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BEHAVIOUR OF ATLANTIC SALMON SMOLTS DURING SEAWARD MIGRATION. I: PRELIMINARY REPORT ON ULTRASONIC TRACKING IN A NORWEGIAN FJORD SYSTEM.

by

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ABSTRACT

In order to find the most effective releasing techniques for future ocean ranching programmes, the behaviour of wild and hatchery reared Atlantic salmon smolts during seaward migration was studied by tracking fish tagged with acoustic transmitters. Four fish were tracked in 1981 and seven fish in 1982. Preliminary results are presented on vertical and horisontal migration. Some hydrographical data are also presented and their influence on fish behaviour is indicated.

RÉSUMÉ

Afin de trouver la technique des lachers de smolts la plus efficace pour les programmes d'avenir de Sea Ranching, le comportement migratoire de smolts sauvages et de smolts elevées de saumon atlantique a été étudié en suivant des poissons munis de transmetteurs acoustiques. Quatre smolts ont été suivi en 1981 et sept smolts en 1982. Des résultats preliminaires sont presentées sur des migrations verticales et horisontales. Quelques informations hydrologiques sont aussi données et leur signification pour le comportement des poissons sont discutées.

INTRODUCTION

Different types of transmitters attached to animals is today a widely used method of monitoring migratory behaviour of free living animals. The method is applicable also to fish. Thereby valuable information can be obtained, that cannot be uncovered by ordinary fish tagging. When working with small fish the method is hampered by the fact that the small acoustic transducers needed send on such high frequencies that give the transmitters a very limited range, which makes tracking difficult. However the method has been quite successfully used on tracking Atlantic salmon smolts by among others La Bar et al. (1980) in the U.S. and Tytler et al. (1978) and Ross (1981) in Scotland.

In Norway experiments with tracking smolts could be started when the Technical University of Trondheim developed a miniature version of their acoustic fish tag (Knutsson 1980, 1981).

The aim of the experiments is to find the most effective releasing techniques for future ocean ranching projects by collecting data on the migratory behaviour of smolts of Atlantic salmon (Salmo salar L.) migrating seawards. The experiment started in 1978 focusing on the behaviour of migrating wild smolts in order to get some reference for comparing the migratory behaviour of hatchery reared smolts. The experiments were first carried out in the small river Lone, 35 km north of Bergen. In 1979 a cooperation was started with the Directorate of Wildlife and Freshwater Fish. In 1981 the experiments were transferred to the Høgsfjord area southeast of Stavanger where the Directorate of Wildlife and Freshwater Fish has its research hatchery and a smolt trap in the Imsa River. Thus wild smolt of suitable size as well as hatchery fish of desired age and origin could easily be obtained at the same time. The area is also interesting because of its topography, since it is a large fjord system with a wast archipelago, giving the fish many possibilities of choosing its way (or possibly drifting) out to the open sea.

The present paper gives preliminary results of the 1982 tracking and a few data from the 1981 experiment.

MATERIALS AND METHODS

In late May 1981 eight fish, one of which was a 2 year old hatchery reared smolt of Imsa origin, were tagged either by pushing the tag carefully down the pharynx into the stomach or attaching it externally under the dorsal fin with a thin wire as shown in figure 1.

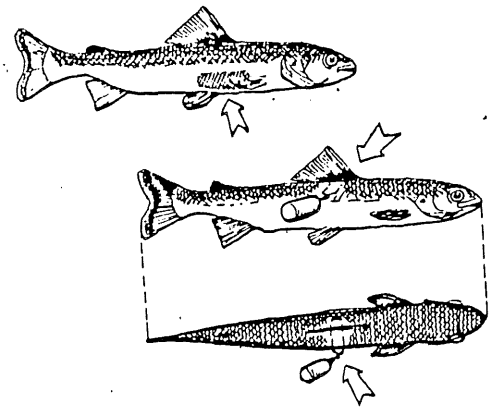

Fig. 1. Attachment of transmitters.

Four of these fish were tracked. Some data on these fish are given in table 1.

The experiments were continued in 1982 (20-31 May) by tagging and tracking one wild smolt (Imsa) and eight hatchery reared 2-year old smolts. The reared smolts originated from Imsa (no. 2, 6 and 7), the river Figga (no. 3, 4 and 5) located in Mid-Norway. The fish are presented in table 1.

The ultrasonic tags used in 1981 were position only transmitters. They were 18-20 mm long, cylindricae with a diameter of 8.0 mm and weighed 3.5 g in air (~1.5 g in water), emitting different pulse rates at somewhat different frequencies in order to distinguish one tag from another. In 1982 the Technical University had developed miniaturized depth and temperature sensitive ultrasonic tags. These were 22 mm long and 9 mm in diameter, weighing 4.0 and 2.5 in air and water respectively. They were emitting at frequencies around 125 KHZ. Changes in pressure were transmitted by frequency modulation and changes in temperature as a change in pulse repetition rate. The range of

the transmitters was 300-1 000 m depending on hydrographical conditions in the sea. Expected battery life was 10-21 days. A detailed description of tags is given by Holand (1982).

A highly directional hydrophone was mounted in the bow of the tracking vessel and connected to a receiver in the wheelhouse. The hydrophone could be turned 360° horisontally by wires from the wheelhouse.

Calibration of pressure to depth data was made by lowering the tag from 0-10 m into the sea and tuning the received signal to zero-beat frequency for each metre and noting the readouts for each receiver on its meter. When tracking the fish the receiver was constantly to be tuned to Zero-beat when the fish moved up or down and the readouts were read into a tape-recorder.

After tagging the fish were left to recover from anesthetization (6-48 hours) and if they behaved normally they were released either in fresh water in the river mouth or in brackish water a few hundred metres away from the river mouth.

The intention was to follow the fish continuously for 2-3 days or until the fish disappeared or reached open sea. In a few cases the fish had to be given up as "non-migrants", but most fish started migration and were traced for shorter or longer distances until the signals disappeared.

