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Growth Pattern in Cod Otoliths as
Indicator for Mixing of Stocks

by



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ABSTRACT

Different pattern of otolith-growth zones has made it possible to distinguish between cod of various origin. In the southern Kattegat and in subdivision 22 and 23 (the Danish Belts and the Sound) the cod seems to be of 3 types, Kattegat cod, Belt Sea cod and Baltic cod, having quite different otolith growth zones. A part of cod otoliths sampled in different harbours and from research ships in the area in question since 1960 have been examined. The percentual distribution of the 3 types according to area, season and year has been compared with results from tagging experiments and fishing mortalities generated from V.P.A.

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INTRODUCTION

In subdivision 22 assessments on cod and catch predictions have been carried out since 1974 (anon. 1974, 1975, 1976, 1977, 1978, 1979, and 1980). Subdivision 22 comprises the Danish Belts, Kiel Bay and Fehmern Belt, bounded towards east by longitude 12°E and in the North by the line Griben-Hasenøre, Fig. 1. Thus the subdivision is the true transition area between the North Sea - Kattegat and the Baltic.

It is supposed that the stock of cod within this area forms a unit stock which means that losses from emigrations or gains from immigrations, if any, are negligible in relation to the rates of growth and mortality, further that the stock is not affected by fishery in other areas.

Tagging experiments carried out in the southern part of the area Mecklenburg Bay and Kiel Bay (Bagge 1969, Berner 1965, 1968 and 1970) have shown a varied yearly migration, (January and February) from the southern to the northern part of the subdivision and to a lesser degree to the southern Kattegat.

These migrations to some extent explain the high fishing mortalities generated from the V.P.A., because in the period 1970-1979 sampling has been limited to the southern part of the area only representing 50% of the landings. The landings in the northern part of the area have been distributed by age according to the age distribution of the samples from the southern area.

In order to improve the data monthly sampling was started in the northern part in 1979 (south of Ebeltoft), fig. 1.

The age distribution of the cod in these samples was found to be quite different from the age distribution of those from the southern part of the subdivision, further 3 distinctly different patterns of growth were observed in the otoliths. This observation led to a reexamination of samples of otoliths collected since 1960 in the southern Kattegat (Grenå, Anholt, Gilleleje, Sjællands Odde) and the northern, the middle and the southern part of subdivision 22 (Ebeltoft-Sejrø-Kerteminde and Bagenkop respectively). In addition otoliths from the Sound (subdivision 23) sampled by research ship in 1979 and 1980 were dealt with.

METHODS

A total of 4823 otoliths were reexamined and each one was classified as belonging to one of the following groups:

- 1) Belt Sea Cod. The otolith is characterized by broad well-defined seasonal growth zones (Fig. 2a).
- 2) Kattegat Cod. The otolith has well-defined seasonal growth zones, but the bands are more narrow than those found with Belt Sea Cod (Fig. 2 b).
- 3) Baltic Cod. The otolith shows a more or less confused growth pattern and usually it is difficult to distinguish the seasonal bands (Fig. 2 c).

As the otoliths previously had been used for ageing they all were broken into halves, but great care was taken to select the half containing the better part of the O-group growth. In most cases the fractured surface needed grinding on wet grinding paper (220 grit), in order to obtain a cross section close to the nucleus. The cross section should be in a right angle to the longitudinal direction of the otolith to provide a uniform view of the structures.

The surface of the cross section was held horizontally immersed in alcohol and view under microscope. The beam from the microscope lamp should be directed horizontally to the ventral side of the otolith as to produce as much contrast between the hyaline and opaque zones as possible.

The results of the classification are shown in tables 1 and 2.

