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RELEASE OF ARTIFICIALLY REARED O-GROUP COASTAL COD (*Gadus morhua* L.) IN A LANDLOCKED FJORD IN WESTERN NORWAY

by

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ABSTRACT

In 1983 and 1984 about 14 000 seven month old pond or basin reared coastal cod were tagged and released in Heimarkspollen and Osen in Western Norway. In May 1984 fishing in the release areas was initiated and local fishermen were asked to report recaptures.

Growth of released cod was at least as good as growth of wild cod in the area. The 1983 release contributed about 30% of this yearclass in Osen and about 50% in Heimarkspollen. The 1984 release contributed about 80% of this yearclass in Heimarkspollen. There seems to be no difference in food preference between released and wild cod. The reared cod are very stationary.

INTRODUCTION

As part of a tagging and release experiment in Western Norway with artificially reared cod (Svåsand, 1985), detailed investigations were initiated in 1984 at two of the release locations. The purpose of these investigations was primarily to study and compare growth, feeding and maturation of wild versus released cod. An attempt was also made to calculate predation and cannibalism on released cod compared to wild. Blaxter (1976) has suggested that laboratory raised cod are too naive to avoid predators. It would be of great interest for further large scale releases to find out if this is also the case for pond and basin raised cod.

Determining the optimal fish density in an area and the optimal size and time for release is of great economic interest. In 1984 nearly 8000 cod were released in Heimarkspollen, a 3 km^2 landlocked fjord. Special attention was directed to this release to detect a possible decline in growth rate or a change in migration patterns indicating too high fish density in the release area. The cod were graded in four size groups, to detect possible differences in mortality and growth between these groups.

MATERIAL AND METHODS

The fish released in 1983 were reared in a pond (Øiestad *et al*., 1985) and those released in 1984 were reared either in a pond or a basin (Øiestad *et al*., 1984).

Tagging

In October-November, the six to seven month old juveniles were starved for at least 48 hours prior to tagging. All cod in 1983 were tagged with Floy Anchor Tags (FAT, Svåsand 1985) while in 1984 about half of the fish were tagged with the anchor tags and the rest with Internal Steel Tags (IST, Fig. 5). Internal Steel Tags have earlier been used for tagging 0-group cod (Moksness and Øiestad, 1984). The cod were kept for at least three hours before release to remove dead or injured fish due to tagging.

Release

Altogether six groups were released:

83-1 released 1983 in Heimarkspollen(Fig. 1)
83-2 released 1983 in Osen, the fjord outside Heimarkspollen
84-1 small
84-2 medium – four size groups released 1984
84-3 large in Heimarkspollen
84-4 extra large

Table 1 gives the fish size at release and tag types of each group.

The cod were released in shallow nearshore water, one by one or in groups of about 25. During the release in 1984 divers observed the behaviour of the fish during the first minutes of freedom. Gill nets were set to catch potential predators (Table 2) and stomachs from fish caught in the gill nets were examined for tagged cod juveniles.

Tag return

Local fishermen and households have received an information form, requesting them to be on the lookout for tags and to fill out the catch form regarding the recapture area and the fish characteristics (Fig 1, Svåsand 1985). The fishermen receive a reward of 20 Nkr a tag.

Fish samples

Periodic fishing for tagged and wild cod in Heimarkspollen and Osen began in May 1984 (Table 4). As the rocky bottom prohibits beach seining or trawling, we used trammel nets with small-meshed, loosely hung inner nets (Fig 2). These nets are believed to be size selective only for small fish. To test this we used two different mesh lengths (70 mm and 45 mm) of inner net and compared the mean length of the different age groups caught by the two net types. If the nets were sampling in the same way and were not size selective, we should expect an equal length distribution of each age group caught by the two net types.

The nets were placed between 2 - 25 m depth, after recommendations by local fishermen. Only a few tagged cod were reported caught deeper than 20 m.

All cod were measured for total length in cm, rounded downwards, weight to nearest 5 g (both roundfish and gutted), and maturity stage was recorded. Otoliths were taken to calculate the age of wild fish. All stomachs with contents were preserved in 4% formaldehyde within two hours after the nets were taken from the sea. Empty and regurgitated stomachs were regcorded but not preserved. For other species the number of each fish species was recorded, total length was measured for most of the fish and some individuals of different size were weighed to calculate length-weight relationships for the most abundant species.

