultaneous data on position and depth were recorded when the tag remained within reach of the buoy system or the hand set hydrophone.

The fish in the 1992 experiment consisted of NAC caught in beginning of October 1992 by R/V G. O. Sars and the brought directly to Bergen. The CC were caught about the same time at Øygarden outside Bergen and transferred to the tank in Bergen. Both type of cod were kept together in the same tank until the experiment start on December 1.

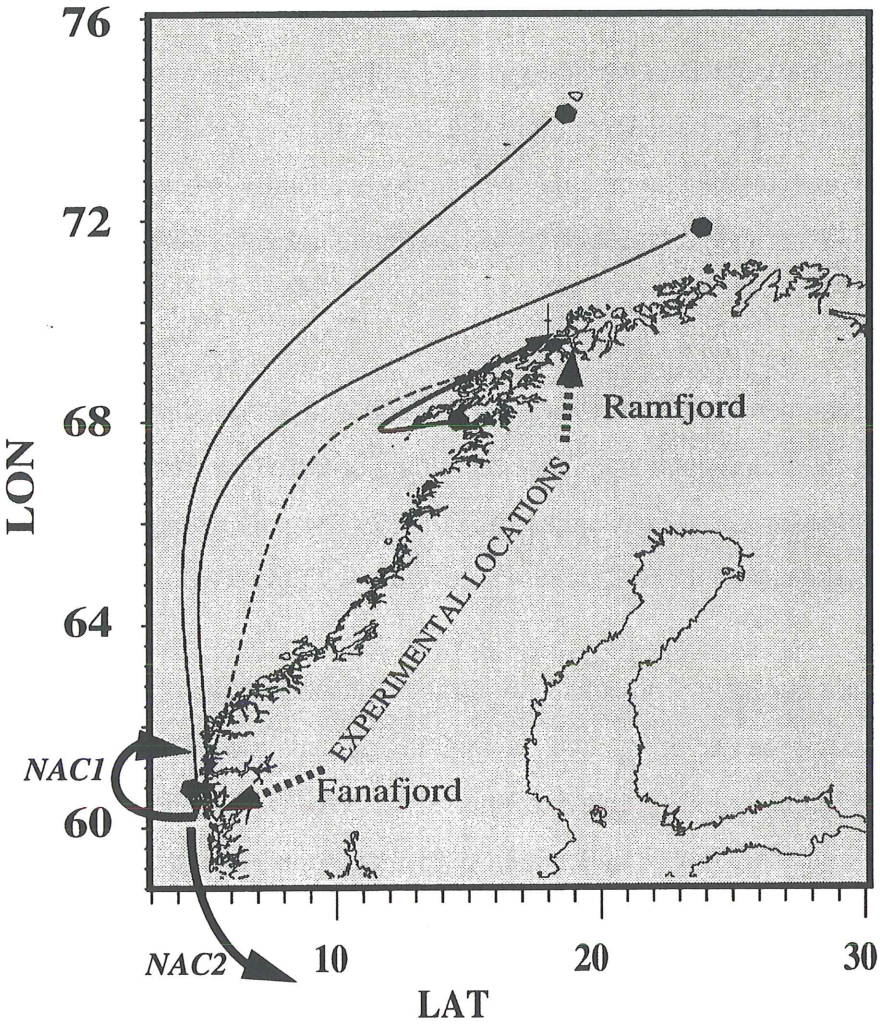

Fig. 1. Experimental locations and transplantations of NAC (continuous line) and CC (broken line). Recapture positions of the two NAC reported from outside the Fanafjord are indicated (NAC1, NAC2)

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Table 1: Releases and recoveries of acoustic and conventional tags. Size at release is average fish length(cm) of the fish tagged with acoustic transmitters.

Date	Location	Size at rel. CC	Size at rel. NAC	CC rel. Ac.	CC rel. Conv	NAC rel. Ac.	NAC rel. Conv	CC recov. Ac.	CC recov. Conv	NACrecov Ac.	NACrecov Conv
Dec. 1992	Fanafjord	45	62	2	3	2	1	2	0	0	0
Sept. 1993	Ramfjord*	60	73	3	13	2	3	0	2	1	0
Dec. 1993	Fanafjord	58	68	1	16	3	32	1	4	0	2

*) CC include both local CC and transplanted CC.