The boats were positioned by taking fixes by the help of a radar (or sometimes by "common sense") which was considered to be accurate enough for our purposes. The direction of the fish relative to the boat could be fairly accurately estimated because of the highly directional hydrophone. The distance to the fish was roughly estimated through experience of judging signal strength and the sector in which the tag could be heard when scanning (large sector - fish close by, narrow sector - fish far away).

Buoys with instruments (Sensordata Ltd.) for automatic recording of temperatures, current speeds and directions every 20 minutes,

were located at stations I, II and III. At station I there were current meters also in 2 and 12 metres. In addition hydrographical stations 1-7 were sampled daily for temperature and salinity profiles from 0-30 m. Stations 8-11 were taken especially when fish no 5 moved to the outer area. The current speed and direction was also measured by 1.5 m cross waned drogues. The stations are shown in fig.9.

RESULTS AND DISCUSSION

Since a large amount of data from the 1982 cruise still remains to be thoroughly analysed, this paper presents only preliminary results focusing on a few points of interest.

Table 2 shows time and date of release, active migration time and distance from site of release when loosing the track. It must be mentioned that the tracking distance often was substancially longer since the fish from time to time were milling around in coves and sounds before continuing a more steady migration. Longer periods of standing still or milling around in one place is also deducted to get the active migration time. Thereby a rough estimate of migrating speed is obtained. It should also be noted that all the smolts adapted to seawater some weeks prior to release migrated at least outside the small fjord between Imsa and Ådnøy island.

Figures 2-9 present the migration routes of the fish. Areas where the fish showed active periods of vertical movements are indicated.

The diving activities of the fish are also roughly demonstrated in fig. 10 as number of dives per hour along the track.

The salinity data, fig. 11, show that in the fjord there was a clear stratification in the upper water masses. A 2-3 m layer of more brackish water was found above the more saline water masses beneath. This stratification could not be seen from the temperature data. The stratification did not seem to exist in more coastal waters (outside Aamøy, see maps).

The depth data, although only tentatively treated, show that the smolt migrate in the upper brackish layer, but make short dives into the deeper more saline water.

CONCLUSIONS

Mc Cleave (1978) and La Bar et al. (1980) found clear coincidence between the direction of the tidal currents and direction of fish movements. In the Høgsfjorden area the tidal currents are negligible, but there is a movement of the water masses in and out the fjord that is largely induced by winds and the coastal current. The tentative results of this study also indicates that the smolt follow the outgoing currents and that they tend to mill around and start diving activities when they come to areas with complicated current patterns.

The pressure sensing smolt tags were a valuable aid to the understanding of the smolts diving activities, but they still need some technical refinement since there was considerable drift in the emitted frequencies, which makes the interpretation of the depth data difficult.

REFERENCES

Knutsson, S. 1979. Utvandring av laksesmolt. Årsmelding 1978 til NFFR.

- 1980 Utvandring av laksesmolt. Årsmelding 1979 til NFFR.
(Migration of salmon smolts. Annual reports 1978 and 1979 to the Norwegian Council for Fisheries Research).

La Bar, G.W., McCleave, J.D. and Fried, S.M. 1980. Seaward migration of hatchery-reared Atlantic salmon (Salmo salar) smolts in the Penobscot River Estuary, Maine: Open water movements. J.Cons. Int.Explor.Mer. 38:257-269.

McCleave, J.D. 1978. Rhytmic aspects of estuarine migration of hatchery-reared Atlantic salmon (Salmo salar) smolts. J.Fish.Biol. 12:559-570.

Tytler, P., Thorpe, J.E. and Shearer, W.M. 1978. Ultrasonic tracking of the movements of Atlantic salmon smolts (Salmo salar L.) in the estuaries of two Scottish rivers. J.Fish.Biol. 12:575-586.

Ross, L.G. 1981. Smolt acoustic tracking in a lake, in Report of meeting on Practical Aspects of Fish Tracking. Dec.1981. Leatherhead, U.K.

Table 1. Origin, length, weight, tagging method and releasing site of smolts in 1981 and 1982.

Fish no.	Origin	Length cm	Weight g	Sea water adapted	Releasing site	Tagging method	Transmitter type
1981							
2	Wild, Imsa	21.5	-	-	River mouth	Internal	position only
4	" "	19.5	-	-	"	"	"
5	" "	22.2	82	-	Estuary	External	temperature
7	Hatchery, Imsa	22.7	89	-	River mouth	"	"
1982							
1	Wild, Imsa	20.1	63	-	"	"	pressure and temperature
2	Hatchery, Imsa	30.5	259	-	"	"	"
3	" Figga	36.5	393	yes	Estuary	"	"
4	" "	34.0	326	"	"	"	"
5	" "	28.4	216	"	"	"	"
6	" Imsa	29.5	281	-	"	"	"
7	" "	29.0	195	-	"	Internal	position only

Table 2. Data on tracking in 1981 and 1982.

	Fish no.	Released Date	Released Time	Active Migration time	Track	Speed
1982						
	1	20.5	22.45	5.5 h	3.5 km	17.6 cm/s^{-1}
	2	22.5	10.00	0.8 "	0.7 "	24.8 "
	3	24.5	00.15	32.0 "	27.7 "	23.0 "
	4	25.5	21.08	9.0 "	12.0 "	37.0 "
	5	26.5	21.20	40.0	42.5 "	29.5 "
	6	29.5	11.15	18.0 "	14.0 "	21.0 "
	7	30.5	13.35			
1981						
	2	21.5	17.20	12.5 "	12.9 "	28.8 "
	4	23.5	10.00	~24.0 "	impossible to calculate	
	5	26.5	23.56	~21.5 "	16.6 "	21.4 "
	7	29.5	23.12	22.5 "	20.5 "	25.9 "

