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The Propagation of Cod *Gadus morhua* L.

COD (*Gadus morhua* L.) OFF MØRE - COMPOSITION AND MIGRATION

O.R. Godø

Institute of Marine Research, P.O. Box 1870,
N-5011 NORDNES Norway

ABSTRACT

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Important spawning- as well as nursery- and feeding areas for cod, *Gadus morhua* L. are found off the Møre coast.

In this paper age compositions, age at first spawning, otolith patterns and migration of cod in the Møre area are studied. The results are used to describe the dynamic of a local cod population. The relationship between coastal cod and north-east Arctic cod is discussed.

Immature coastal cod tagged off the Møre coast were mainly stationary before maturation. When mature, cod from various localities tended to migrate partly to the main spawning ground off Sunnmøre, and partly to local spawning areas. A limited number passed the Møre coast to the southern Norway coast and the North Sea.

The otolith pattern and age at first spawning seemed to be relatively consistent for cod from various localities off the Møre coast. However, during the spawning season the influence of older cod with a more complex otolith pattern and higher age at first spawning gradually increased. The parameters gradually change from those characteristic of the Møre coastal cod to those of the north-east Arctic cod which dominated the catches during the time of most intense spawning. However, the original coastal cod was still present and spawning on the same grounds.

The spawning population off Sunnmøre was made up of cod from various feeding areas, both off and north of Møre, which to a great extent returned for repeated spawning. Further cod in the various feeding areas off Møre were composed of groups of fish with different migratory tendencies, including those spawning in or close to the nursery area and long distance migrants.

The difficulties of using otoliths as an stock discriminating parameter are discussed.

INTRODUCTION

Important spawning, nursery, and feeding areas for cod are located off the Møre coast. The main spawning ground which is located in the southern part of the area is used both by local cod populations and north-east Arctic cod (Godø and Sunnanå, 1984; Godø, 1981). Rollefsen (1933) described two cod types: local coastal cod (CC) stocks and the north-east Arctic cod (NAC) stock on the basis of differences in the otolith pattern. Møller (1968, 1969) studied the genetic diversities of the cod resources in Norwegian waters and concluded that CC and NAC are sibling species.

In this paper CC off Møre are studied. The biology of a local CC resource is elucidated by observations of age, maturity age and migration. Further a comparison between feeding CC from various localities off Møre and spawning CC is carried out: Differences in otolith patterns between CC samples taken during the feeding- and spawning-periods are discussed. These are compared to variation in age compositions and mean age at first maturity in the same samples. The results are discussed in connection with immigration and emigration of spawning CC and NAC. Otolith pattern variations in the spawning population are discussed in connection with suggested nursery grounds and the traditional use of otolith zonation as a stock discriminating parameter (Rollefsen, 1933; Møller, 1968).

MATERIALS AND METHODS

The Møre coast is considered to be the coastal area between 62^{o}N and 64^{o}N and the names Nordmøre and Sunnmøre are used for the northern and southern regions respectively (Fig. 1).

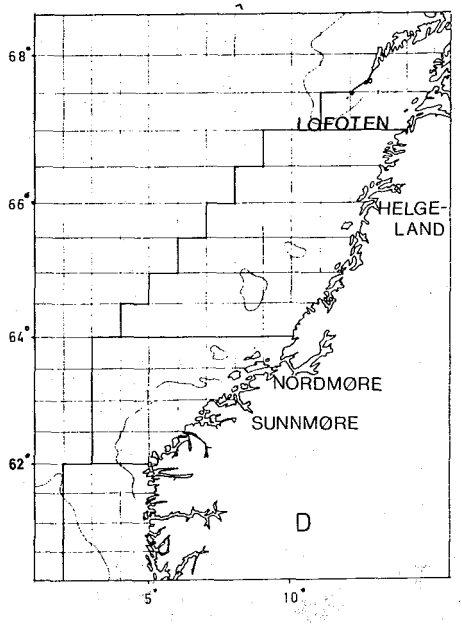

Fig. 1. The coastal area Møre-Lofoten.

The year is divided into two periods: the "spawning period" of January to April and the "feeding period" during the remainder of the year.