In 1993 NAC were obtained from pens in Tromsø. The cod were caught during the spawning season in Lofoten in 1991. The coastal cod consisted of two groups: The first group included CC from outside Bergen which was transported by plane in a cage with excess of oxygen at the day of experiment start. The second group was local CC. One fish in this group was tagged under water by inserting the tag in a bait which was eventually swallowed by the cod (fish no. 8896). Species identification was done by video camera inspection of the fish when consuming the bait.

In the 1993 December experiment two groups of cod were released in the Fanafjord. NAC were caught in the Bear Island area in the beginning of October by R/V Michael Sars and transported to Bergen. CC were caught during the 1993 September experiment and transported to Bergen after the end of the trials and kept together with the NAC until experimental start.

CC and NAC are normally grouped according to differences in the otolith structures. In these experiments cod of the two groups were caught in areas and time periods excluding (minimizing) the possibilities of mixing. One exception is the NAC used in the 1993 experiment in Ramfjord. CC and NAC mix at the Lofoten spawning ground. Based on the external characteristics of the fish as well as otolith studies from the rest of the catch, the probability of mistake in the identifications is assumed to be very low (Kjell Midling, Norwegian Institute for Fisheries and Aquaculture, pers. communication).

RESULTS

1992

Two CC were tagged with acoustic transmitters. They had a very similar behaviour after release: A sudden dive to 30-40 m towards bottom and subsequent movement to the closest shore about 300 m away. There they apparently established territorial behaviour where the fish seldom moved outside a circle with radius 50 - 100 m (Fig. 2). The actual movement distances were difficult to estimate because the fish much of the time were out of reach of the buoy system. This problem is supposed to be due to blocking of the acoustic signals by rocks when the fish settle and stay on rough bottom, as was the case. After the end of the experiment, the presence and approximate position of the fish were observed from a shore position once or twice a week until the beginning of January 1993. Apparently no substantial change in position or behaviour occurred.

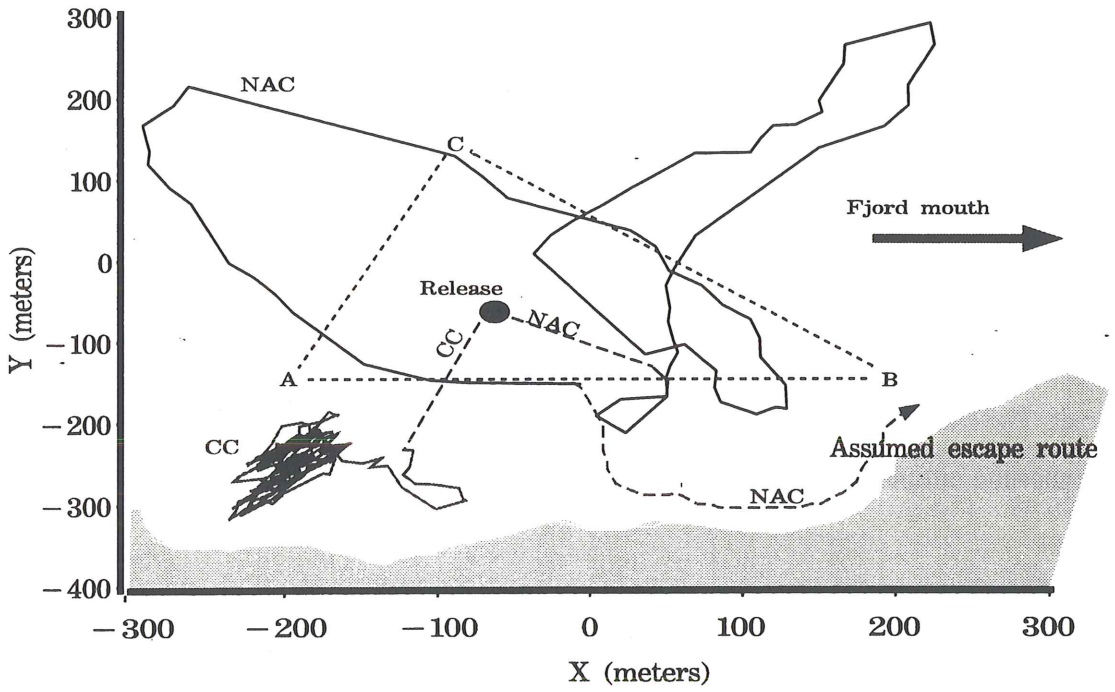

Fig. 2. Movements of a Coastal Cod (CC) and a Northeast Arctic Cod NAC after release in December 1992. The hatched part of the movement lines are partly assumed and partly indicated by the handset hydrophone. A, B and C are the hydrophone buoys.

