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RESULTS OF INVESTIGATIONS OF MIGRATION PATTERN OF ARTIFICIALLY REARED
COASTAL COD (Gadus morhua L.) IN WESTERN NORWAY

by

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ABSTRACT

Investigations of the migration pattern have been a central part in an ongoing enhancement study of cod in western Norway. In Sept. - Nov. 1983, 20,947 juvenile, basin-reared cod fry were tagged and released at three sites in western Norway.

Tag returns to 01 June 1987 were 15.4% (83-I), 2.0% (83-II) and 20.4% (83-III). Most cod were recaptured in shallow nearshore waters near the release sites. No significant changes in migration pattern with age were found.

There did not seem to be any significant differences between the migration patterns of reared cod and wild cod tagged as juveniles in the same area.

INTRODUCTION

After the breakthrough in mass rearing of cod in 1983 (Øiestad et al., 1985) a tagging and release experiment was initiated in western Norway (Svåsand, 1985). The largest releases were carried out in 1983, and this year 20,947 tagged cod fry were set out in three areas in western Norway.

Before any larger enhancement or restocking program can be initiated, it will be of vital importance to clarify the migration and recruitment pattern of reared cod compared to wild.

This paper presents the results of investigations into the migration patterns of the three groups of reared cod released in 1983, and compares these results to relevant information on migration pattern on wild coastal cod from areas close to the release sites (Høyen, 1964a; Godø et al. 1986).

MATERIAL AND METHODS

Reared cod - 1983 experiment

The fish released in 1983 were reared in a pond (Øiestad et al., 1985). In Sept. - Nov. 1983, 20,947 cod fry were tagged with Floy Anchor Tags (Svåsand, 1985). The main area of release (Fig. 1) was Austevoll ($60^{\circ} 03' N 5^{\circ} 14' E$) where 19,002 cod were set free at 18 different locations (group 83-I). Smaller groups were also released at two other sites in western Norway, group 83-II comprising 958 individuals at Vikanes ($60^{\circ} 42' N 5^{\circ} 40' E$) and group 83-III comprising 987 at Skogsvågen ($60^{\circ} 16' N 5^{\circ} 5' E$).

The juveniles used in this experiment hatched in the end of March 1983 (Øiestad et al., 1985) and birthday of the released groups were therefore set to 01 April 1983. Age of recaptured cod is given in quarter years (Q_1 = April, May, June 1983, Q_2 = July, August, September 1983,, Q_{17} = April, May, June 1987).

Tag return

The tagging experiments were announced in local newspapers and a pamphlet (Svåsand, 1985) including a catch form to fill in information about recaptured cod was sent to local fishermen and households near the release sites. A reward of 25 Nkr. is offered for every returned tag.

Description of displacement

The tag return was grouped in quarter years ($Q_3 - Q_{17}$) calculated from the age of birth, and the following methods were used to describe migration of cod.

1) Mean Absolute Displacement (MAD)

$$MAD = n^{-1} \sum_{i=1}^n r_i \quad (\text{See Fig. 2})$$

n : total number recaptured fish

r_i : displacement distance of recaptured fish no. i

MAD gives mean displacement distance of all recaptured cod from a group.

2) Mean Direction Displacement (MDD, Ψ)

$$MDD = n^{-1} \sqrt{x^2 + y^2} \quad (\text{See Fig. 3})$$

$$x = \sum_{i=1}^n (r_i \sin\theta_i)$$

$$y = \sum_{i=1}^n (r_i \cos\theta_i)$$

MDD gives the mean direction displacement of all recaptured cod from a group, and Ψ gives the angle of displacement.

3) Other methods

To describe the distribution of the displacement distances, percentage cod recaptured closer or equal to 2km (L2), 4km (L4), 6km (L6), 8km (L8) and 10km (L10) from the places of release, and percentage recaptured more than 10 km (G10) and 100km (G100) from the sites of release were calculated.

RESULTS

Tag return

Reported tag return to 01 June 1987 was 2,930 (15.4%) from 83-I, 19 (2.0%) from 83-II and 201 (20.4%) from 83-III (Table 1). Most tag returns were reported in the period from one to three years after release. There were relatively few catches of tagged cod during the first year and after three years in liberty. Compared to 83-I and 83-III, very few tags were recovered from 83-II.