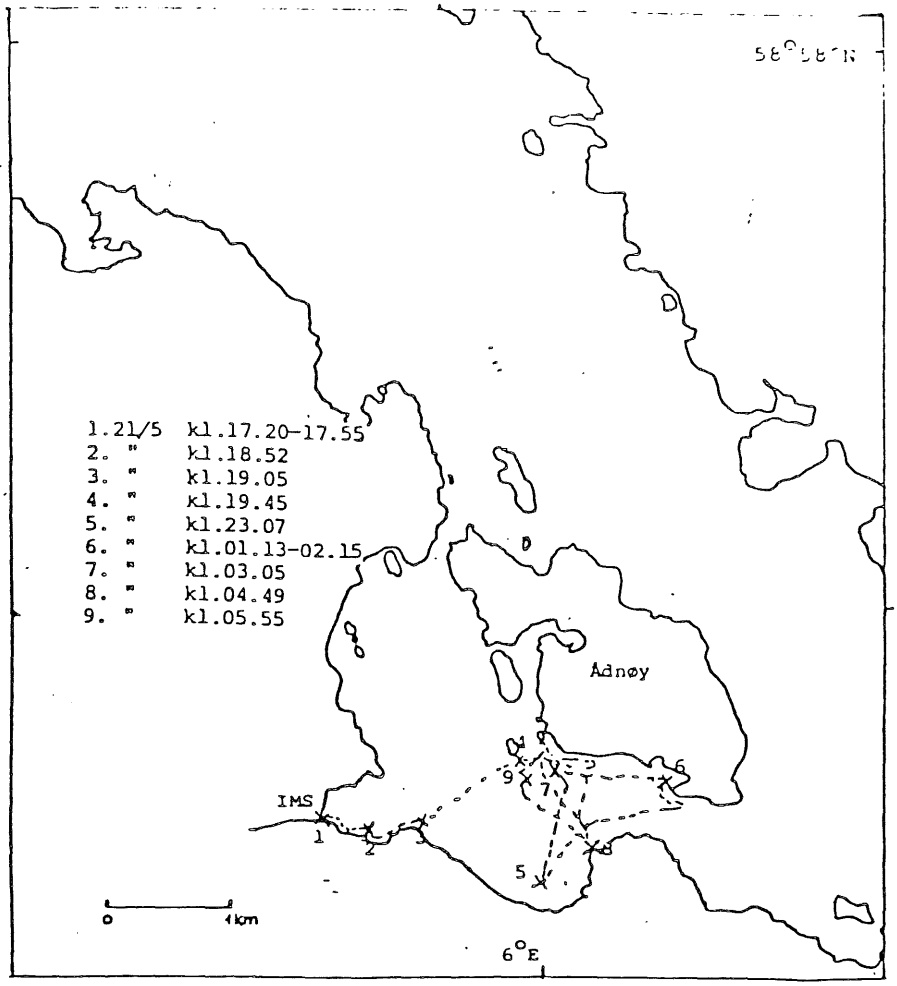

Fig. 2. Track of fish no. 2 (1981)

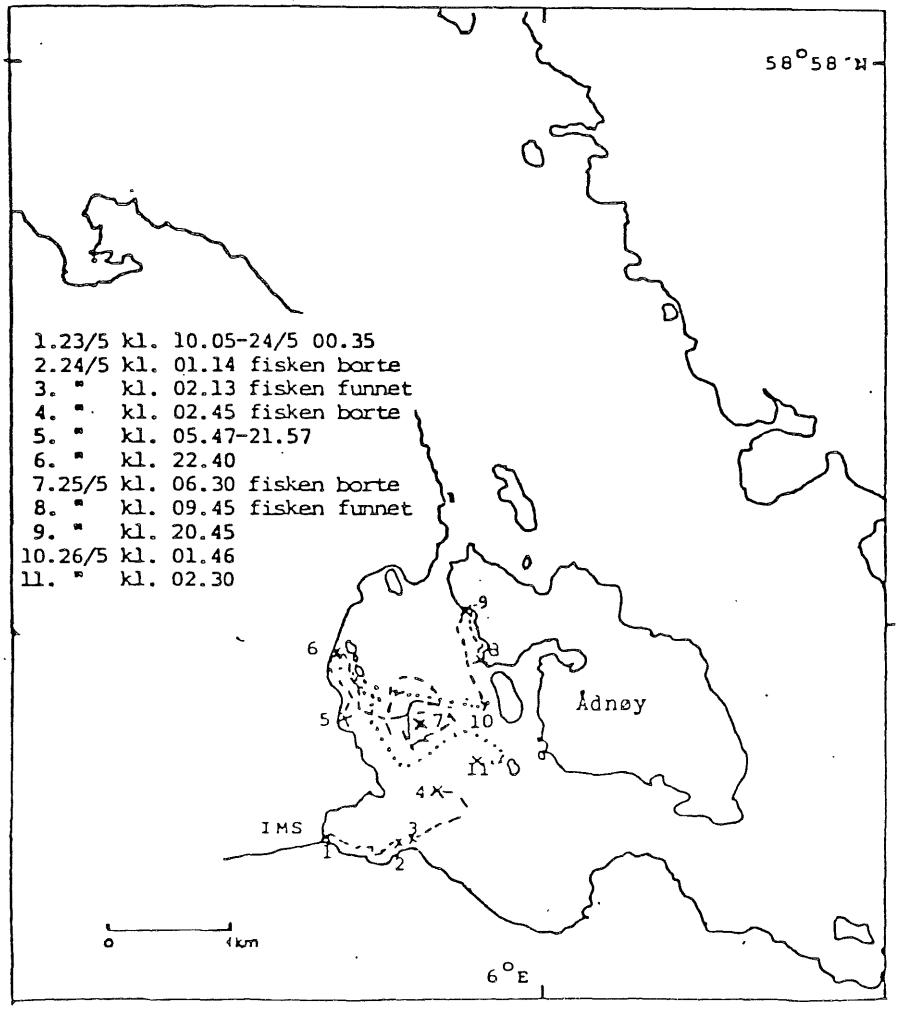

Fig. 3. Track of fish no. 4 (1981)