To locate the tagged fish, we used a rubber boat and the hand set hydrophone on January 7. We used divers to check the mobility of the fish, i.e. that the fish was still alive. One fish was found in the same position as at the end of the experiment, and was clearly mobile. This fish was recaptured in March 1993 some hundred meters away from this location by a local fisherman. The second coastal cod was already recaptured, the tag ribbed of and dropped. The divers found the tag under a pier, popular for sport fishing, close to where it was located at the end of the cruise. Both CC showed no sign of migration until the termination of the experiment. Even though the fish were transplanted from a location outside the fjord, there was no evidence of return or movement out of the fjord.

Two NAC were released in the same position as the CC. Immediately after release they dived towards bottom. Thereafter, they gradually approached surface water again and moved in great circles around the buoy triangle (Fig. 2). The first one was subsequently lost for the buoy system probably among pleasure boats or rocks close to the shore, and we were not able to regain contact during several attempts with the hand set hydrophone. The second fish was followed with the hand set when out of reach of the buoys. The hand set was operated from a

small rubber boat, and due to rough weather, the fish was lost about 2 hours after release more than 1 n.mile away from release position. After the first circles this individual was apparently aiming directly out the fjord at 10-15 m depth (bottom depth 80-160 m). As we were not prepared for such an immediate reaction, we probably lost the first NAC because it left the release area and headed out the fjord. No recaptures of NAC have been reported from this experiment.

1993 September

The coastal cod transplanted from the Bergen area behaved similar to what was observed in the Fanafjord. The fish dived and moved shorewards where it kept within a small territory for the whole experimental period (Fig. 3).

The local CC (8896) and the northern transplanted CC (8807) moved substantially more than the southern transplanted CC (8908) (Fig. 3). The last one had a stationary -territorial behaviour, compared to movements between several "favourite" positions of the two first.

One of the NAC clearly moved more than the other studied individuals (Fig. 3, fish no. 8901), while the movement distances of the other NAC (8903) was not substantially different from the local cod. No diurnal pattern was observed. The individuals released at surface appeared to use substantial time to gain a "preferred" depth, except the NAC with the extensive movements (8901), which remained in the surface layer during the whole period (Fig. 4).

1993 December

The CC (8898) from Ramfjord covered a larger area (Fig. 5) than was observed for CC in Fanafjord in 1992 (Fig. 2) and for southern CC transplanted to Ramfjord in September 1993 (Fig. 3). After release the fish moved to the outer part of the fjord and settled on bottom at 15-20 m. This fish was, however, recaptured close to the release location on March 1, 1994.

The first NAC (8902) took up a behaviour after release similar to the NAC in 1992. After a short time of orientation in the release area, the fish headed out the fjord and was followed until it reached oceanic waters (Fig. 5). Observation was then terminated, due to the priority to obtain similar data with additional releases of NAC. Two NAC (8904, 8906) were tagged and followed for several days. Their behaviour was similar but diverged distinctly form the previously tagged NAC: After a dive and some orientational movements (similar to the previous

