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TAGGING EXPERIMENTS ON ARTIFICIALLY REARED O-GROUP COASTAL COD (*Gadus morhua* L.) IN WESTERN NORWAY - RESULTS FROM THE RELEASES IN 1984

by

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ABSTRACT

In November - December 1984, 8,038 seven to eight month old pond or basin reared cod fry were tagged and released in Heimarkspollen, a landlocked fjord in western Norway. The aim of this study was to investigate whether recapture rate (survival) was influenced by tagging method, release method or size at release, and to study the growth pattern of the different size groups after release. The juveniles were graded in four size groups and tagged with either Internal Steal Tags or Floy Anchor Tags. The fry were released in shallow nearshore waters one by one or in small groups.

Tag return to 01 June 1987 from fishing surveys and recaptures reported by local fishermen were 7.6 %. There were no significant differences in percentage recaptured between cod tagged with Internal Steal Tags and Floy Anchor Tags or between single and group released fry. The recapture rates increased with increasing size at release, which indicated size dependent mortality. There was a tendency of growth compensation in the smallest size groups, and for recaptured cod older than two years there was no significant difference in mean length at age between the size groups.

INTRODUCTION

An enhancement program with artificially reared cod was started in western Norway in 1983 and by now nearly 50,000 tagged codling have been released at Austevoll and nearby regions.

Determination of optimum fry size and method of release will be of great interest in a future large scale enhancement or restocking program with cod. From an economical point of view, it is best to release the codling as early as possible due to high price of dry pellets which the fry are fed on. Natural mortality caused by predation is, however, probably size dependent, as found by Daan (1983) in the North Sea. Groups released at a too small size may therefore be havily reduced by predation or cannibalism.

This paper primarily deals with comparison of recapture results between groups, with different sizes (mean lengths), release methods and tag types, released in 1984. The aims were to find possible correlations beween recapture rates and size at release, tagging methods, or release methods. Further information on results from the tagging and release project in Austevoll are given by Svåsand (1985), Svåsand and Kristiansen (1985), Kristiansen (1987), Svåsand _et al_. (1987) and Svåsand and Godø (1987).

MATERIAL AND METHODS

The cod released in 1984 were reared either in a pond (Øiestad _et al_., 1985), or a basin (Øiestad _et al_., 1984).

Tagging and release

During 22 Nov. - 05 Dec. 1984, 8,038 seven to eight month old juveniles were tagged, about half of the cod with Floy Anchor Tags (FAT) and the rest with Internal Steal Tags (IST) (Svåsand, 1985; Svåsand and Kristiansen, 1985). The juveniles were prior to tagging graded in four size classes (Table 1). Earlier experiments had indicated that FAT should not be used on cod fry smaller than 14 - 15 cm (unpublished data). Moksness and Øiestad (1984) reported successful tagging of cod smaller than 14 cm with IST and this tag type was therefore chosen for the smallest size group.

The cod were released in Heimarkspollen (Fig. 1), a 2,9 km^2 land-locked fjord in western Norway. The bottom consists mainly of rock and boulders, but there are also areas of sandy or muddy bottom. The largest depth is 117 metre, about 1.0 km^2 is shallower than 20 metre and 1.2 km^2 is deeper than 40 metre. The connection to the outside fjord (Osen, Fig. 1) is through three narrow sounds, where the largest is about 3 metre deep and 30 metre wide.

From May to October the watermasses have a thermocline at a depth of about 30 metre. Below the thermocline the temperature is constant about 5^{0}C, but in the upper layer the temperature varies from 2^{0}C in the winter to more than 15^{0}C during the warmest time of the summer. The oxygen contents of the water can be close to zero near the bottom in the deepest part of the fjord, and in late autumn there can be oxygen contents less than 5 ml/l up to 50 m depth. The deep water is usually exchanged during the winter, by salter and colder water from the outside fjord. (T. Brattegard, Departement of Marin Biology, University of Bergen, unpublished data). The salinity ranges from 31.5 to 32.5 $^0/_{00}$ and is only slightly less than in the outside fjord.