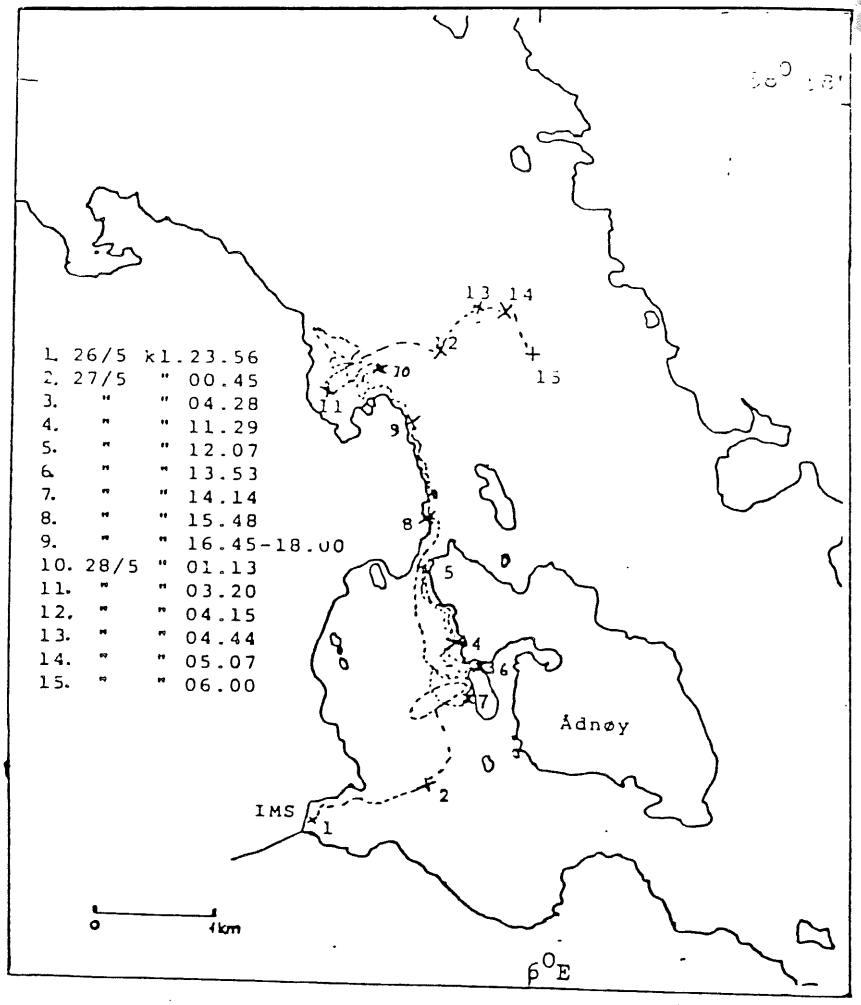

Fig. 4. Track of fish no. 5 (1981)

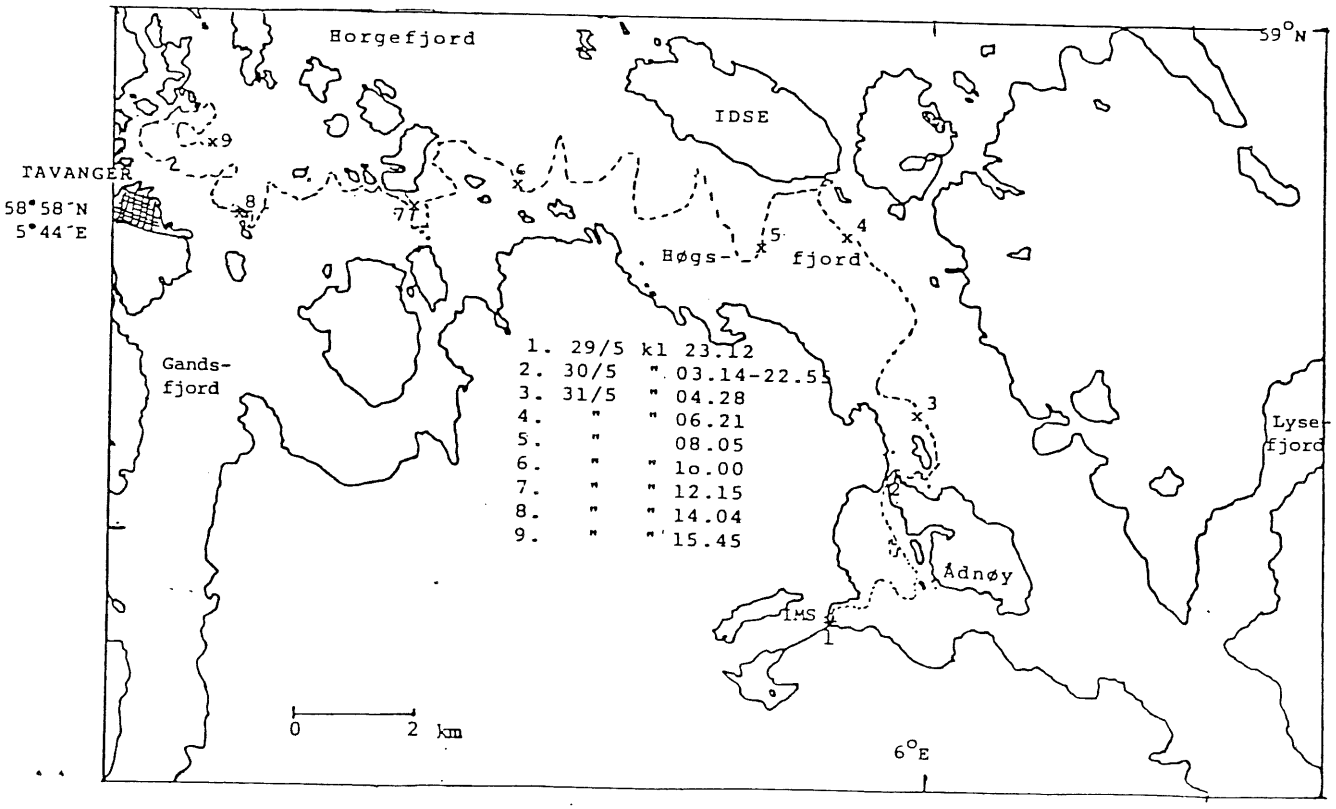

Fig. 5. Track of fish no. 7 (1981)