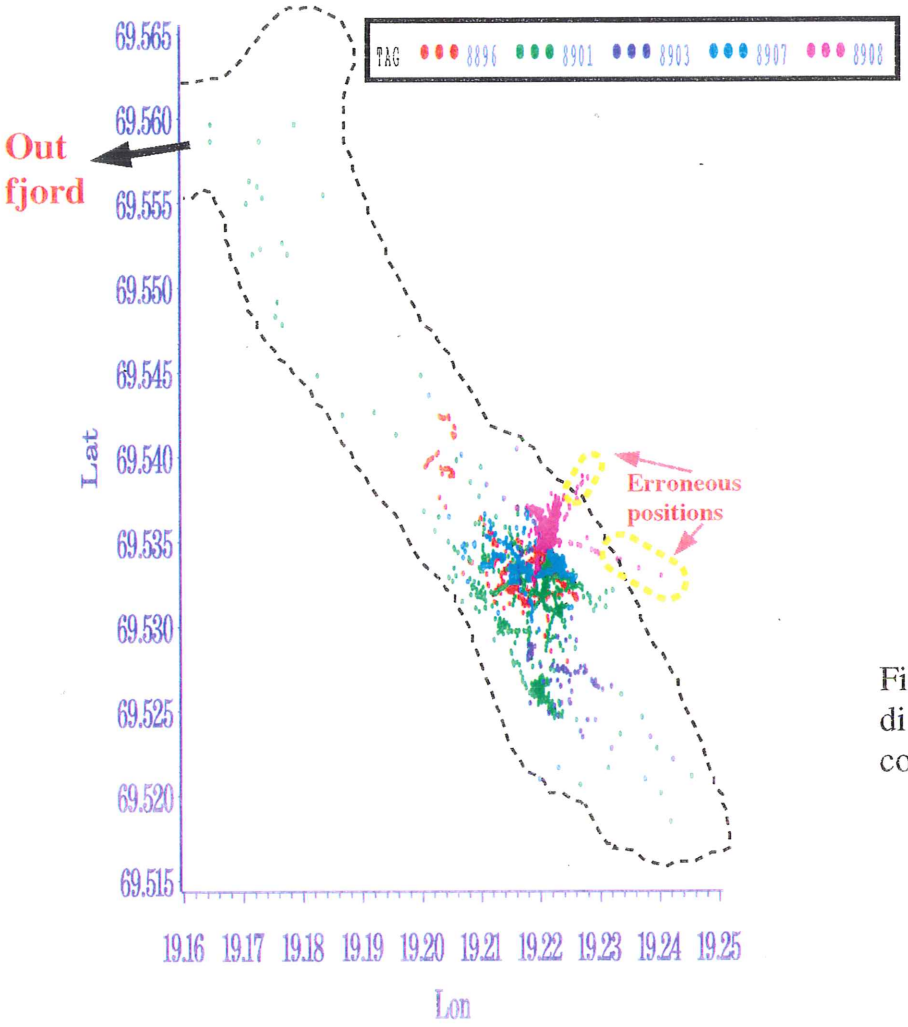

Fig. 3. Observed geographic distribution of the released cod in Ramfjord.