The juveniles were set free in nearshore water, one by one or in groups of about 25. Half of each group listed in Table 1 were released one by one and the rest in groups. When released singly the distance between each cod was about 1 metre and groups of 25 juveniles were released about 25 metre apart.

For each tag, information on date of release, release site (within 500 m), size class (1-4), tag type (FAT/IST), and method of release (single/group) were registered.

Table 1. Number and fish size (Number measured (N), Mean (Length and Weight) and Standard deviation) for each released group. The groups are separated in Internal Steel Tagged (IST) and Floy Anchor Tagged (FAT).

Group	Number released		LENGTH			WEIGHT		
	FAT	IST	N	Mean (cm)	Sd	N	Mean (g)	Sd
84-1		1,113	193	12.1	1.34	193	14.8	5.31
84-2	1,575	1,551	581	15.9	1.38	578	39.5	11.62
84-3	1,585	1,126	535	18.6	1.66	534	65.1	19.90
84-4	594	494	194	21.2	1.26	194	97.1	17.17

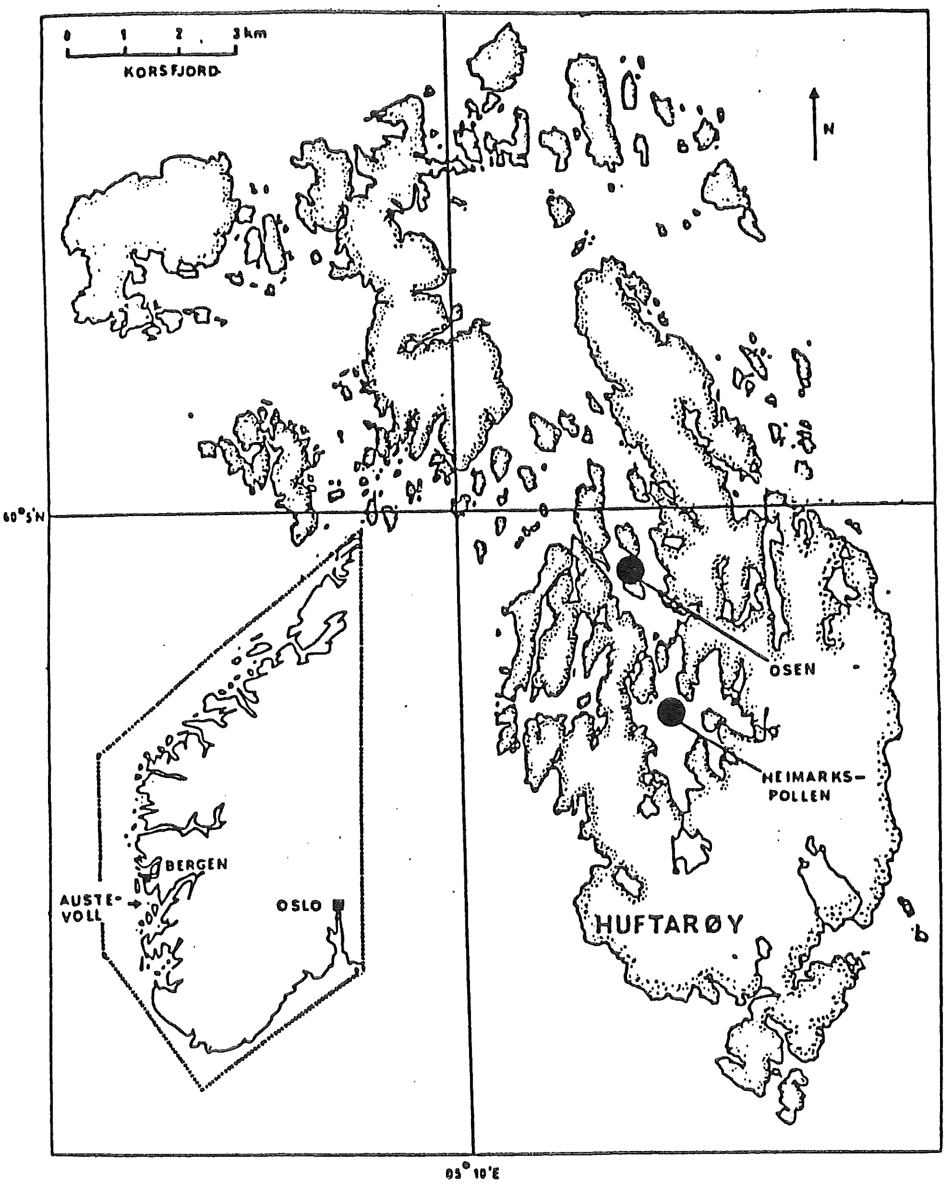

Fig 1. Map of the release area (Heimarkspollen) for juvenile cod in Austevoll in 1984.