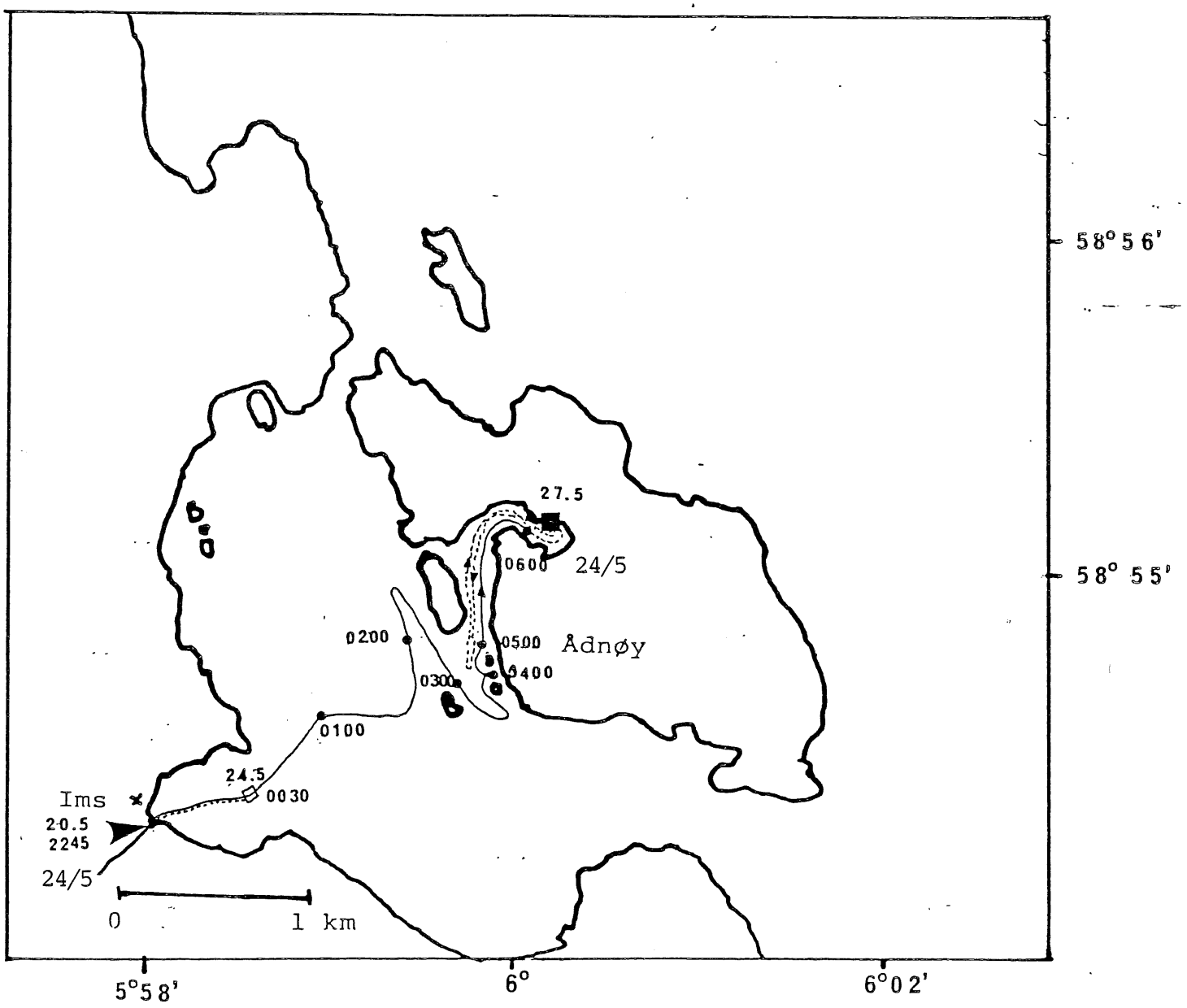

Fig. 6. Track of fish no. 1 (1982). Arrow indicates releasing site. Open square indicates start of active migration. Black square indicates disappearing point.