Otolith studies

The otoliths were identified and aged according to Rollefsen (1933). Fig. 2a and f show the typical growth patterns for CC and NAC otoliths from cod off the Møre coast. Criteria for separation are as follows:

Coastal cod: Nucleus round and first hyaline zone distinct. Second years opaque zone broad compared with later growth rings.

North-east Arctic cod: Nucleus oval. First hyaline and second opaque zone do not differ markedly from the following ones.

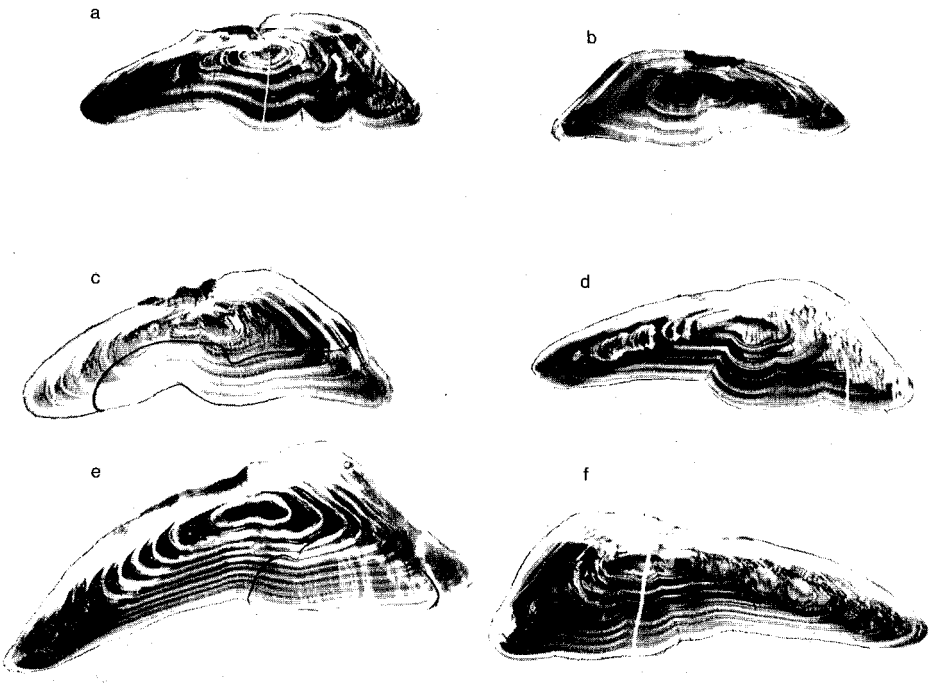

Fig. 2. Examples of otolith types in cod samples from catches taken off Møre. Young Møre coastal cod (a-b), spawning coastal cod off Sunnmøre (c-d) and north-east Arctic cod (e-f) off Sunnmøre.

The age at first maturity for repeat spawners was found by omitting the spawning zones when ageing the fish (Rollefsen, 1933). For this study samples were collected over a three year period (1980-1982) (Table 2). Samples were obtained throughout the year from a variety of gear types. A total of 5271 cod were collected and analysed.

Tagging experiments

Tagging experiments employed hydrostatic Lea tags fastened anterior to the first dorsal fin.

Table 1 shows the numbers of cod tagged in each year during the spawning and feeding periods.

Results have previously been presented for the trap net and Danish seine experiments (Hylen, 1964a,b; Godø, 1983). This paper compares the results from the various experiments and includes returned tag recoveries to April 31, 1983.

TABLE 1

The numbers of cod tagged off Sunnmøre and Nordmøre during the spawning (S) and feeding (F) periods in the years 1956 -1982.

Main tagging gears	Period	Numbers tagged	
		S	F
Trap net	1956-1979	395	780
Danish seine	1964-1981	413	716
Trawl	1980-1982		1579

RESULTS

Otolith pattern studies

A selection of the different otolith types which indicate the variation in otolith zonation observed is shown in Fig. 2. Variations in otolith patterns due to time of sampling were noted.

Otoliths sampled from catches taken with various gears during the feeding period were primarily of the type illustrated in Fig. 2a and b and easily read. The nucleus is well defined and the annular growth rings easily separated.