Depth of recapture

Most cod were recaptured nearshore in shallow waters. For all groups, recaptures were most frequent in the upper 20 metres, and few tagged cod were caught deeper than 40 metres (Fig 4.).

Migration

Information on the place of recapture was given for 2,849 of the 3,150 returned catch forms (Table 2).

Most cod (2413, 84,7 %) were recaptured closer than 4 km from the site of release (Table 3), and displacement distances of more than 10 km were only registered for 101 (3.5 %) cod. The most distant recapture were caught in the Tomrefjord ($62^{\circ}36'N$ $6^{\circ}55'E$) 401 km

north from the release area in Austevoll (83-I).

A small increase in the Mean Absolute Displacement (MAD) with age were found in recaptures from 83-I, but not from 83-II and 83-III (Table 2). No significant change in migration directions (MDD, Ψ) with age were found for none of the groups (Table 2).

DISCUSSION

The migration data from the 1983 experiment indicate that reared cod are very stationary both as juveniles and as mature adults (Table 2 and 3). The majority of the cod in the Austevoll region reach maturity at an age of three to four years (Svåsand and Kristiansen, 1985; Svåsand et al., 1987).

Migration of wild cod off the west coast of Norway has been studied by Hysten (1964 a,b), Giskeødegård et al. (1980) and Godø (1983, 1984, 1986) and Godø et al. (1986).

The experiments most comparable to the taggings of reared released cod are those conducted by Hysten (1964a) in 1964 and Godø et al. (1986) in 1981 and 1982. In 1964, wild cod were tagged at the north end of Sotra ($60^{\circ}32'N$ $4^{\circ}55'E$), in 1981 at northeast side of Sotra ($60^{\circ}25'N$ $5^{\circ}01'E$) and in 1982 in the Sørfjord ($60^{\circ}30'N$ $5^{\circ}49'E$).

In the 1964 experiment (Hysten 1964a), cod were tagged during the spawning season, and the fish were probably mainly mature cod. Most of the recaptured cod from this experiment were caught more than 35 km away from the area of release, and the Mean Absolute Displacement (MAD) was about 80 km (calculated from map data in Hysten, 1984a) which is considerable higher than the values found in the Austevoll experiment.

In the experiments from the early 80' (Godø et al., 1986), mainly juvenile cod of 2 - 3 years age were tagged on the nursery grounds in sheltered coastal and fjord areas. Calculations of displacement distances (from map data in Godø et al., 1986) of re-

captured cod gave MAD = 2 km for the Sotra experiment and MAD = 8 km for the Sjørfjorden experiment.

These results indicate that coastal cod in western Norway, both wild and artificially produced, with nursery grounds in sheltered coastal and fjord areas, are very stationary. The discrepancy between the migration of cod tagged on spawning ground (Hysten, 1964a) and the migration of juvenile cod (Godø et al., 1986) might be a result of difference in the location of the nursery grounds. Godø (1986) found that displacement distances of tagged cod increased when moving from sheltered coastal and fjord nursery grounds towards more exposed offshore grounds. The cod tagged during the spawning season were probably on spawning migration, and might have arrived from more or less distant offshore nursery grounds. The results from the tagging experiments 1981 and 1982 (Godø et al., 1986) indicate no systematic difference in migration with time at liberty, neither in displacement distance nor in migration direction (Godø et al. 1986), which is in accordance with the results in this report.

Also coastal cod near the southern Norway seems to be stationary, as found by Løversen's (1946) tagging of wild cod and Moksness and Øiestad's (1984) release of pond-reared cod on the Norwegian Skagerak Coast.

Based on the the available migration studies, the released reared cod appear not to diverge significantly from its wild counterparts.

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Table 1. Number and percentage reported recaptures from groups 83-I, 83-II and 83-III in each quarter year from release (Sept.-Nov. 1983) to 01 June 1987 (Q₁₇). Numbers released from groups 83-I, 83-II and 83-III were 19,002, 958 and 987.