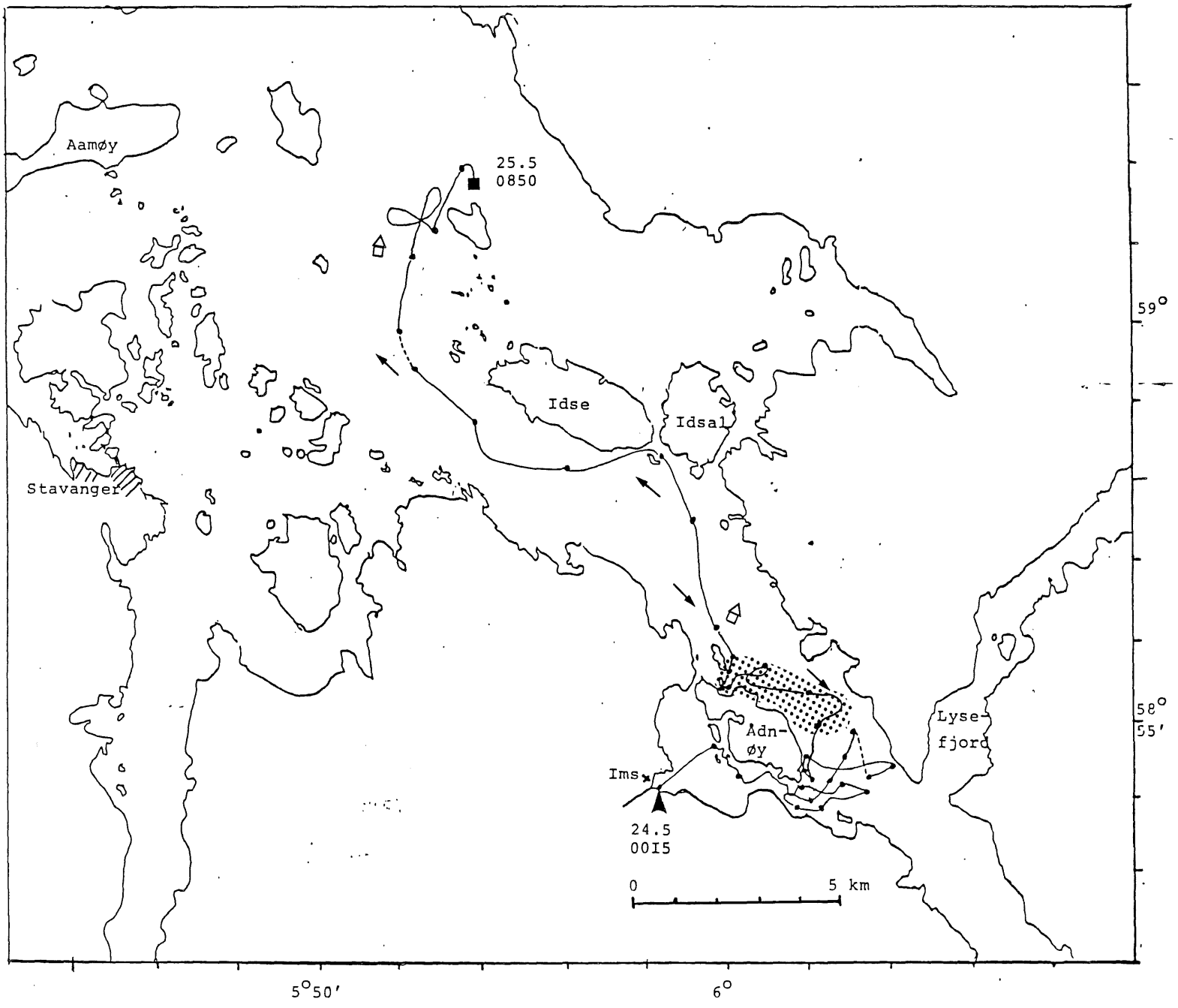

Fig. 7. Trade of fish no. 3 (1982

driving activity

wind direction

current direction in 1 m depth

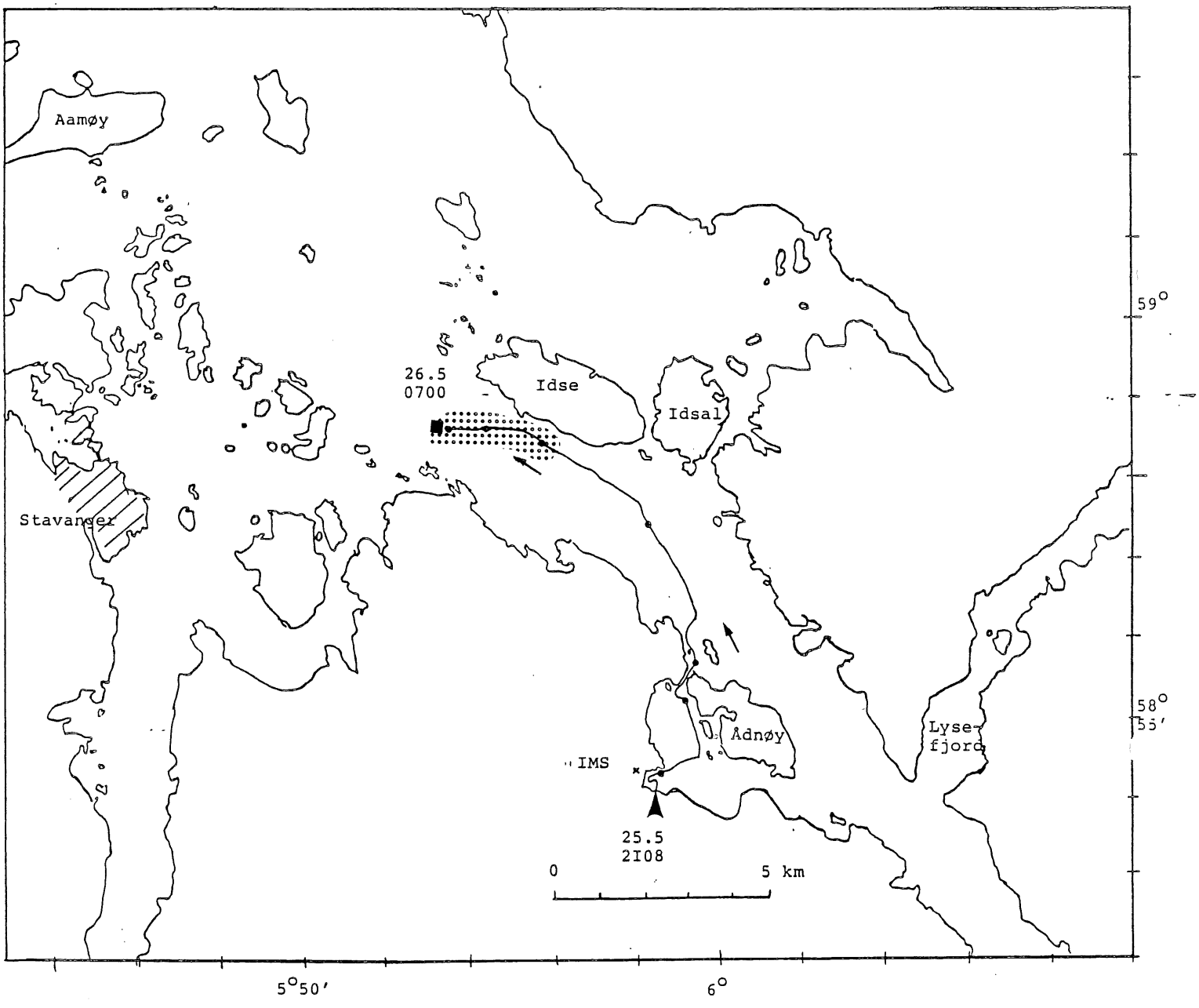

Fig. 8. Track of fish no. 4 (1982

legends see previous figures