Samples of otoliths from catches taken during the spawning period off Sunnmøre were also studied. The Møre-type (Fig. 2a, b) dominated during the feeding period, but an increasing proportion of other more complex CC types which were difficult to read were found in the period January to April especially in the gill net and trawl catches (Fig. 2c-d).

The frequency of NAC otoliths was insignificant in the sampled catches except in February and March (Fig. 4c). The NAC otoliths dominated in the trawl and gill net catches these two months (Fig. 4c). Also among the NAC otoliths various types were found (Fig. 2e-f). Some of them tended towards the CC types. In spite of variation and transition types in the two main groups, all otoliths were classified either as CC or NAC when ageing was possible.

Attempts were made to separate the various CC otolith types in the samples to allow for statistical testing; however, the large number and variation of transition types made it difficult.

Age and age at first maturity

Trawl, Danish seine and trap nets are three important gears in the exploitation of the CC resources off Møre during the feeding period. The gear types are employed in discrete geographic areas (Fig. 3). The gill net fishery off Sunnmøre is a spawning season fishery.

The mean age variations with time and gear in the samples are shown in Fig. 4a. The background age compositions are presented in Table 2. Excluding the samples from the trawl and gill net catches in February-March, it is shown that the commercial fishing exploit the CC at a mean age of 3.0 to 4.2 years. The trap net caught cod seem to have a lower mean age

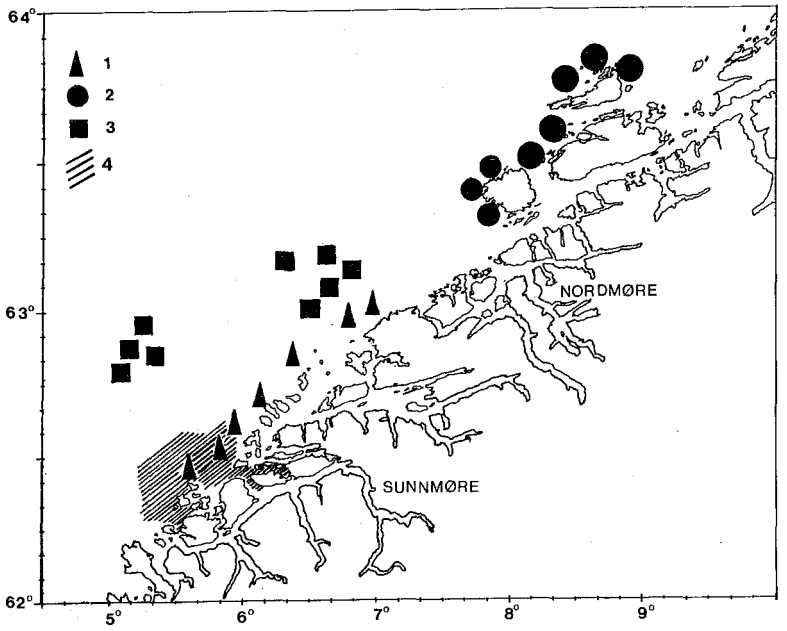

Fig. 3. The primary areas exploited by Danish seine (1), trap net (2), trawl (3) and the main area exploited by the spawning period gill net fishery (4).

most of the year compared to the CC taken by trawl and Danish seine.

The trawl and gill net catches during February-March contain CC with a mean age of 5.0-6.0 years. This is between one and two years higher than the mean age before and after. From Fig. 4c it is also demonstrated that the samples with highest mean age is those with considerable amount of immigrated NAC (45-88%).

In Fig. 4b and Table 2 the mean age at first maturity in the various samples are presented. Some of the samples lack this observation. This is because the sampled catches were landed gutted and consequently the maturity stage is not known.

TABLE 2

Age compositions (%) and mean age at first maturity in cod samples from Sunnmøre (SM) and Nordmøre (NM) from Danish seine, trawl, gill net and trap net catches.