QUARTER YEARS	EQUIVALENT MONTHS	83-I		83-II		83-III	
		Number rec.	% recaptured	Number rec.	% recaptured	Number rec.	% recaptured
Q ₀	Recapture date not given	78	0.41	0	0.00	3	0.30
Q ₃	Oct.-Dec. 1983	16	0.08	0	0.00		
Q ₄	Jan.-Mar. 1984	41	0.22	0	0.00	0	0.00
Q ₅	Apr.-June 1984	216	1.14	1	0.10	2	0.20
Q ₆	July-Sept. 1984	341	1.79	5	0.52	21	2.13
Q ₇	Oct.-Dec. 1984	314	1.65	0	0.00	50	5.07
Q ₈	Jan.-Mar. 1985	509	2.68	1	0.10	23	2.33
Q ₉	Apr.-June 1985	338	1.78	4	0.42	27	2.74
Q ₁₀	July-Sept. 1985	253	1.33	5	0.52	10	1.01
Q ₁₁	Oct.-Dec. 1985	182	0.96	0	0.00	29	2.94
Q ₁₂	Jan.-Mar. 1986	242	1.27	0	0.00	11	1.11
Q ₁₃	Apr.-June 1986	144	0.76	1	0.10	7	0.71
Q ₁₄	July-Sept. 1986	94	0.49	2	0.21	2	0.20
Q ₁₅	Oct.-Dec. 1986	57	0.30	0	0.00	10	1.01
Q ₁₆	Jan.-Mar. 1987	92	0.48	0	0.00	6	0.61
Q ₁₇	Apr.-June 1987	13	0.07	0	0.00	0	0.00
TOTAL		2,930	15.42	19	1.98	201	20.36

Table 2. Mean Absolute Displacement (MAD), Mean Direction Displacement (MDD) and Angle of Displacement (ψ) for recaptured cod from groups 83-I, 83-II and 83-III at ages in quarter years from release (Sept. - Nov. 1983) to 01 June 1987 (Q₁₇).

Age in quarter years (Q)	83 - I				83 - II				83 - III			
	N	MAD	MDD	ψ	N	MAD	MDD	ψ	N	MAD	MDD	ψ
3	12	.92	.10	133.04	0				0			
4	34	1.34	.31	158.12	0				0			
5	190	1.37	.12	120.74	1	1.00	1.00	.00	2	1.15	1.12	63.76
6	264	1.83	.32	237.29	5	.96	.89	26.52	17	1.73	1.18	38.76
7	278	2.14	.41	204.12	0	.00	.00	.00	43	1.83	.28	121.33
8	482	2.26	.69	218.93	1	1.40	1.40	45.12	23	1.33	.86	10.34
9	321	2.23	.19	254.62	4	1.25	1.25	36.96	27	3.06	1.22	51.13
10	240	2.69	.82	236.00	5	1.24	.63	18.56	10	1.08	.70	82.04
11	167	3.08	1.07	216.55	0				29	1.34	1.08	350.49
12	224	4.27	.26	124.72	0				11	1.69	.92	69.77
13	133	6.73	3.78	18.39	1	1.40	1.40	315.84	7	1.09	.68	342.93
14	86	2.77	.76	320.94	1	1.40	1.40	45.12	2	1.15	.51	.62
15	51	3.09	.23	141.81	0				10	2.21	1.81	.44
16	88	4.53	1.38	126.79	0				5	3.66	3.64	329.38
17	13	4.63	.86	148.66	0				0			