Growth

Only an increase in length has been considered. A regression line where Length = a Age + b, was fitted by the least squares method (Sokal and Rohlf, 1981) to the data of captured cod, both released and wild. Wild captured cod were separated into two groups:

W-1 wild cod captured in Heimarkspollen.
W-2 wild cod captured in Osen.

For captured cod from all released groups the daily length increment was calculated from:

$$DLI = \frac{L_2 - L_1}{T_2 - T_1}$$

where L_1 is mean length of the group (Table 1) at time of release (T_1) and L_2 is individual length at time of recapture (T_2).

Length data was taken both from our own fish samples and the returned catch forms. Recaptured cod which had migrated out of the release area were omitted from the growth calculations. The birthday of all cod was set to April 1.

The length data were statistically analysed by BMDP statistical software (Dixon, 1981). A F-test was used to test regression lines and a Student t-test was used to test equality of DLI between the groups.

Analysis of stomach contents

After removal of excess moisture the stomach contents was weighed (mg). Each food item in the stomach contents was identified to species, or as low a taxa as possible. Total length (mm) of each prey was measured for later weight calculations and size preference studies.

Number percent (N%) and frequency of occurrence (F%) were calculated, where:

$$N\% = \frac{n_i * 100}{\Sigma n_i}$$, n_i = total number of species i found in stomachs,

F% = frequency in percent of the stomachs containing this species or species group.

Only data from the catches in November and December, 1984, were available. Any difference between the food preferences of released and wild cod were tested by using the formula for Niche Overlap (α) (Pianka, 1975):

$$\alpha_{r,w} = \frac{\Sigma(p_{ir} * p_{iw})}{\surd(\Sigma(p_{ir})^2 * \Sigma(p_{iw})^2)}$$

where p_{ir} is the proportion of food category i in the stomach contents of released cod, and p_{iw} that of wild cod. Identical diet gives $\alpha = 1$.

RESULTS AND DISCUSSION

Observations during release in 1984

Two divers observed the behaviour of the cod as they were released from a boat at two locations. One location was near a wharf in 2-3 m water where the bottom consisted mostly of large boulders sloping down to 10 m at an angle of 30^0. The other location was near a cliff which went straight down to about 7 m depth. At both locations the cod were released one by one and in groups of about 25.

When released in groups they formed a more or less compact school and descended quickly to the bottom, where they hid between the rocks. Some of them did not follow the school and swam around in the water column, but within 2-3 minutes they also had found a hiding place. The individually released cod swam more randomly and seemed to spend more time to find a hiding place. The cod released by the cliff had more problems finding the bottom and spent a longer time in the water coloumn.

The fish in the water column had a tendency to join schools of later released groups or individual fish passing by. Two cod even followed a much larger pollach (Pollachius pollachius L.). This behaviour of following a moving object, is described as an "optomotor reaction" (Pavlov, 1967) and is believed to be a means of orientating in water currents and maintaining contact within a school. This behaviour may be used to transport the fish quickly to the bottom by releasing the fish in small schools in shallow (2-3 m) water with good hiding places. Predation by birds, although no problem during the release in 1984, can be avoided by releasing the fish through a two meter long tube.

Predation / Cannibalism

During the release period (Nov. 26 - Dec. 5, 1984) we were fishing with trammel nets to catch potential predators and to see if their stomachs contained any cod fry or tags. Table 2. shows the gear and catches, and Fig. 4 the length distribution of the most abundant species: cod, pollach, saithe (Pollachius virens L.).

Four tags were recovered, three in pollach (36.5cm, 40.5 cm and 43.5 cm) and one in a ballan wrasse (Labrus bergylta Asc., 36.0 cm). One wild cod (9 cm) was found in a pollach (42.5 cm). All tags were Internal Steel Tags (IST), three from the small size group (84-1) and one from the medium (84-2, caught by the largest pollach). No tagged or wild cod were found in cod or saithe stomachs.

From these results it seems that pollach is the main predator on juvenile cod in the area and that the smallest size group is most vulnerable. The ballan wrasse is not known to be a major piscivore (Dipper et al., 1977), and their narrow mouth would also indicate this. We have during diving observed this species eating dead crabs and fish, so it is possible the consumed cod was dead or wounded.