Year	Month	Area	Gear	Sample size	Age 1	2	3	4	5	6	7	8	9+	Mean age	Mean mat.age
1980	May	SM	Danish s.	204		1	65	26	2	3	2			3.4	
1980	June	SM	Trawl	639		4	55	28	8	3	2			3.6	4.0
1981	Jan	SM	Danish s.	372			13	68	16	1	2	1		4.2	4.2
1981	Jan	SM	Trawl	123			8	67	21	3	2			4.2	
1981	Febr	SM	Trawl	100				17	17	29	21	17		6.0	
1981	Febr	NM	Trap net	70		2	18	59	21					4.0	4.1
1981	March	SM	Trawl	464			6	28	25	19	15	6	1	5.5	4.7
1981	March	SM	Gill net	762				14	29	29	16	6	6	5.9	4.9
1981	June	SM	Trawl	337		1	15	64	18	2	1			4.1	4.2
1981	June	SM	Danish s.	73		11	32	52	6					3.5	
1981	Oct	NM	Trap net	80	2	22	47	27	2					3.0	4.2
1981	Dec	NM	Trap net	70		29	43	24	2	2				3.0	4.2
1982	Jan	NM	Trap net	68			23	58	18	0	0	2		4.0	4.2
1982	Febr	SM	Trawl	219			11	16	39	22	7	3	2	5.1	
1982	March	SM	Danish s.	91		1	58	27	14	0	1			3.6	
1982	March	SM	Trawl	568			11	29	23	26	11			5.0	4.8
1982	March	SM	Gill net	448			3	7	38	34	12	4	2	5.7	5.1
1982	June	SM	Trawl	296		12	3	31	20	3	1	1		3.7	4.5
1982	Sept	NM	Trap net	70	1	45	26	22	6					2.9	
1982	Nov	SM	Trawl	88		9	41	22	15	12	0	1		3.8	
1982	Nov	SM	Danish s.	129		19	62	13	6					3.1	

The mean age at first maturity for CC caught during the feeding period and in early spawning period is mainly from 4.0 to 4.2 years. The trawl catch from June 1982 contained CC with mean age at first maturity of 4.5 years. The trawl and gill net catches in February-March were composed of CC with mean age at first maturity from 4.7 to 5.1 years. According to Fig. 4 the same samples were dominated by NAC as well as characterized by the highest mean age observations of CC.