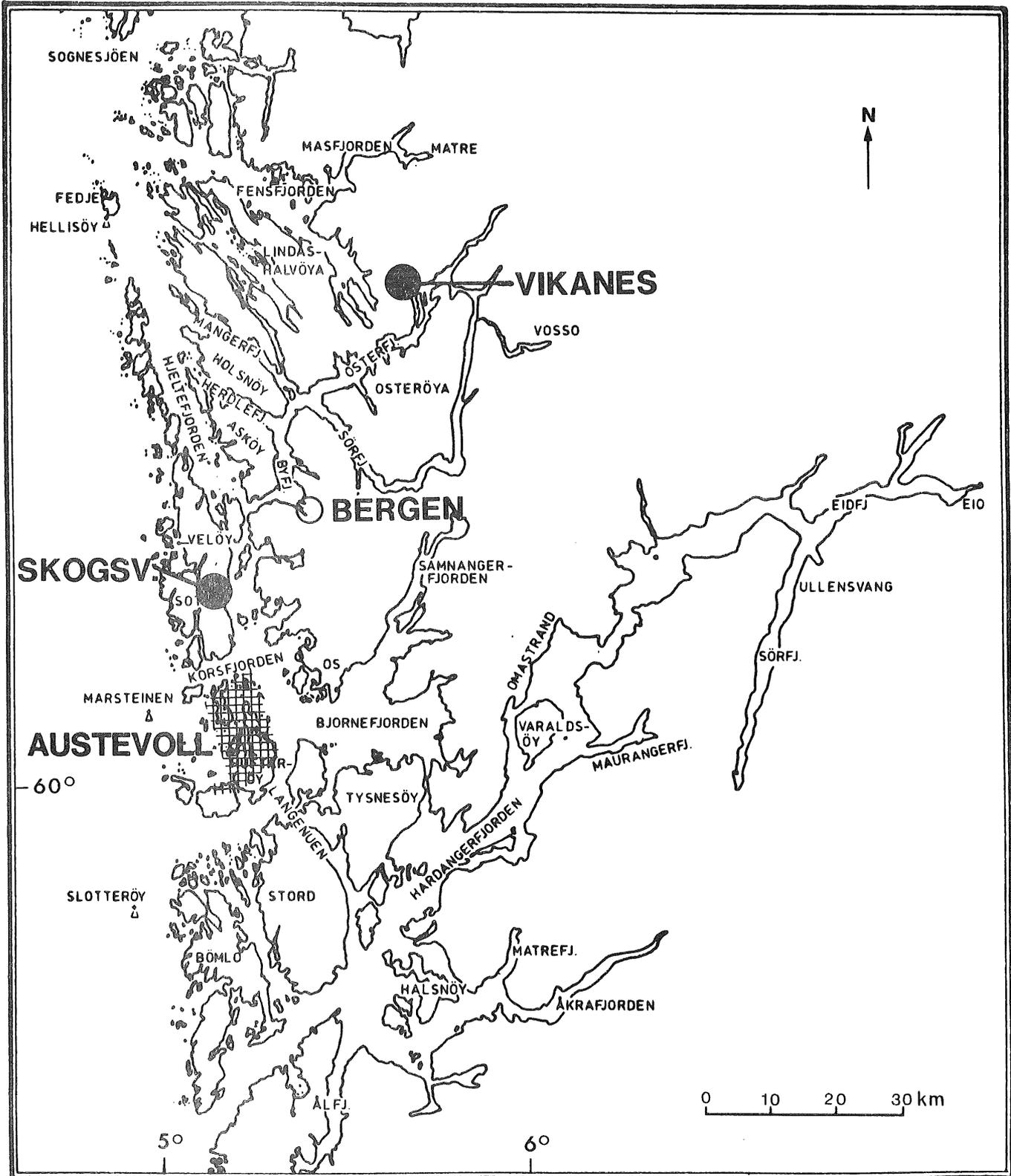


Fig. 1. Map of release sites of juvenile cod in 1983. Group 83-I was released at 18 different locations at Austevoll (squared area), and 83-II at Vikanes and 83-III at Skogsvågen.