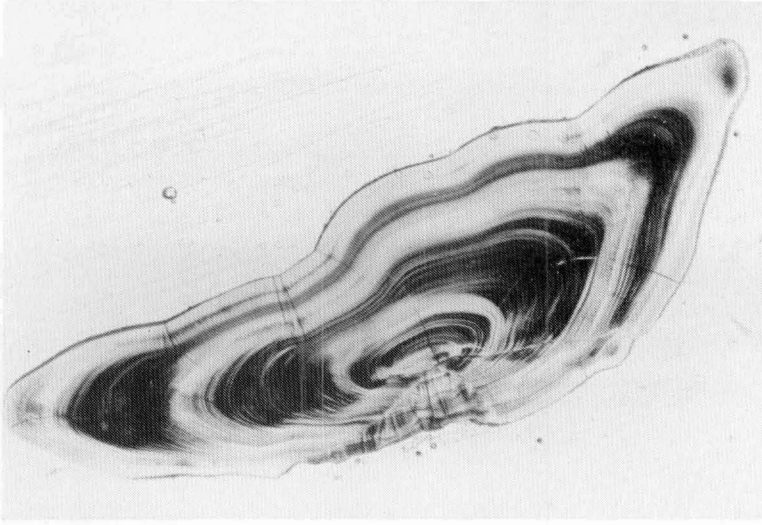


Fig. 2a: Belt Sea Cod

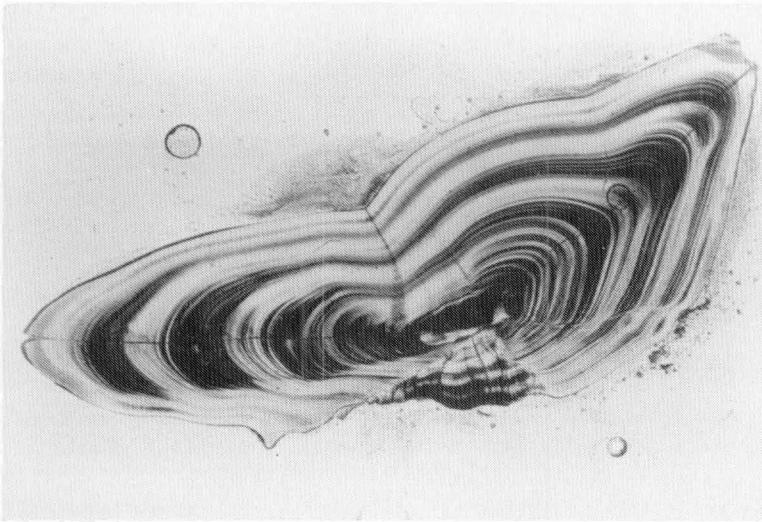


Fig. 2b: Kattegat Cod

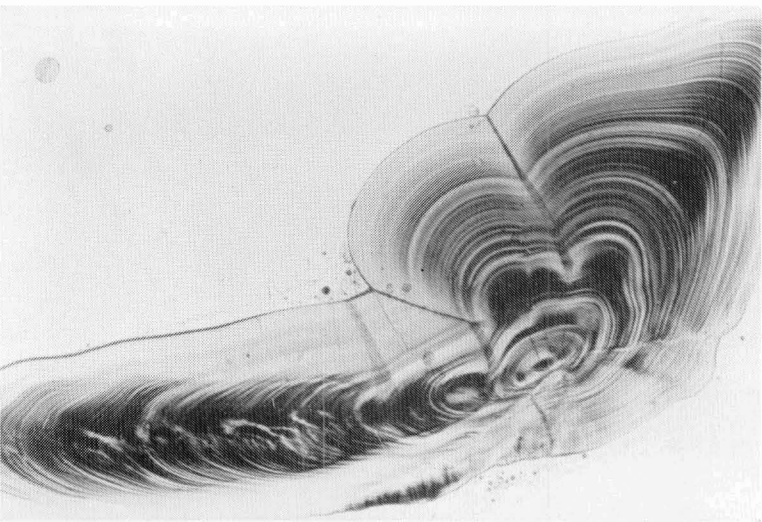


Fig. 2c: Baltic Cod

RESULTS

a. Distribution of Groups.