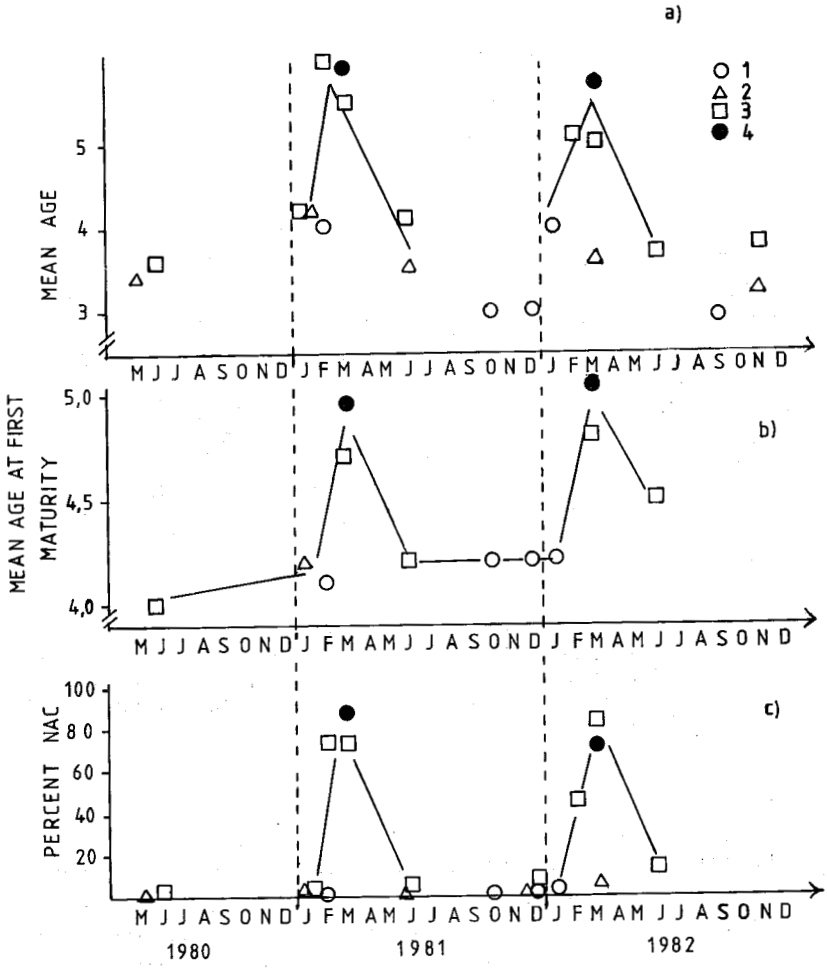

Fig. 4. Variations of mean age (a), mean age at first maturity (b) and percent of NAC (c) in the samples through the years 1980, 1981 and 1982. Legend: 1- trap nets, 2- Danish seine, 3- trawl and 4- gill nets.

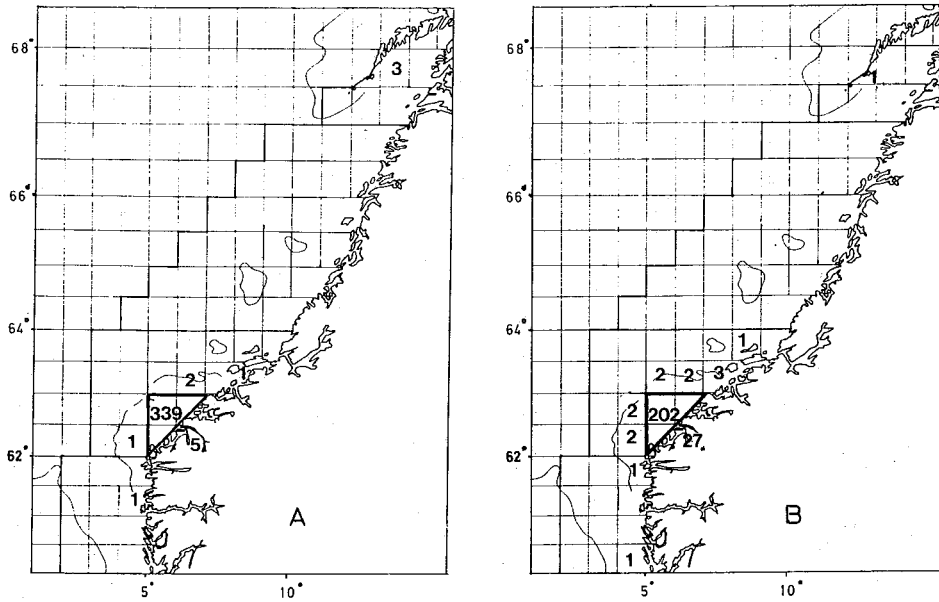

Fig. 5. Location of returns from coastal cod tagged on the Danish seine grounds in 1964, 1975 and 1979-1981. A. feeding period and B. spawning period experiments. Tagging area is outlined with heavy lines. Partly adopted from Hylen (1964b) and Godø (1983).

Migration

No principal difference in migration between cod tagged in the periods 1957-1964 and 1975-1981 were observed by Godø (1983). The results are therefore summarized in Fig. 5 and Fig. 6 and compared with tagging experiments carried out on the trawling grounds.

The results from the CC taggings (the spawning period and feeding period releases) with Danish seine are presented in Fig. 5. The great bulk of the recaptures (97% and 83%) were returned from the statistical localities of release. Recaptures from the spawning season experiments had the most scattered distribution. In total, only seven tags were