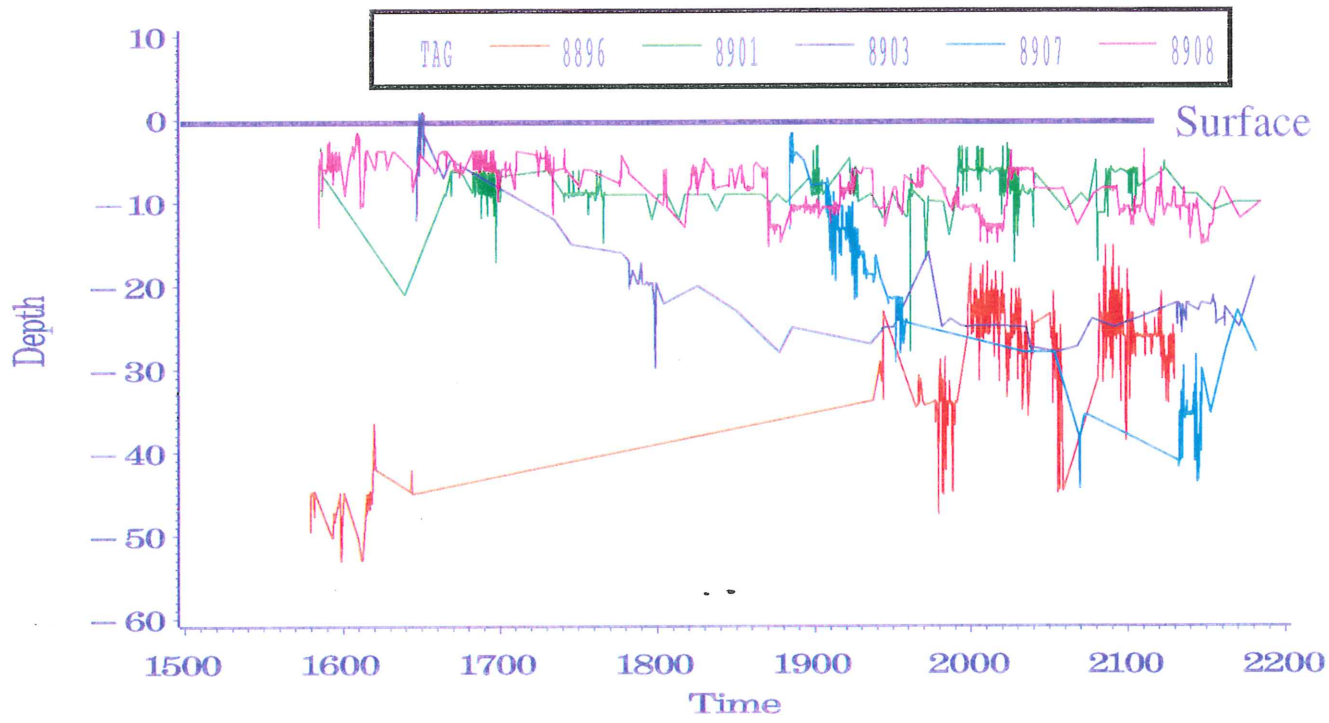

Fig. 4. Observed variation in depth with time for the various fish in the Ramfjord experiments. Time = (day numb. in September)*100+(hours*100/24).