Fishing surveys and catch forms

Fishing for tagged and wild cod in Heimarkspollen was initiated in May 1984 (Svåsand and Kristiansen, 1985). Results from the periodic fishing from December 1984 to March 1987 were used in this paper (Table 2).

Table 2. Catches of cod and sampling gear used in fishing surveys from December 1984 to March 1987. Gear is labeled with T-trammel nets, S-singel walled nets, and stretched mesh length (e.g. T-70 is trammel nets with 70 mm mesh length in inner net). Index 'rel-84' is recaptures of cod released in 1984, 'wild-84' is wild cod of the 1984 year class, ΣN_{rel} and ΣN_{wild} is total catches of released (1983 to 1986) and wild cod (all year classes).

FISHING PERIOD	SAMPLING Type	GEARS No.	CATCHES OF COD N_{rel-84}	$N_{wild-84}$	ΣN_{rel}	ΣN_{wild}
December.. 1984	T-70	12	0	0	10	25
	T-45	12	4	1	6	16
Feb., Mar. 1985	T-70	15	0	0	7	15
	T-45	14	12	3	16	12
	S-39	20	16	3	16	4
April..... 1985	T-45	18	17	5	21	17
	S-39	15	8	6	8	10
May....... 1985	T-70	18	4	3	8	26
	T-45	18	19	4	21	15
	S-39	15	10	3	11	7
Feb., Mar. 1986	T-104	16	4	1	5	2
	T-45	5	0	2	15	14
Apr., May. 1986	T-48	80	13	17	64	87
	T-45	62	17	9	42	62
	S-39	71	6	7	38	61
Oct., Nov. 1986	T-70	66	11	8	45	37
	T-48	73	2	1	32	33
March..... 1987	T-104	28	3	4	5	10
	T-70	28	2	7	10	31
	T-48	48	1	1	18	43
	T-45	33	1	0	11	27
Total		667	150	85	409	554

Local fishermen and households received information and catch forms, requesting them to be on the lookout for tagged cod 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 25 Nkr per tag. Data from returned catch forms were compared to results from the fishing surveys for testing possible differences in recapture rate and catchability between the size groups.

A binominal test (Norusis, 1986) was used to compare the proportion between groups at recapture against the proportion at release. Returns of Internal Steel Tags (IST) from local fishermen (catch forms) were not used, since the tags are difficult to find for untrained people and no information had been given about the release of cod with this tag type.

Growth

The main goal of the growth study was to investigate the development of the size differences between the size groups. The recaptures were grouped in quarter of years (Q_3 - Q_{12}) calculated from age of birth (01 April 1984), (e.g. Q_1 = April, May, June 1984, ..., Q_3 = October, November, December 1984, ..., Q_{12} = January, February, March 1987). Mean lengths were calculated for the four size groups recaptured in each three months period, and comparisons of mean lengths were done by analysis of variance (Single classification ANOVA, Sokal and Rohlf, 1981). All recaptures from Heimarkspollen (both fishing surveys and returned catch forms) with length and date of recapture registered, were used in the analysis.

RESULTS

Tag return

Reported tag return to 01 June 1987 (Table 3) were 621 (7,7 %), where 150 (1,9 %) were recaptured in the fishing surveys and 471 (5,9 %) by local fishermen and others (returned catch forms). Most of the cod were recaptured in Heimarkspollen (568, 91,5 %), 51 (8,2 %) were recaptured in Osen (Fig. 1) and 2 (0,3 %) outside Osen.