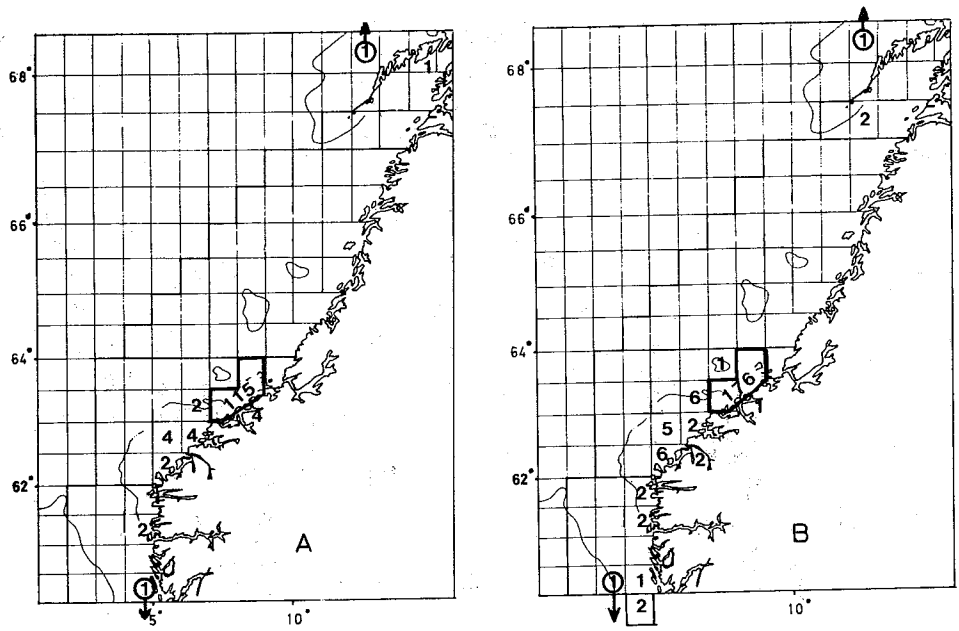

Fig. 6. Location of returns from caostal cod tagged on the trap net grounds off Møre in 1956, 1957 and 1979. A. feeding period and B. spawning period experiments. Tagging area is outlined. Partly adopted from Hylen (1964a) and Godø (1983).

returned from outside the Møre coast, four in Lofoten and three south of Møre. In the trap net tagging experiments (Fig. 6) there was also a high recapture frequency in the statistical localities of release (86% of total number of recapture). The recaptures taken outside the tagging localities were mainly distributed to the south off the Sunnmøre and Western Norway coast.

The tagging experiments from the trawl catches (Fig. 7) are summarized under a northern and a southern tagging locality. From both sets of experiments there was a high frequency of return from the spawning localities off Sunnmøre. In the northern tagging area movement towards the Nordmøre coast was observed as well. The highest number of recaptures

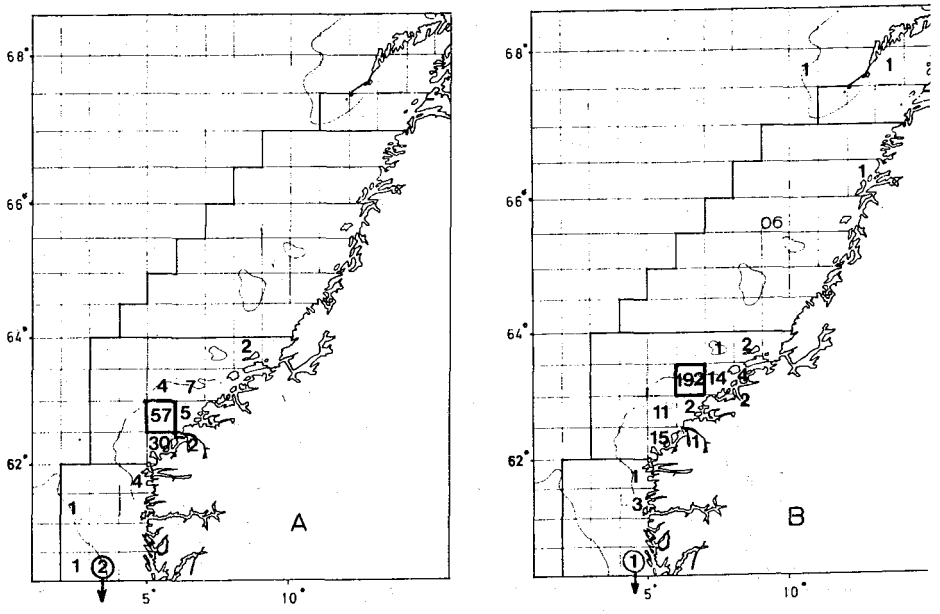

Fig. 7. Location of returns from coastal cod tagged on the trawl grounds (southern (A) and northern(B)) in 1980-1982. Tagging areas are outlined with heavy lines.

were returned from the localities of tagging (50-60% of all recaptures). All together 13 recaptures were taken south of Møre along the Norwegian coast and in the North Sea.