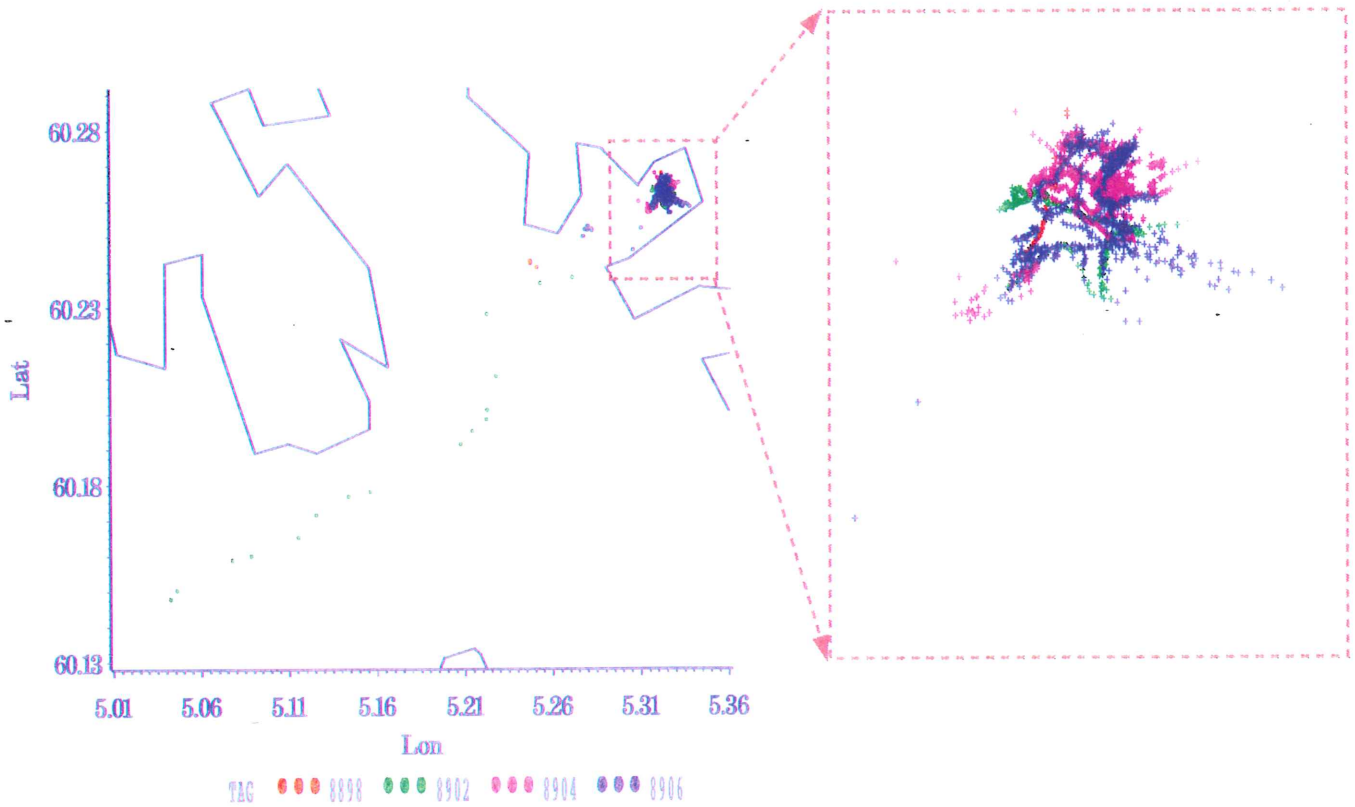

Fig. 5. Observed positions of the released cod in Fanafjord in December 1993. Small scale movements around the position of release is expanded.

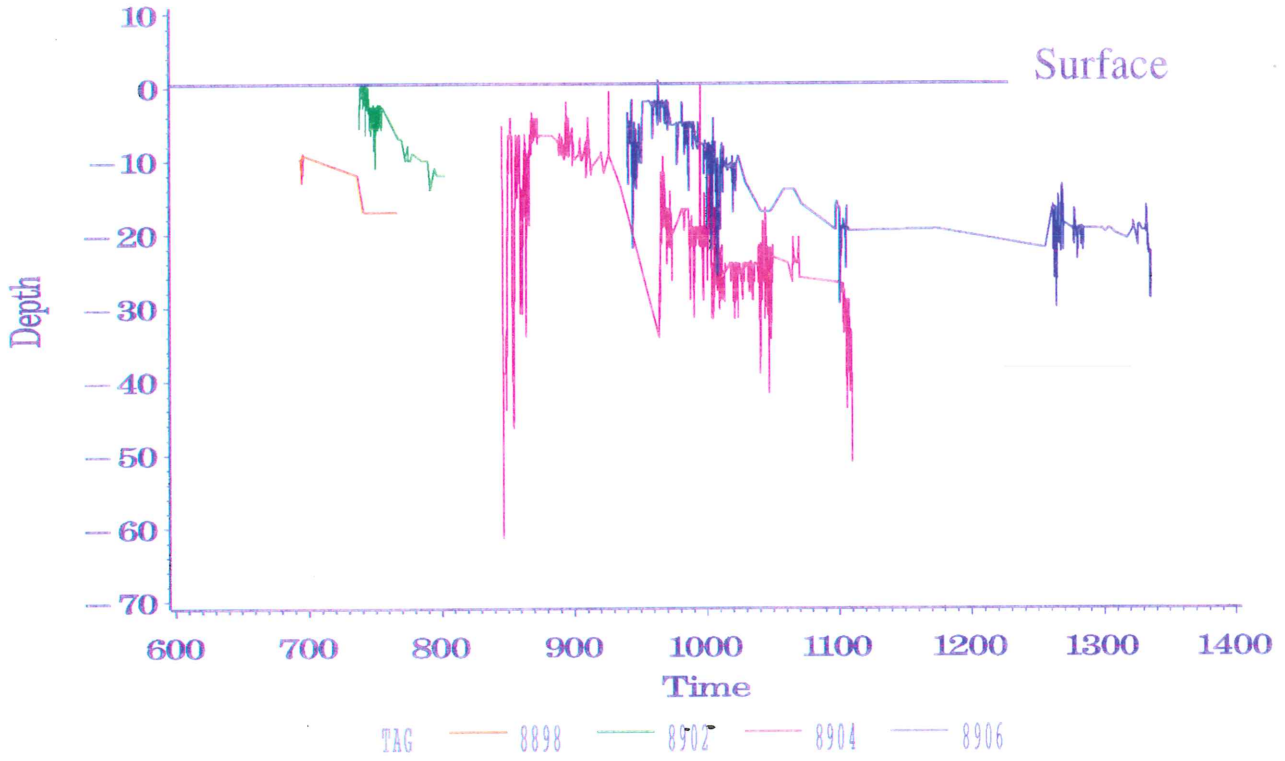

Fig. 6. Observed depth distribution with time of the same fish as shown in Fig. 5. Time is defined in caption of Fig. 4.

observations), the two individuals lined up in front of a river outlet in the bottom of the fjord close to the release position (the area with highest densities of observation in Fig. 5). Short movements around the inner part of the fjord occurred regularly, and signified a none CC behaviour. However, much of the time the two specimens remained apparently inactive like a CC.