Cannibalism was not observed during the release, but in April 1985 we caught an 83 cm long cod who had eaten two tagged cod. The stomach contents data are not yet available for the other sampling periods, but from available data cannibalism seems to be rare. From the North Sea, Daan (1973) estimated that cannibalism on the very abundant 1970 yearclass constituted 3% of total food consumed in the Southern and 20% in the Northern North Sea. Strzyzewska (1959) estimated cannibalism in Eastern Baltic at 4%. These are all areas with flat sandy bottom with few hiding places which may lead to more cannibalism then in a coastal rocky bottom area.

The saithe stock in the area consists mostly of premature 0-II group fish. Although very abundant, they are hardly any danger to juvenile cod larger than 10 cm. However, they may prey on cod fry in the first pelagic phase, as has been observed in nearby areas (Nedreaas, 1984).

To get an estimate of predation/cannibalism mortality these results are too limited. To estimate this we need population estimates of the potential predator species and further stomach contents investigations to calculate the ratio of juvenile cod in the diet.

Tag return

Recaptures to June 1. 1985 are given for each group and tag type in Table 3. Most of the returns from the release in 1983 (86%) are reported by local fishermen and game fishers, but nearly all recaptures from the release in 1984 (93%) are from our own fishing (Table 4). The 1984 release had the greatest recapture of the large size groups (84-3 and 84-4) tagged with

FAT. This may however be an artifact of gear selectivity or low detection of the IST. No significant difference was found in returns of individual or group released cod.

The cod appear to be fairly stationary as no recaptured cod released in 1984 had migrated more than 2 km and less then 10% of those released in 1983 had migrated further. Same results were found by Løversen (1946) of tagged wild cod and Moksness and Øiestad (1984) of pond reared cod released on the Norwegian Skagerak Coast.

Growth

Growth calculations are dependent on representative samples from the population. Table 8 gives mean length and standard deviations of the age groups caught in the two net types used in the fishing (Table 4). The results show that the 70 mm nets are selective on I-group cod, whereas age group II and older are caught nearly equally by the two mesh sizes, supporting our assumption that trammel nets are not size selective on large fish.

The fishermen in the area use both trammel and ordinary gill nets with mesh lengths 90 mm and larger and game fishing is mostly done by angling and different types of gill nets. The catch forms do usually not contain information on mesh and hook size, making it difficult to calculate gear selection. Most of the fishing gear used in the area will, however, give an underrepresentation of the youngest age groups.

All available length data are used in the growth calculations. For wild fish, length data from several age groups are used.

The results of linear regression analysis are given in Table 6 and Fig. 3. The results from 84-1, 84-2, 84-3 and 84-4 are not given because of the few returns and the short time intervals between the first and last returns from these groups. All regression lines were significantly different ($P < 0.01$). Fig. 3 indicates higher growth rate for released than wild cod, both in Osen and Heimarkspollen, but because of possible bias in the data, these differences can be an artifact of gear selectivity. However, we will conclude that growth of released cod is at least as good as growth of wild cod in the area. Moksness and Øiestad (1984) also have reported equal growth of released and wild cod on the Norwegian Skagerak Coast.

The daily length increments are calculated for all recaptured cod from all groups (Table 7). DLI for group 84-1 was significantly higher than 83-1 (P < 0.01) but no significant difference was found between the remaining groups released in 1984 and 83-1. This indicates no decrease in DLI for the release in 1984 compared to the release in Heimarkspollen the year before. It is, however, too early to draw any conclusions, because differences might first be detected when the fish grow larger and demand more food. The calculated DLIs are in accordance with calculated growth rates of released cod on the Norwegian Skagerak Coast (Moksness and Øiestad, 1984).

Species composition in the catches.

The results from our own fish samples are summed up in Table 5, which shows catches in winter and summer for the two mesh lengths most used. The dominant species in the catches have been saithe, pollach, cod and three species of labrids (Labrus bergylta Asc., Labrus ossifagus Risso, and Crenilabrus melops L.). The labrids almost disappear from the catches between December and April, when they probably migrates to deeper and warmer water. The cod contribute to about 20% of fish larger than 28 cm and about 10% of fish larger than 18 cm. Saithe and herring are mostly pelagic species and will be under-represented in the bottom net catches. Also small fish like poor cod (Trisopterus minutus L.) and young labrids are under-represented. Gobies (Gobiosculus flavecens and Gobius minutus), which are the most abundant fish species in the area, are not represented at all due to their small size.