Neither methods of release nor tag types seemed to have any influence on recapture rate. No significant difference between the proportion single/group released cod were found in the recapture data compared to the proportion at release (fishing survey, p=0.43; returned catch forms, p=0.82). The proportion FAT/IST in the fishing surveys was not significant different from the proportion at release (p = 0.97).

Table 3. Number and % recaptured cod in fishing surveys and from returned catch forms to 01 June 1987. Tag returns with incomplete information on tag no., fishing place or date are not given.

Group/Tag	Number released	TAG RETURNS Fishing surveys		Returned catch forms	
		N	%	N	%
84-2/FAT	1,575	24	1.5	112	7.1
84-3/FAT	1,585	30	1.9	178	11.2
84-4/FAT	594	11	1.9	83	14.0
84-1/IST	1,113	15	1.3	25	2.2
84-2/IST	1,551	26	1.7	31	2.0
84-3/IST	1,126	23	2.0	32	2.8
84-4/IST	494	10	2.0	8	1.6

The recapture percentage from size groups seemed to increase with increasing sizes at release (Table 3), however, a significant difference was only found between 84-2-FAT and 84-4-FAT in the returned catch forms ($p < 0.01$).

Size groups 3 and 4 appeared nearly three months before group 2 in the returned catch forms (Fig. 2). The relative differences in recapture rates between the size groups were highest the first year after release. From November 1985 the recapture rates were nearly equal for size groups 3 and 4, but still lower for size group 2 (Fig. 2).

In the fishing surveys the recapture percentage of size group 1 was lower than for group 2, 3 and 4, and the differences between size group 2 and the two largest size groups were smaller than those found in the returned catch forms (Table 3). The recapture percentages were equal for size groups 3 and 4.

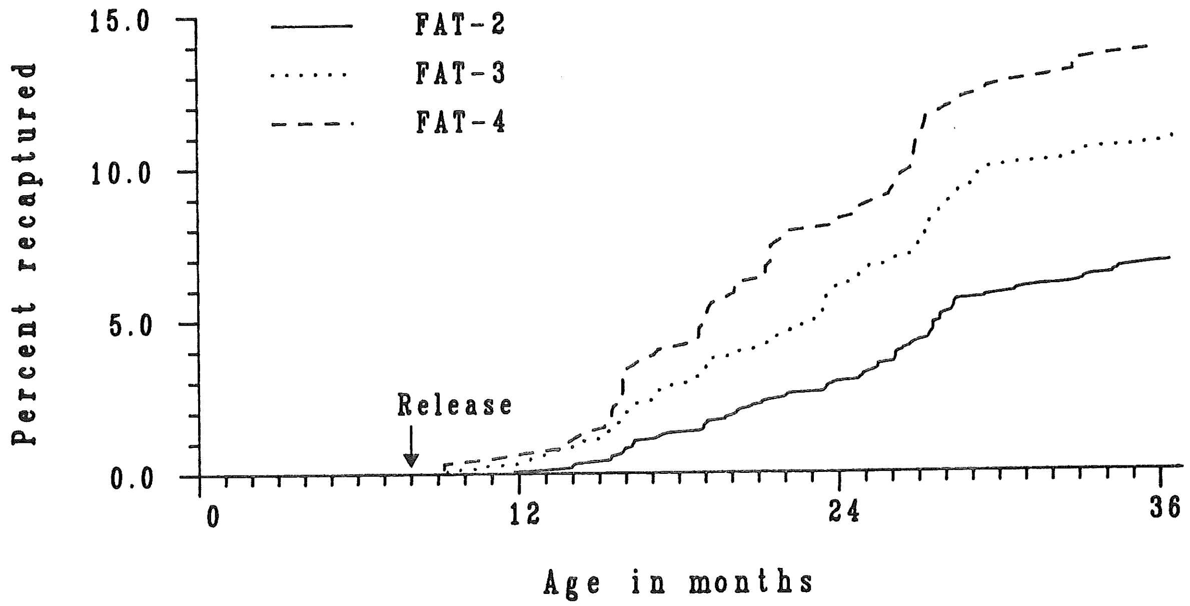

Fig. 2 Percent recaptured cod (cumulative) from groups 84-2-FAT, 84-3-FAT and 84-4-FAT, at ages (in months) of recapture.