All fish except the migrating NAC showed a descending movement in a period after release (Fig. 6). The migrating NAC kept in surface layer and never approached bottom.

Four conventionally tagged CC (all transplanted from Ramfjord) recaptures are reported, and all of them in the Fanafjord. Two conventionally tagged NAC have been reported recaptured on February 22 and 23. One was caught in the North Sea south of Norway, while the other was caught in the outer skerries north of the Fanafjord (Fig. 1).

One environmental feature distinguished the conditions during the experiment with the two last NAC compared to the other three trials with NAC in Fanafjord: The weather calmed down, no wind occurred, the temperature sunk to below 0^{o} C, and an ice cover was formed in the major part of the fjord.

DISCUSSION

The limited number of observed cod in these experiments preclude any firm conclusions to be drawn. However, the results may become more conclusive if additional recaptures of the conventionally tagged cod are reported. Most important, the experiments have given ideas for further investigations on migration mechanisms and differences in them for cod in Norwegian waters.

The preliminary conclusion for the experiments so far is that CC more or less take up its natural "territorial" behaviour when transplanted to a new position. Northern CC is more mobile than the southern CC, which is in accordance with earlier observations from tagging experiments (Godø 1986). The NAC in the Ramfjord experiment moved more than CC, but did not leave the fjord. In contrast, NAC in the Fanafjord winter experiments showed a very aimed migration towards oceanic water under rough weather conditions, whereas, they during calm

weather remained in the fjord. The difference in movement behaviour among the three types of cod studied is probably most relevantly compared with what is called "migratory restlessness" in bird migration theory. An endogenous time program initiate migration, and it last longer and reach higher peaks for long distant migrants (like NAC) compared to short distant migrants (like CC) (see Wallraff 1984). The time program must either be inherited or adopted during the early life history of the individuals. The strength of this stimulus varies through the year probably through a complex interaction between external (light, temperature) and internal stimuli resulting in endosecretory activity (Woodhead and Woodhead 1965). This theory might explain the difference in migration of NAC between Ramfjord and Fanafjord due to the difference in time and light conditions. Maturation play an important role in the migrational behaviour of fish. If the NAC used in the experiments were a mixture of mature and immature individuals, differences in behaviour would be expected. The Ramfjord NAC was caught in Lofoten during spawning and, hence, of same maturation stage. Their limited migration could be because the maturation process for next spawning was not yet strong enough to initiate "migratory restlessness". The NAC used in Fanafjord in 1993 was a mixture of mature and immature fish. Biopsies analysis of fish from the same catch showed that approximately 20% were mature, and that maturation started at a length of about 65 cm (O. Kjesbu, Institute of Marine Research, Bergen, pers. communication). Consequently, the maturation stage of the tagged fish is uncertain. The fish which left the fjord was the smallest (62 cm), while the two others were above 70 cm. Also, migratory tendency for NAC is supposed to be substantial in December both for mature and large immature fish (see Harden Jones 1968). Consequently, we expected substantial "migratory restlessness" of large fish independent of maturation stage.

An aimed migration may arise when the fish in addition to "migratory restlessness" acquire internal or external stimuli which can be used for navigation purposes. One hypothesis for the difference in migratory behaviour between the three first and the two last NAC is that cod may use low frequency noise created by oceanic wave activity as a clue to escape from the fjord. This sound is supposed to create resonance between the "walls" of the fjords and may, hence, lead the fish directly to the ocean. Under extremely calm weather as experienced during the experiment with the last two NAC, the underwater noise level may be to low for the fish to receive and use for navigation. The ambient sound in the fjord in this period was probably dominated by the fresh water influx from the river, and, hence the NAC approached this sound source. In all cases when the tagged NAC showed substantial migration, the individuals kept in

surface layer (above 15 m), indicating that the orientation stimuli were received here. The different choice of direction by the two conventionally tagged NAC recovered outside the Fanafjord in 1994 (Fig. 1) may indicate a conflict or confusion between several stimuli used for navigational purpose after the fish entered oceanic waters. This compare with the findings of Hylen (1963). He transplanted cod from the Barents Sea to the mid Norway coast and tagged fish were recovered both north and south of the release position. With time movements towards north dominated. More extensive experiments of the same type as described in this paper may help to elucidate the questions brought up by these initial trials.

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