driving activity

currant direction in 1 m depth

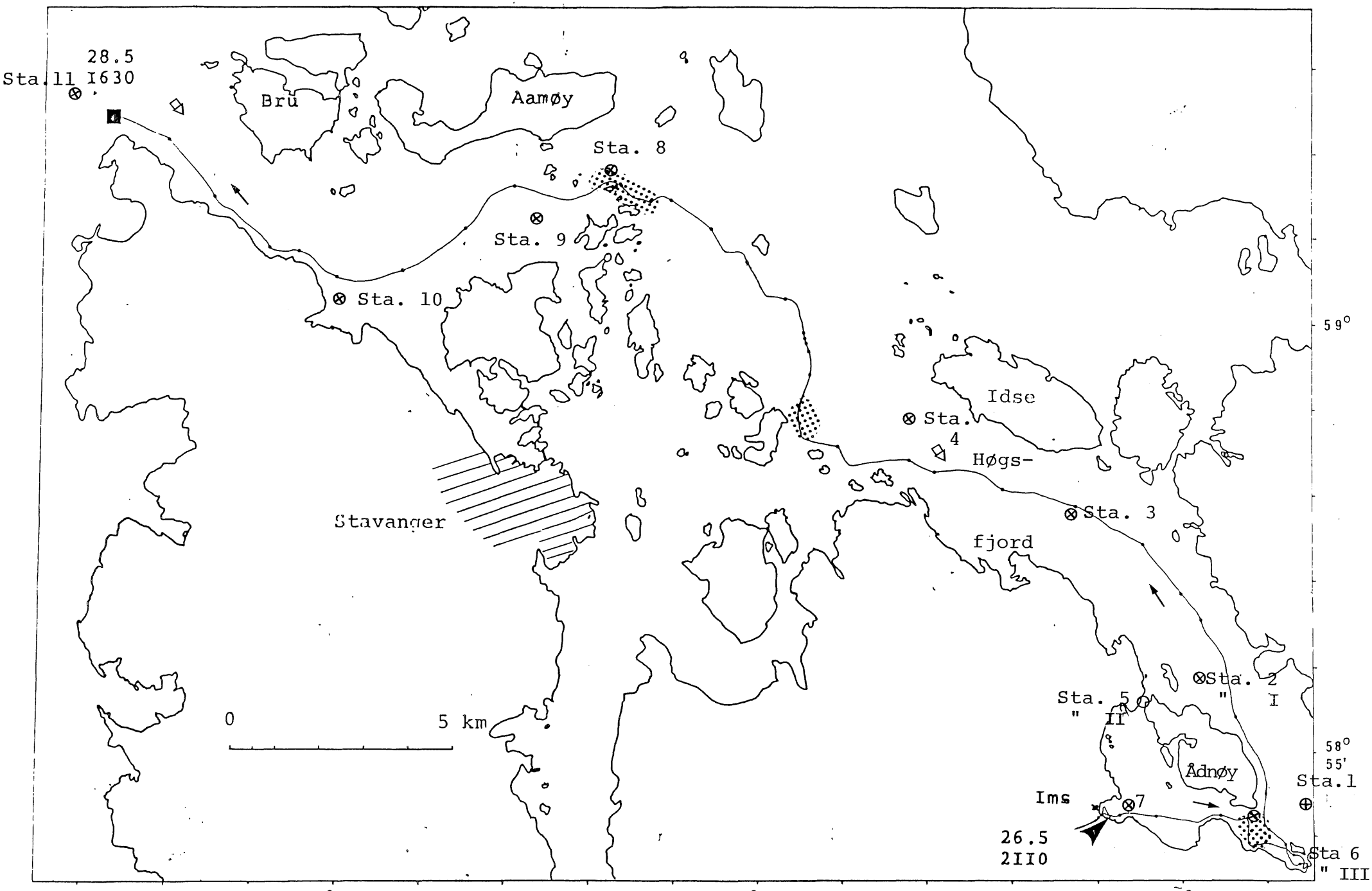

Fig. 9. Track of fish no. 5 (1982). Each dot indicates 1 hour, active diving
⊗ Hydrographica, stations ◁ Winddirections ↗ current in 1 m depth