Growth

Mean length at age (in quarter of years) for recaptures from fishing surveys and local fishermen are shown in Table 4. There was no tendency indicating difference in growth between fish tagged with different tag types and the calculations were done on pooled data from both tag types (FAT and IST).

For comparison of mean length at age between recaptures from fishing surveys and recaptures from local fishermen (catch forms), only Q_5 and Q_9 (Table 4) had enough data from both recapture types to do a proper statistical comparison. In Q_5 mean lengths of size group 2 and 3 were significantly larger ($p < 0.05$) in the recaptures from local fishermen than in the fishing surveys, which indicate larger catchability for the largest fish in these groups in the local fishery. For the other size groups in Q_5 and for all groups in Q_9 there were no significant differences in mean length at age between data from fishing surveys and catch forms.

The calculations of mean length at age (quarters of years) show a clear tendency for growth compensation in the smallest size groups (Fig. 3, Table 4). From Q_6 there were no significant differences in mean length at recapture between the three largest size groups ($p > 0.25$). From the smallest size group there were few recaptures for most of the quarters of years. The best data are from cod recaptured in Q_8 and Q_9 (Table 4). In Q_8 there was a significant difference in mean length between the smallest and the largest size group ($p < 0.025$), but there was no difference in Q_9 ($p > 0.75$). From Q_7 and onwards the growth seemed to level off in all size groups to a very slow growth rate.