Ratio released / wild cod

Table 4 shows the catches of cod in Osen and Heimarkspollen, the gear used and the percent contribution of the released cod to the whole cod stock and to the same yearclass. The 1983 release contributed about 30% of the 83 yearclass in Osen and about 50% in Heimarkspollen. The 1984 release contributed about 80% of the 84 yearclass in Heimarkspollen. Obviously the released fish will have a great influence on the native cod stock, both as competitors of food and space and later as spawners.

Maturity

Table 9 shows the percent and ratio (number spawners/total number) of spawners of different age groups and sexes for the winter-spring 1984 and 1985, based on data from the catches from November to May. Spawners are cod with ripening, ripe or spent gonads.

We found spawning cod already in the I-group, but the majority reach maturity three to four years old, the males generally mature earlier than females. This is about the same maturity age as found for cod on the Sagerak Coast (Dannevig, 1954) and in the North Sea (Oosthuizen and Daan, 1974). Between the released and wild cod there is no significant difference (Fisher's exact test of independence, Box 17.10, Sokal and Rohlf 1981) in percent spawners in age group I and II.

Stomach contents

Because of the limited data available, only the food preference of wild and released cod are compared. Table 10 shows the results from the stomach contents analysis of cod 30-39 cm long from samples taken in November and December 1984. This length group represents most of the 1983 year class.

Wild and released cod have a niche overlap for number percent (N%) of $\alpha = 0.930$ and for frequency of occurrence (F%) of $\alpha = 0.906$. Although these coefficients are based on data from a short period of the year and on a relatively small sample, they indicate that there are no differences in food preference between released and wild cod.

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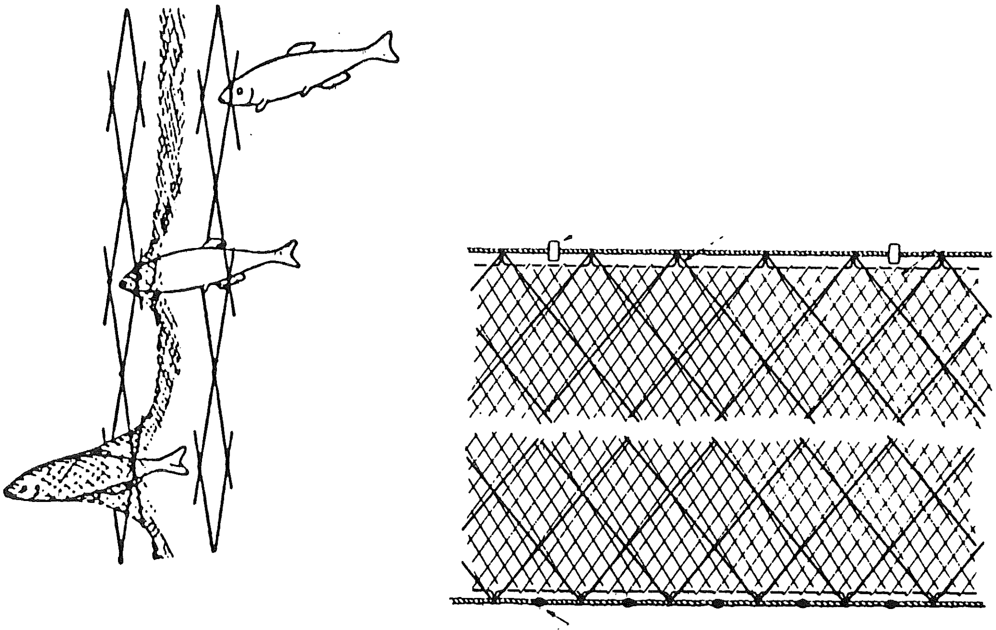

Fig. 2. Trammel net. The fish entangle themselves by forming a pocket of the small meshed webbing between the two big meshed walls (Left: von Brandt 1972).