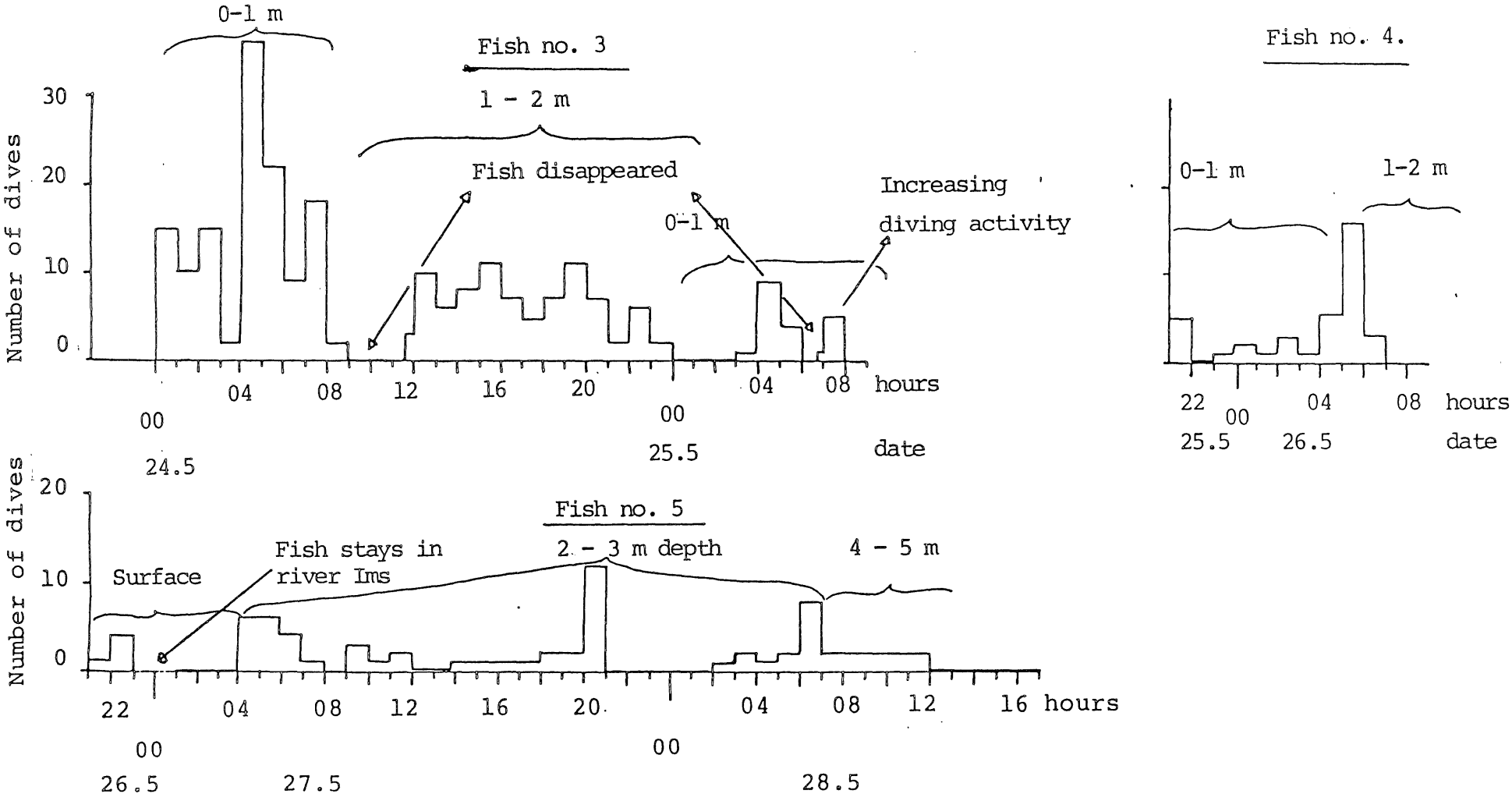

Fig. 10. Diving activity per hour and a crude indication of swimming depth.

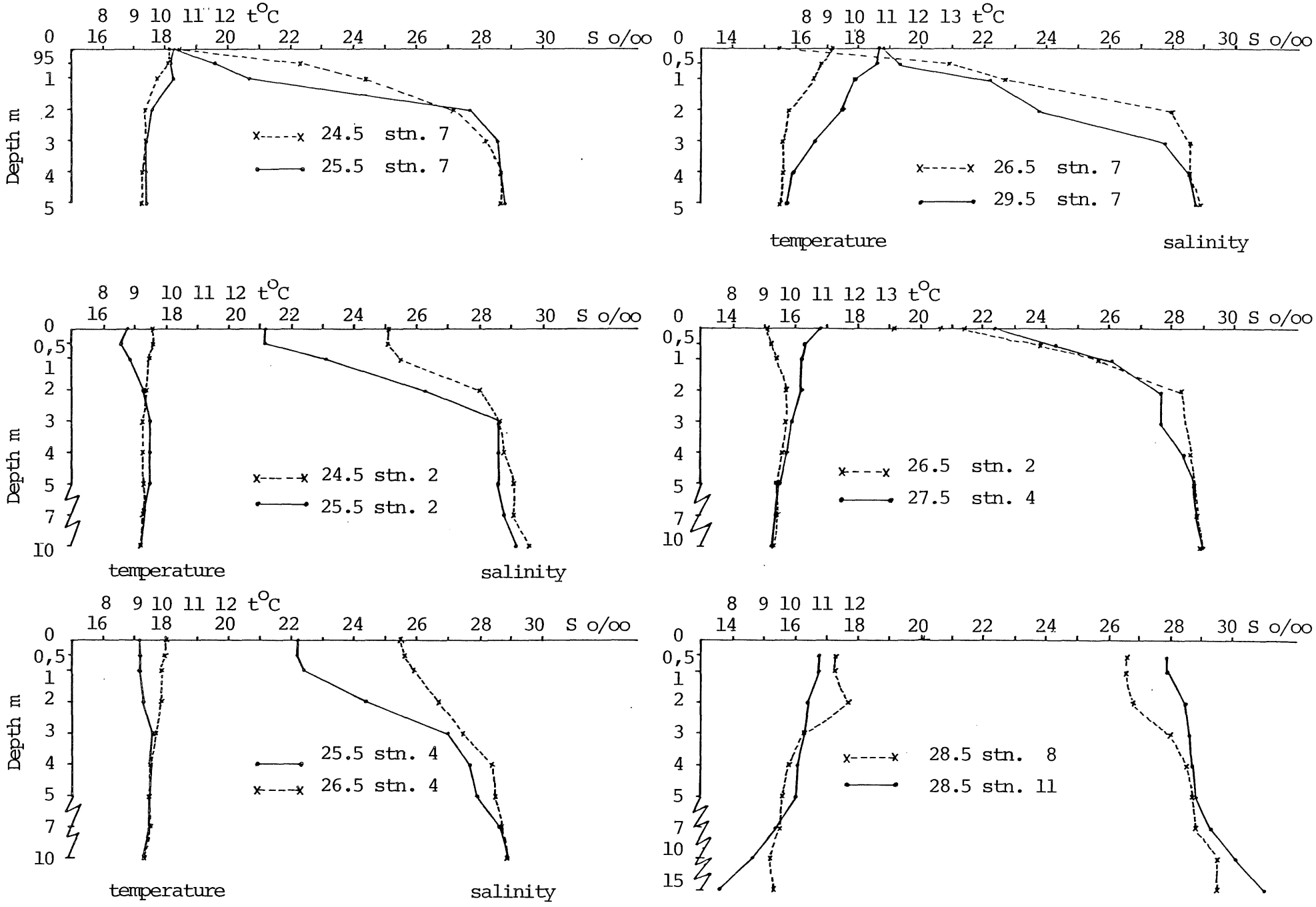

Fig. 11. Salinity and temperature 24.-29.5. at stations 2, 4, 7, 8 and 11.