The major gear types of recapture from the three sets of experiments are shown in Table 3. Very few tags from one gear type were recaptured by the two others (2.1-3.5%). In all experiments the main gears of recapture, excluding the gear of tagging, were gill nets and hand line. The great majority of recaptures with these gears from off Sunnmøre were taken during the spawning season.

The composition of the cod tagged in the various areas are similar to the observations in samples from corresponding gear and season (Table 2, Fig. 4). The smallest specimens

TABLE 3

Number of tagged fish recaptured by the various fishing gears according to the gear of tagging. Coastal cod taggings in 1975, 1979, 1980, 1981 and 1982.

Recapture gear	Tagging gear		
	Danish seine	Trawl	Trap net
Danish seine	118	5	1
Trawl	3	69	3
Trap nets			17
Gill nets	14	61	25
Hand line	8	9	52
Other			8
Total	143	144	106

were not tagged due to their lower survival rate, and consequently the two and partly the three years olds are underrepresented in the tagged population.

DISCUSSION

Migration of the Møre coastal cod

In the discussion no distinction is made between the spawning period and feeding period tagging experiments as no principal differences in the distribution of the recaptures were observed. The spawning period experiments may probably be looked upon as carried out in the feeding period as the time of release was mainly well before the time of most intense spawning.

As the age of the tagged fish is the same or higher compared to the commercial landed cod, it appears from Fig. 4

and Table 2 that most of them matured during the first or second year of freedom. Considerable numbers of tags were returned till the third year after release (Godø, 1983). As the major part of the recaptures were caught within the tagging areas, especially in the trap net and Danish seine experiments, a considerable part of the tagged fish probably spawned in or close to the locality where released.

There was little evidence of intermingling in any of the tagging localities according to the gears of recapture (Table 3), which indicates that mixing on the nursery and feeding areas is hardly occurring.

Godø and Sunnanå (1984) present the coastal area off southern Sunnmøre as the major spawning ground in the Møre area. This is also the most significant area of intermingling. As the recaptures are taken in the gill net/hand line spawning season fishery, this area must be considered as a common spawning ground. In the coastal area off Nordmøre there is an intermingling between cod from the trawl- and trap net-experiments which as well might be a result of migration to common spawning grounds (Fig. 8).

Eight of the 12 recaptures north of Møre were caught on the Lofoten spawning grounds and may represent a trifling northward spawning migration.

The 27 recaptures south of Møre indicate a limited intermingling with cod along the southern Norwegian coast, in the North Sea and Skagerrak.

On the basis of the forgoing results, the migration patterns shown in Fig. 8 are suggested to be occurring.

To conclude: The CC off Møre are composed of both stationary and migrating fish. The migrating specimens seem to have various distances and directions of spawning migration. The considerable intermingling on the spawning grounds, suggest the Møre CC to belong to the same stock complex. Connection with cod in adjacent areas is indicated.