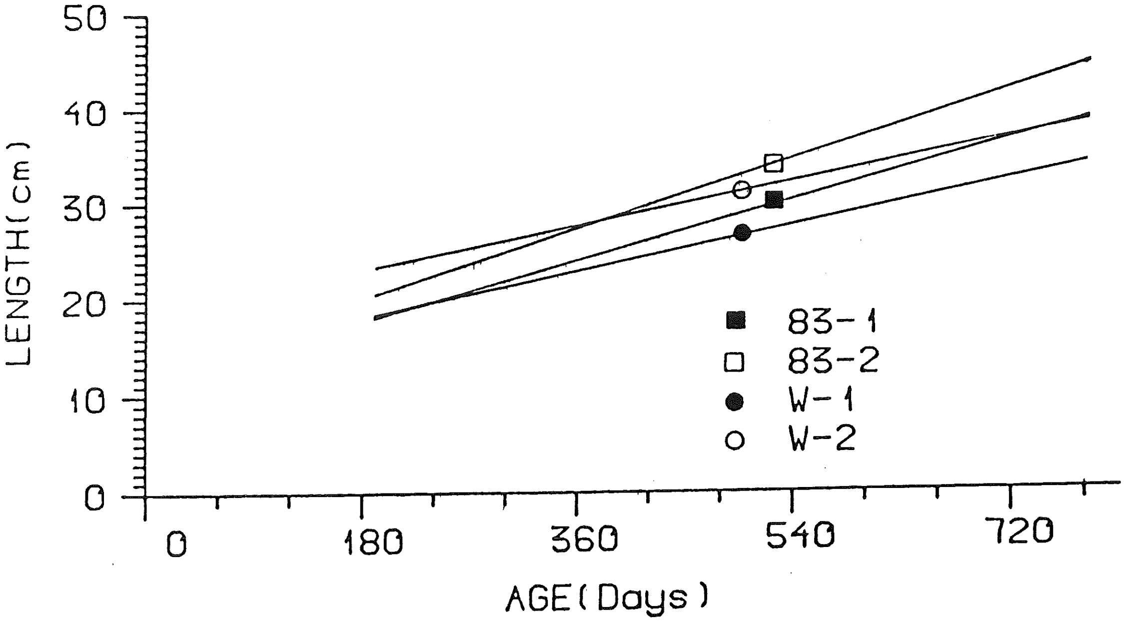

Fig. 3. Regression lines for group 83-1, 83-2, W-1, W-2. For regression parameters see Table 7.