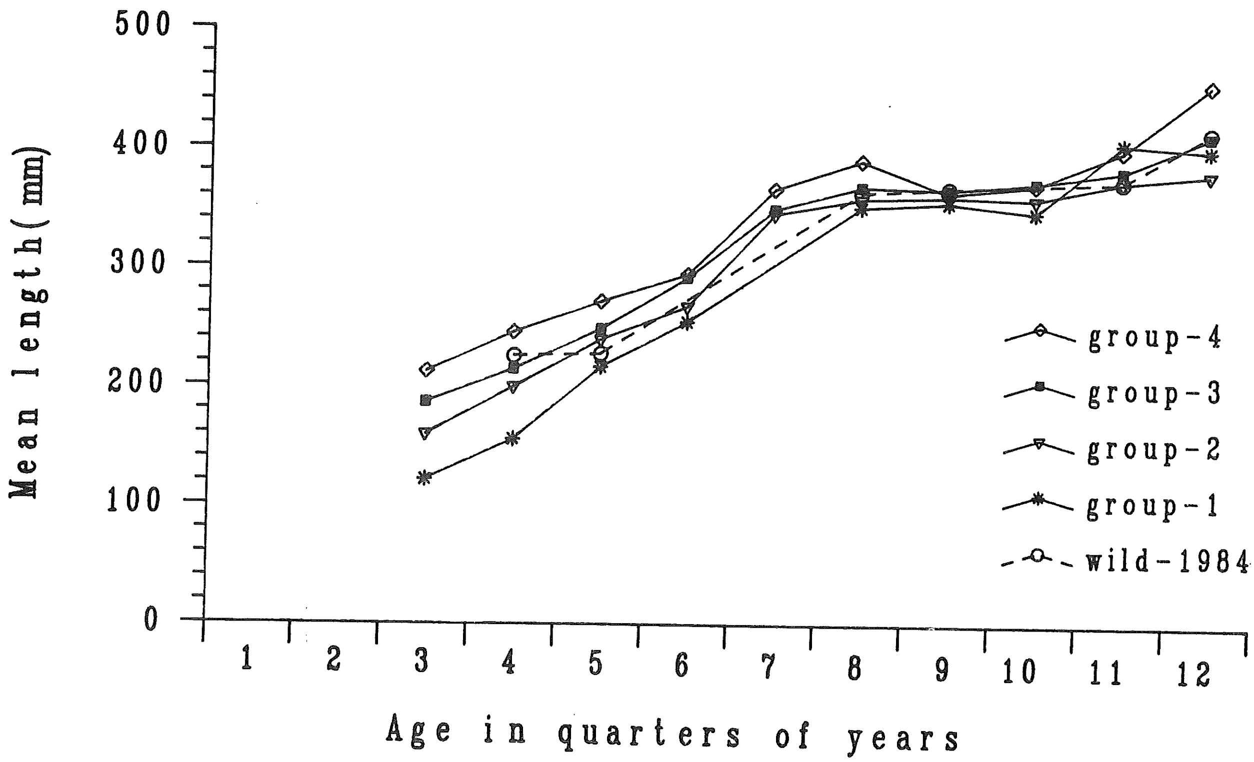

Fig. 3. Mean length at age (in quarters of years) of recaptured cod from the four size groups released in 1984 and wild cod from the 1984 year class. Mean length is calculated from the pooled data (both fishing surveys and recaptures from local fishermen) of Table 4.

For wild cod of the 1984 year class, all data are from the fishing surveys (Table 4). The wild cod showed the same growth pattern as the released cod (Fig. 3, Table 4.). In Q_5 the wild cod had a mean length similar to size group 2, and were significantly smaller than size groups 3 and 4 ($p < 0.05$). For older fish there were no significant differences between wild and released cod.

Table 4. Number recaptured, Mean Length (ML,mm) at age (quarter of years) and Standard deviation (Sd) for the four size groups released in 1984 from fishing surveys and recaptures from local fishermen (catch forms). Only recaptures containing information on tag no., length at recapture, and recapture date and place are given. (- , no data available).

	SIZE GROUPS														
	1			2			3			4			WILD		
Age in quarter of years	N	ML	(Sd)	N	ML	(Sd)	N	ML	(Sd)	N	ML	(Sd)	N	ML	(Sd)
Q_3 (at release)		121			159			186			212			-	
Fishing surveys:															
Q_4 Jan-Mar 85	1	155	(0)	13	193	(16)	8	218	(20)	3	265	(13)	6	225	(34)
Q_5 Apr-Jun 85	6	217	(13)	13	227	(18)	24	240	(20)	7	270	(22)	21	227	(35)
Q_8 Jan-Mar 86	0	-	( )	2	365	(21)	2	365	(64)	0	-	( )	3	363	(76)
Q_9 Apr-Jun 86	5	361	(32)	12	371	(30)	13	355	(61)	2	392	(88)	33	367	(70)
Q_{11} Oct-Dec 86	2	400	(7)	6	363	(59)	4	418	(65)	4	401	(63)	9	373	(34)
Q_{12} Jan-Mar 87	1	400	(0)	5	402	(41)	2	401	(114)	1	310	(0)	12	417	(71)
Catch forms:															
Q_4 Jan-Mar 85	0	-	( )	3	227	(8)	3	200	(20)	3	225	(25)	-	-	-
Q_5 Apr-Jun ''	1	215	(0)	6	265	(26)	14	262	(35)	6	273	(19)	-	-	-
Q_6 Jul-Sep ''	0	-	( )	12	268	(70)	23	291	(54)	16	294	(57)	-	-	-
Q_7 Oct-Dec ''	3	292	(25)	16	345	(36)	16	349	(75)	11	366	(80)	-	-	-
Q_8 Jan-Mar 86	11	351	(33)	19	358	(44)	42	368	(62)	12	390	(40)	-	-	-
Q_9 Apr-Jun ''	4	347	(25)	22	354	(35)	26	371	(42)	14	358	(71)	-	-	-
Q_{10} Jul-Sep ''	3	347	(6)	28	358	(72)	38	372	(73)	12	370	(47)	-	-	-
Q_{11} Oct-Dec ''	2	400	(14)	5	385	(63)	4	345	(10)	1	390	(0)	-	-	-
Q_{12} Jan-Mar 87	0	-	( )	9	368	(39)	7	415	(92)	1	600	(0)	-	-	-

DISCUSSION

Methods of release

The proportion between Singly and Group Released cod in recapture data was not altered from the point of release. This implicates that survival of cod fry released in densities as in our experiment (2,700 released 0-group cod/km^2), will be independent on whether the fry are released one by one or in small groups. Observations by divers showed that the newly released fish swam to the bottom and hid between the rocks within few minutes and the fish released in groups swam in a school, faster and more determined to the bottom than singly released (Svåsand and Kristiansen, 1985). There were, however, no indications of predation, and positive effects of the school behaviour against predation were probably small. Recaptures in fishing surveys just after release, showed that fish from different release localities within few days were dispersed in the shallow parts of Heimarkspollen. Because of the fast dispersion, the effect of the release method will be small and not detectable in the recapture data.