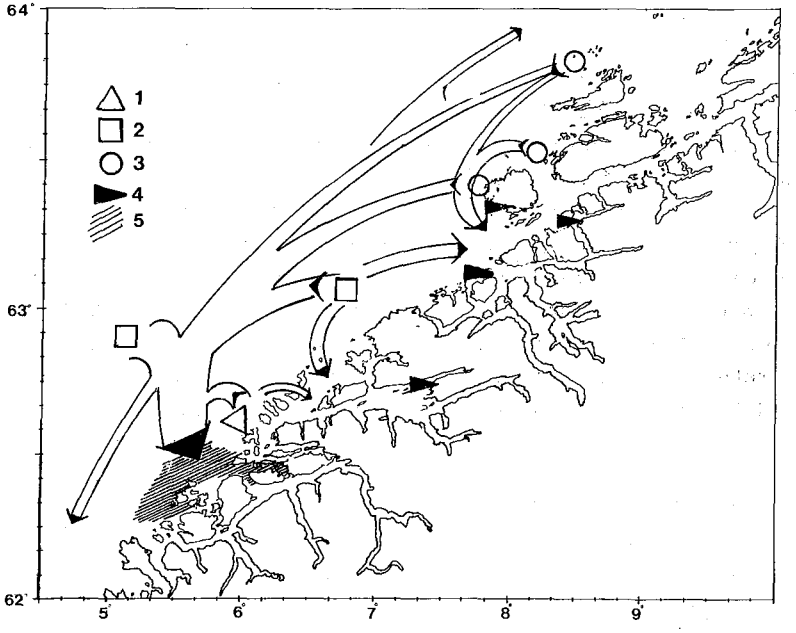

Fig. 8. Spawning migrations of the Møre coastal cod indicated by tagging experiments. Tagging areas are shown, 1- Danish seine, 2- trawl and 3- trap net grounds. Local spawning areas (4) and main spawning ground (5) are indicated according to Godø and Sunnanå (1983).

The cod spawning population off Sunnmøre

The spawning population off Sunnmøre is composed of a greater part (70-90%) of NAC (Godø, 1981; Godø, Nakken, Raknes and Sunnanå, 1982 and 1983) and a minor CC share. According to the NAC share of the trawl catches (Fig. 4) the migrating cod seemed to pass the trawling grounds on the way to the main spawning ground.

An increasing CC mean age and mean age at first maturity together with a higher frequency of otoliths with complex zonation is observed in samples from the trawl and gill net

catches dominated by NAC. This indicates that there is a fraction of CC with origin from outside the Møre area arriving on the spawning ground together with the NAC. The gill net selection may be considerable. It can, however, hardly explain the increase in the mean age at first maturity and the fraction of more complex otoliths.

From tagging experiments carried out on the mixed NAC and CC population, recaptures from the feeding period recorded as CC has been returned from various localities off Møre as well as along the coast north to Lofoten (Fig. 9 from Godø, in press). Those from the Barents Sea were all NAC. This may be a return migration to former nursery area, as also is observed in other cod populations (Templeman, 1979).

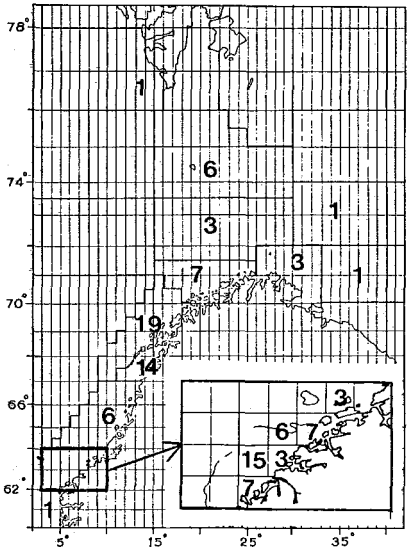

Fig. 9. Geographic distribution of feeding period recaptures from tagging experiments carried out on spawning cod off Sunnmøre. Adopted from Godø (in press).

The conclusion from the results is that the spawning area off Sunnmøre is some kind of mixing spot for CC from various localities both off and north of Møre as well as for NAC. The unsolved question is to what extent the various groups of cod are interbreeding.

Otolith studies

Otolith zonation differences is to day the basis for separating the CC and the NAC into different stocks (Rollefsen, 1933; Møller, 1968 and 1969). Trout (1957) connected different otolith patterns in NAC to variation in the environments of the nursery grounds. It has already been discussed that the spawning population off Sunnmøre probably is composed of CC from various coastal locations as well as NAC with nursery area in the Barents Sea. The variation in otolith patterns observed in the Sunnmøre spawning population may thus be connected to the changes in the environments of the nursery grounds from Møre and northwards towards the Barents Sea.

The variation in otolith patterns in relation to the standard CC and NAC otoliths seem to be more pronounced in these investigation compared to earlier works (Rollefsen, 1933; Møller, 1968 and 1969). The great variation observed on the Sunnmøre spawning ground is an illustration of the difficulties of using otolith pattern as a stock discriminating parameter.

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