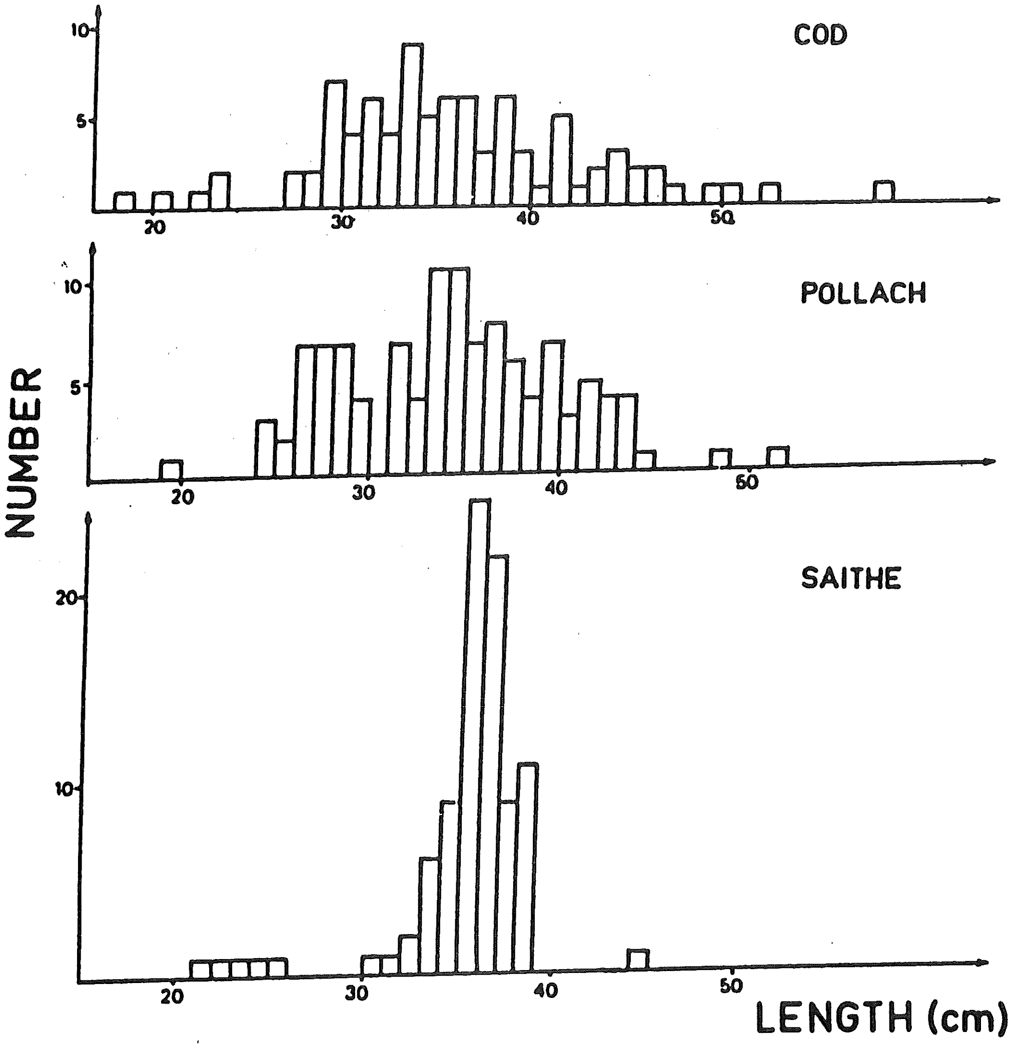

Fig. 4. Length distribution of cod, pollach and saithe from trammel net catches during the release period 1984.

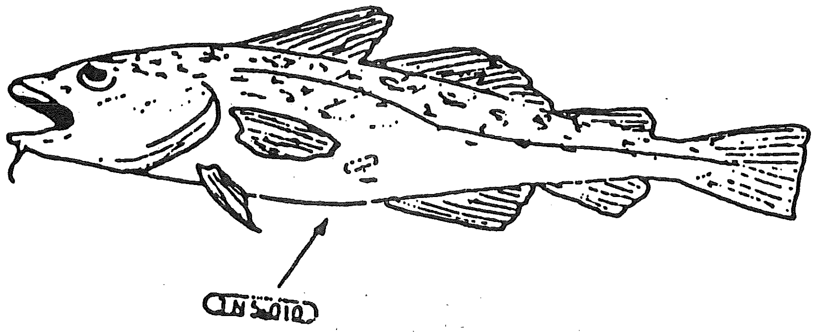

Fig. 5. A tagged cod fry with Internal Steel Tag (IST). (Moksness and Øiestad 1984).

Table 10. Stomach contents of released and wild cod in length group 30-39 cm caught in Heimarkspollen between Nov. 26 and Dec. 6. 1984. N% = number percent and F% = frequency of occurence of this prey found in stomachs.

	Released N = 13			Wild N = 22		
Prey	N	N%	F%	N	N%	F%
Gobidae	18	7.2	53.8	16	5.8	40.9
Labridae	0	0.0	0.0	1	0.3	4.5
Pisces unid.	1	0.4	7.7	2	0.7	9.1
Macropipus arcuatus	34	13.5	69.2	23	8.4	50.0
Macropipus sp.	1	0.4	7.7	4	1.5	13.6
Cancer pagurus	0	0.0	0.0	3	1.1	9.1
Pagurus bernardus	2	0.8	7.7	0	0.0	0.0
Pagurus sp.	4	1.6	23.0	0	0.0	0.0
Upogebia stellata	1	0.4	7.7	0	0.0	0.0
Galathea nexa	8	3.2	23.0	11	4.0	27.3
G. squamifera	1	0.4	7.7	2	0.7	9.1
G. strigosa	3	1.2	7.7	0	0.0	0.0
G. intermedia	1	0.4	7.7	0	0.0	0.0
Galathea unid.	10	4.0	46.1	19	6.9	40.9
Thoralus cranchii	15	6.0	30.8	38	13.8	31.8
Hippolyte varians	22	8.8	38.5	31	11.3	27.3
Eualus pusiolus	5	2.0	30.8	3	1.1	9.1
Hippolytidae unid.	68	27.1	69.2	89	32.4	54.5
Gammaridae	11	4.5	38.0	5	1.8	13.6
Preunus flexousus	40	15.9	15.4	24	8.7	36.4
P. inermis	3	1.2	23.0	0	0.0	0.0
Polychaetae	3	1.2	23.0	0	0.0	0.0
Acidiacea	0	0.0	0.0	2	0.7	4.5
Gasthropoda	0	0.0	0.0	2	0.7	9.1