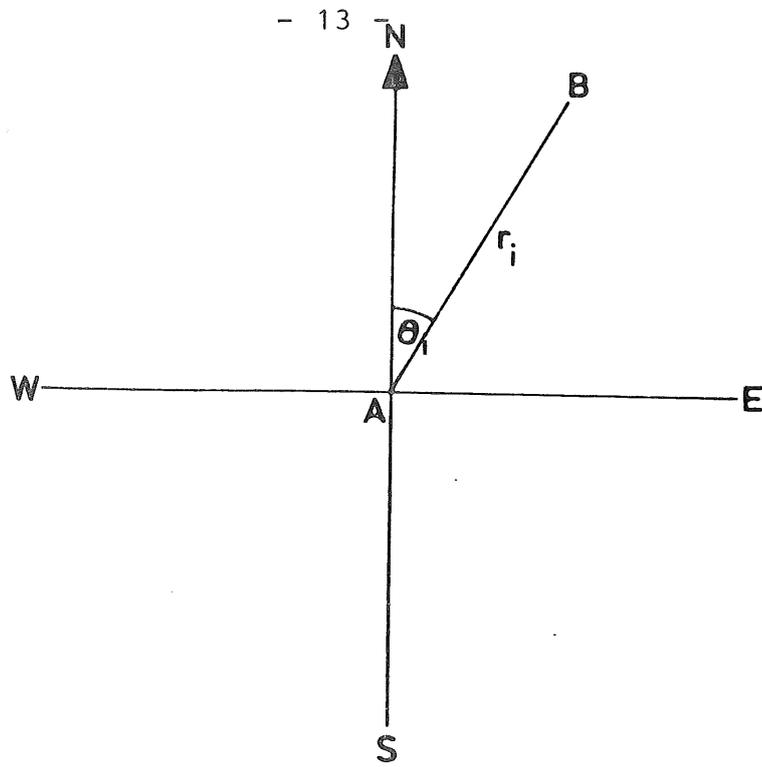


Fig. 2. Showing the relationship between the position of liberation (A) and recapture (B) of fish no. i with reference to the coordinate system NESW. Modified from Jones (1976)

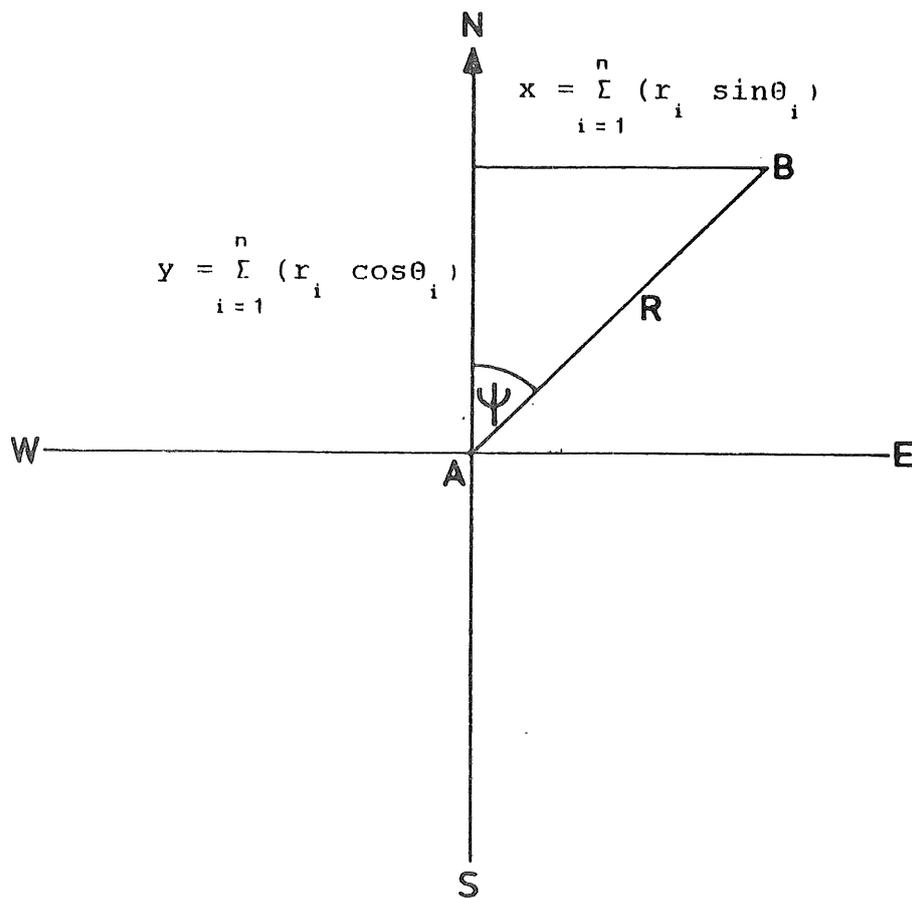


Fig. 3. Determination of Mean Direction Displacement (MDD) and Angle of Displacement (Ψ) with reference to the coordinate system NESW. $MDD = R/n$, $\Psi = \arctg(x/y)$. Modified from Jones (1976).