Size dependent mortality

The results show a higher recapture rate with increasing size at release. In the first period after release the differences in recapture rates between the size groups could to some extent be explained by higher catchability in fishing gears for the largest size groups (Table 4). For fish older than two years (from Q_9) there were no significant size differences between the groups, and the catchability should have been similar for all groups. However, recaptures of cod older than two years also showed lower recapture rate of size group 2 (Fig. 2). If we assume equal catchability for all size groups from Q_9, the differences in recapture rates in Q_9 - Q_{13} indicate that the relative abundance of 2 year old cod of size group 2 was 25 - 30 % lower than of size group 3 and 4 (Fig. 2) compared to the number released (Table 3).

Lower relative abundance of the smallest size groups can have been caused by higher tagging mortality, or higher natural mortality caused by predation or desease. Preliminary control group experiments and several years use of Floy Anchor Tags at the

Aquaculture Station Austevoll, have shown low tagging mortality (0-10%) for cod larger than 14 cm. Even if we reduce the number released in size group 2-FAT by 10 % (assuming 10 % immediately tagging mortality), this will only increase the recapture rate from this group from 7.1 to 7.9 %, and this can not explain the observed differences in the returned catch forms (Table 3, Fig. 2)

The observed differences may be explained by size dependent natural mortality. Analysis of stomach contents from cod in the North Sea, has shown that 0 - and I - group less than 20 cm are most in danger of cannibalism (Daan, 1983). Observations on predation on tagged cod in Heimarkspollen also indicate a larger predation mortality on the smallest size groups (Svåsand and Kristiansen, 1985; unpublished data).

Growth

The difference in mean length at age between the size groups seemed to decrease with time, and from the age of two years (Q_9, Table 4) there were no significant differences in mean lengths between the groups. These results indicate higher growth rate (growth compensation) in the smallest size groups, but other factors like size selection in the recapture gears, higher fishing mortality of the largest cod or higher predation mortality of the smallest cod will also decrease the size differences between the size groups.

The small meshed trammel nets used in the fishing surveys in Q_5 have earlier been shown not to be size selective in the actual size range (20-30 cm) (Kristiansen, 1987), but as shown in the results, the mean lengths at age of cod recaptured in this period by local fishermen were larger than in the fishing surveys, which means that at least in the first quarters of years after release the mean lenghts are overestimated. In Q_9 there were no significant differences between the calculations based on data from fishing surveys and other recaptures, and the lack of significant difference in mean length between the size groups from Q_9 can probably not be explained by size selection in the recapture gears.

The lower recapture rates of the smallest size groups shown above, indicated size dependent predation mortality. Since the slowest growing individuals within the smallest size groups will spend a longer time in the "predation field", they will probably have a higher mortality than the similar individuals in the larger size groups. The predation mortality will therefore have strongest effect on the mean length at age of the smallest size groups and thereby be an important factor in the observed growth compensation.

A similar tendency for growth compensation in the second and third year of life of cod has been reported by Beacham (1981), and he explained this growth pattern by different levels of competition at different stages in life. This may also be the cause in this study. In the pond, where the fish are mainly fed artificially, there will be competition for food at the feeding stations and probably a size hiearchy where the biggest fishes possess the most favourable feeding positions. After release the density of cod will be low, and fish of different sizes have the possibility of avoiding competition by choosing different prey. Cod has been shown to be size selective on prey, where mean weight of prey increase proportionally with the body weight of the predator (Daan, 1973; Ursin, 1973; Armstrong, 1982). As there is a close negative correlation between prey size and prey density (Ursin, 1973) the smallest cod should have the best feeding conditions and the best growth. The cod in Heimarkspollen show a decreasing growth rate when they reach a size of about 35 cm, which is consistent for all year classes and for both wild and released cod. This may suggest lack of food of the appropriate size and increased intra specific competition.

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