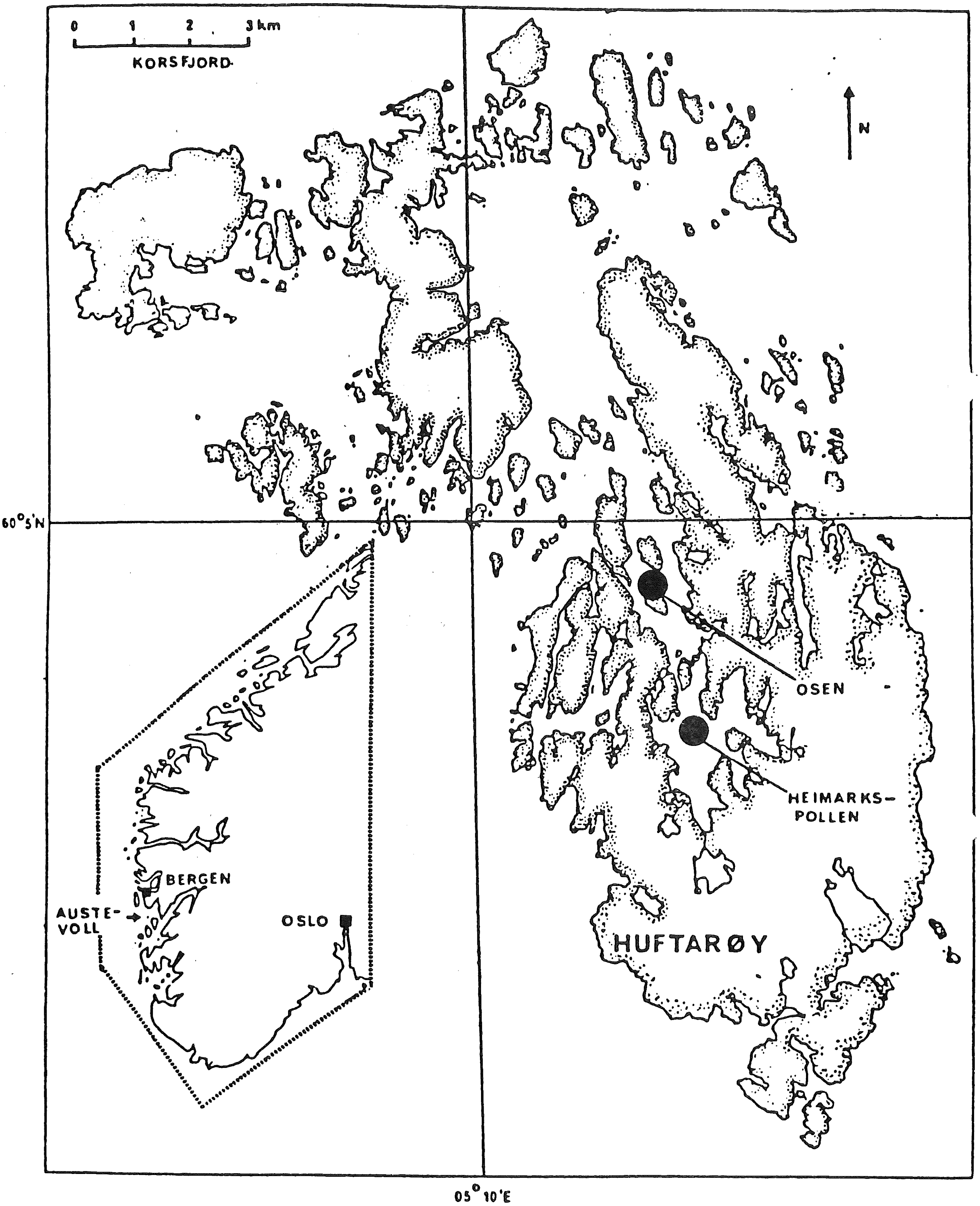

Fig. 1. Map of two of the release areas for juvenile cod in Austevoll in 1983 and 1984.

Table 5. Species composition in the catches in the different fishing seasons in both Osen and Heimarkspollen.