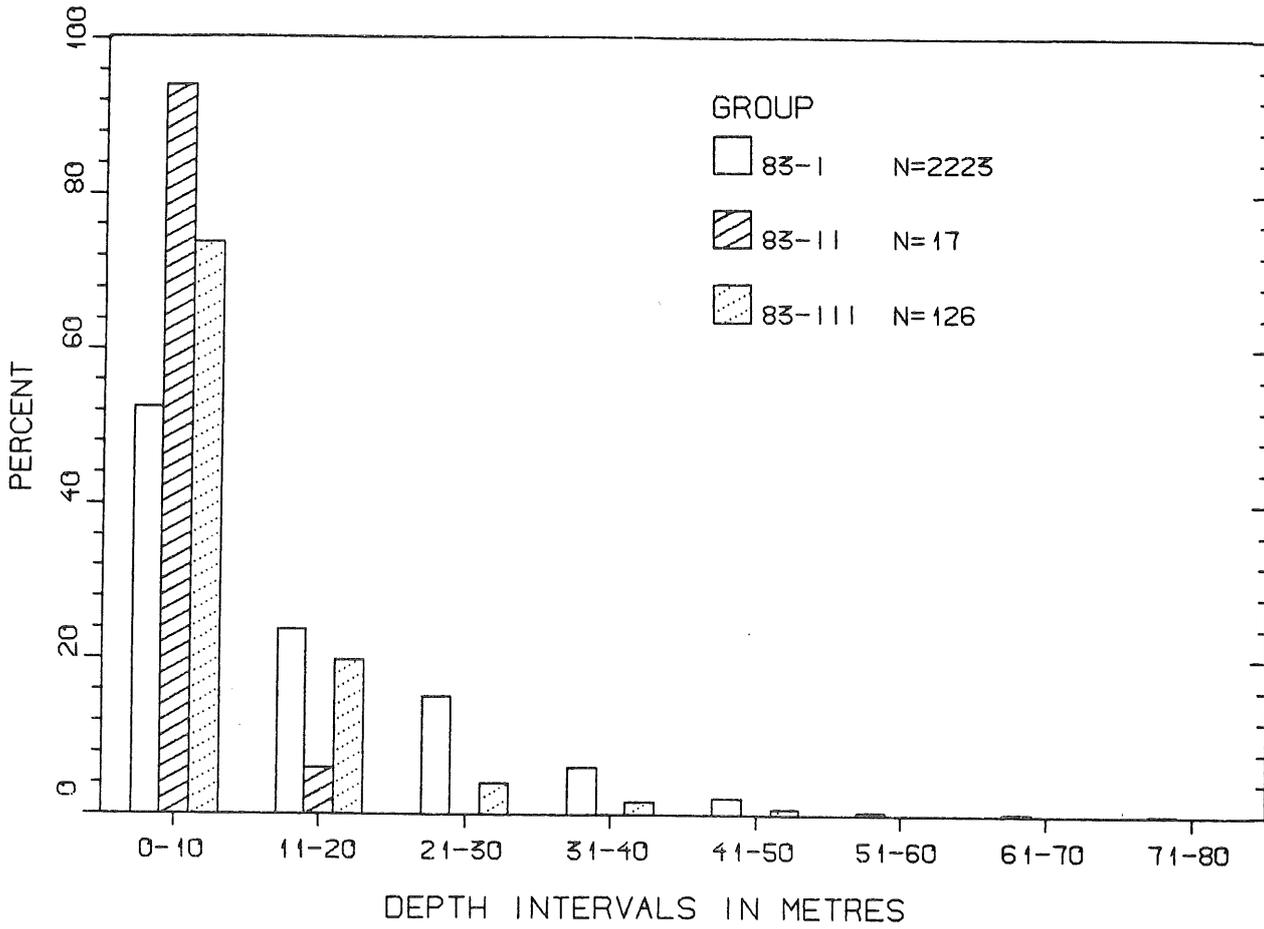


Fig. 4. Distribution of fishing depth of cod recaptured from groups 83-I, 83-II and 83-III. The distribution is given in percentage of total tag return with information of depth of recapture from each group to 01 June 1987.