Entangling nets:	70 mm mesh length				45 mm mesh length			
Species	May-Aug 119 nets		Oct-Feb 81 nets		May-Aug 48 nets		Oct-Apr 77 nets	
GADIDAE	N	%	N	%	N	%	N	%
Gadus morhua L.	234	24.1	138	19.4	68	9.0	109	12.2
Pollachius virens L.	298	30.7	301	42.2	136	18.1	196	22.0
P. pollachius L.	82	8.4	160	22.4	118	15.7	242	27.2
Trisopterus minutus L.	15	1.5	14	2.0	41	5.4	41	4.6
Merlangius merlangus L.	2	0.2	5	0.7	2	0.3	8	0.9
Raniceps raninus L.	8	0.8	-	-	1	0.1	-	-
LABRIDAE								
Labrus bergylta Asc.	259	26.6	66	9.3	173	23.0	59	6.6
Labrus ossifagus Risso.*	15	1.5	2	0.3	90	12.0	122	13.7
Crenilabrus melops L.	6	0.6	2	0.3	111	14.7	90	10.1
Ctenolabrus rupestris L.	4	0.4	1	0.1	-	-	-	-
FLATFISH								
Microstomus kitt Walb.	15	1.5	3	0.4	1	0.1	1	0.1
Pleuronectes platessa L.	6	0.6	1	0.1	1	0.1	-	-
Platichtys flesus L.	3	0.3	2	0.3	-	-	3	0.3
Limanda limanda L.	2	0.2	-	-	-	-	-	-
Hippoglossoides platessoides Fabr.	1	0.1	2	0.3	2	0.3	-	-
Zeugopterus punctatus Bloch.	2	0.2	1	0.1	-	-	-	-
OTHERS								
Merluccius merluccius L	-	-	1	0.1	-	-	1	0.1
Anarhicas lupus L.	3	0.3	-	-	-	-	1	0.1
Lophius piscatorius L.	-	-	1	0.1	-	-	-	-
Acanthocottus scorpius L.	4	0.4	1	0.1	6	0.8	-	-
A. liljeborgi Coll.	-	-	-	-	-	-	2	0.2
A. bubalis Euphr.	-	-	-	-	-	-	1	0.1
Trachinus draco L.	-	-	-	-	1	0.1	-	-
Sebastes viviparus Kr.	-	-	-	-	-	-	1	0.1
Trachurus trachurus L.	-	-	1	0.1	-	-	1	0.1
Scomber scombrus L.	-	-	-	-	-	-	1	0.1
Cyclopterus lumpus L.	-	-	1	0.1	1	0.1	-	-
Clupea harengus L.	13	1.3	10	1.4	1	0.1	9	1.0
Salmo trutta L.	-	-	-	-	-	-	1	0.1
Anguilla anguilla L.	-	-	-	-	-	-	1	0.1
Squalus acanthias L.	-	-	-	-	-	-	1	0.1
Total	972	100.0	713	100.0	753	100.0	891	100.0

* some Centrolabrus exolotus L. are included in these numbers.

Table 6. Regression equations for the relationship between length (cm) and age (days) for captured fish from the groups 83-1, 83-2, W-1 and W-2. Length = a Age + b.

Group	a	b	N	R	P(R)
83-1	.0350	11.397	231	.628	< 0.005
83-2	.0403	12.877	247	.669	< 0.005
W-1	.0263	13.459	120	.789	< 0.005
W-2	.0255	18.521	66	.671	< 0.005

Table 7. Calculated daily length increment rate, DLI, (cm/day) for recaptured cod from each of the released groups in 1983 and 1984.

Group		D L I	
	N	Mean	SD
83-1	231	.0384	.0150
83-2	247	.0492	.0156
84-1	7	.0506	.0089
84-2	29	.0373	.0157
84-3	45	.0358	.0174
84-4	14	.0404	.0162

Table 8. Mean length (m) and estimated standard deviation (s) of age group 0 - V caugth on trammel nets with mesh length 45 mm and 70 mm of inner net.

meshl.	age:	0	I	II	III	IV	V	VI+
45 mm	N	5	96	41	25	8	1	few data
	m	21.6	24.5	34.6	42.2	51.4	52.0	
	s	1.2	3.5	4.2	5.8	8.8	-	
70mm	N	1	96	137	97	27	4	few data
	m	18.0	30.5	34.9	41.5	50.0	50.8	
	s	-	3.3	4.2	7.1	10.1	5.7	

Table 9. Percent and ratio (number spawners/total number) of spawners of different age groups and sex (M=male, F= female). Catches from November to May are used. As spawners are counted fish with ripening, ripe or spent gonads.

	I		II		III	IV	V	VI+
	Released	Wild	Released	Wild	Wild			
M	5.7	10.5	15.8	11.8	73.8	89.5	100.0	100.0
F	3.9	5.0	13.0	19.4	56.1	79.3	100.0	100.0
M	2/35	2/19	3/19	4/34	31/42	17/19	3/3	3/3
F	2/52	1/20	3/23	7/36	23/41	23/29	1/1	1/1