The percentual distribution of Kattegat, the Belt Sea and the Baltic cod in subdivision 22 according to locality, season and year is shown in figs. 3 and 4 and table 1. The corresponding distribution for subdivision 23 and southern Kattegat is shown in table 2. The distribution is shown for age group III and IV and for all age groups found in the samples.

According to the results of tagging experiments mentioned above the migrations from the southern part of subdivision 22 take place in January and February (table 3). Immigration from the southern Kattegat has been discussed by Poulsen (1931) who based on tagging experiments in the Kattegat (Strubberg 1922) and the meristic characters of cod in the Kattegat, the Belt Sea and the Baltic concludes that immigration takes place in the winter months by all age groups. Danish tagging experiments in the southwestern Kattegat January 1978 and 1980 (not published) have shown a moderate migration to the northern part of subdivision 22 (5 and 18%), 2 and 1 cod were recaptured in the southern part (Kiel Bay and Fehmern Belt) and 5 and 4 cod in subdivision 23, all of them belonging to age group III and IV. Tagging experiments in subdivision 23 (Bagge 1976) have shown a pronounced emigration to the southern Kattegat in January and February.

It appears from table 1 and fig. 3 that the percentage of Kattegat cod in January and February in the southern part of subdivision 22 (Bagenkop) has varied from 9.9% in 1967 to 25.7% in 1968, mean January and February 1965-69 14.9%; it is further shown that in 1968 where samples from 8 months are presented that the highest percentage of Kattegat cod is found in January and February (14.4 and 25.7%), but that 11.5% is found in July.

In the middle part of the subdivision (off Kerteminde) an increase of Belt Sea cod from January to February is found each year from 1965-69 possibly corresponding to the northwards migration of cod from the southern part of the subdivision.

The increasing percentage of Kattegat cod in the southern area in January and February could also be explained by a small constant immigration of Kattegat cod during all seasons. The emigration from the southern area of Belt Sea cod in January and February making the Kattegat cod more numerous proportionally in that part of the year.

A varying immigration of Baltic cod is observed. Thus in the southern part of subdivision 22 0-27.0%, in the middle part 0-9.1% (in the southern Kattegat 4% was found in January 1972).

In table 2 samples from subdivision 23 and the southern Kattegat are shown.

It appears that Baltic cod is much more frequent in subdivision 23 than in subdivision 22. Thus in November 1979 61.2% of the cod age II-X were Baltic cod and only 3.6% of Kattegat origin. In January and February 1980 the corresponding figures were 44.5, 44.7 and 33.9, 5.0% respectively. In the southeastern Kattegat (off Gilleleje) in January and February 1980 the landings were dominated by Belt Sea cod 83.3 and 71.5%, the Kattegat and Baltic cod were found in almost equal proportions 7.1, 14.6 and 9.5, 13.9% respectively.

The high percentage of Belt Sea cod and Baltic cod in the southeastern Kattegat corresponds very well to the results from tagging experiments. Several cod tagged in the Baltic (subdivision 24, 25 and 26) have been recaptured in subdivision 23, but the number does not compare to the high percentage estimated from otoliths (61.2, 44.5 and 33.9), which may to some degree be explained by the very low fishing effort in that subdivision (trawling and seining prohibited).

b. Growth.

The mean lengths for age groups III and IV were calculated for Belt Sea and Kattegat cod 1965-69 with the following results:

		III	IV
Belt Sea.	Mean Length	43.8 cm	53.4 cm
	Number	642	153
Kattegat	Mean Length	37.0 cm	43.8 cm
	Number	207	102

It appears from the above mean lengths that Kattegat cod have a slower growth than Belt Sea cod in spite of living under equal conditions.

It seems from the preliminary results presented above that it is doubtful if the cod in subdivision 22 and in the southern Kattegat is allowed to be dealt with as unit stocks for assessment purposes. The immigrations from subdivision 22 estimated from otoliths seem to be more frequent than indicated by tagging experiments, and explain the high F's generated by the V.P.A.

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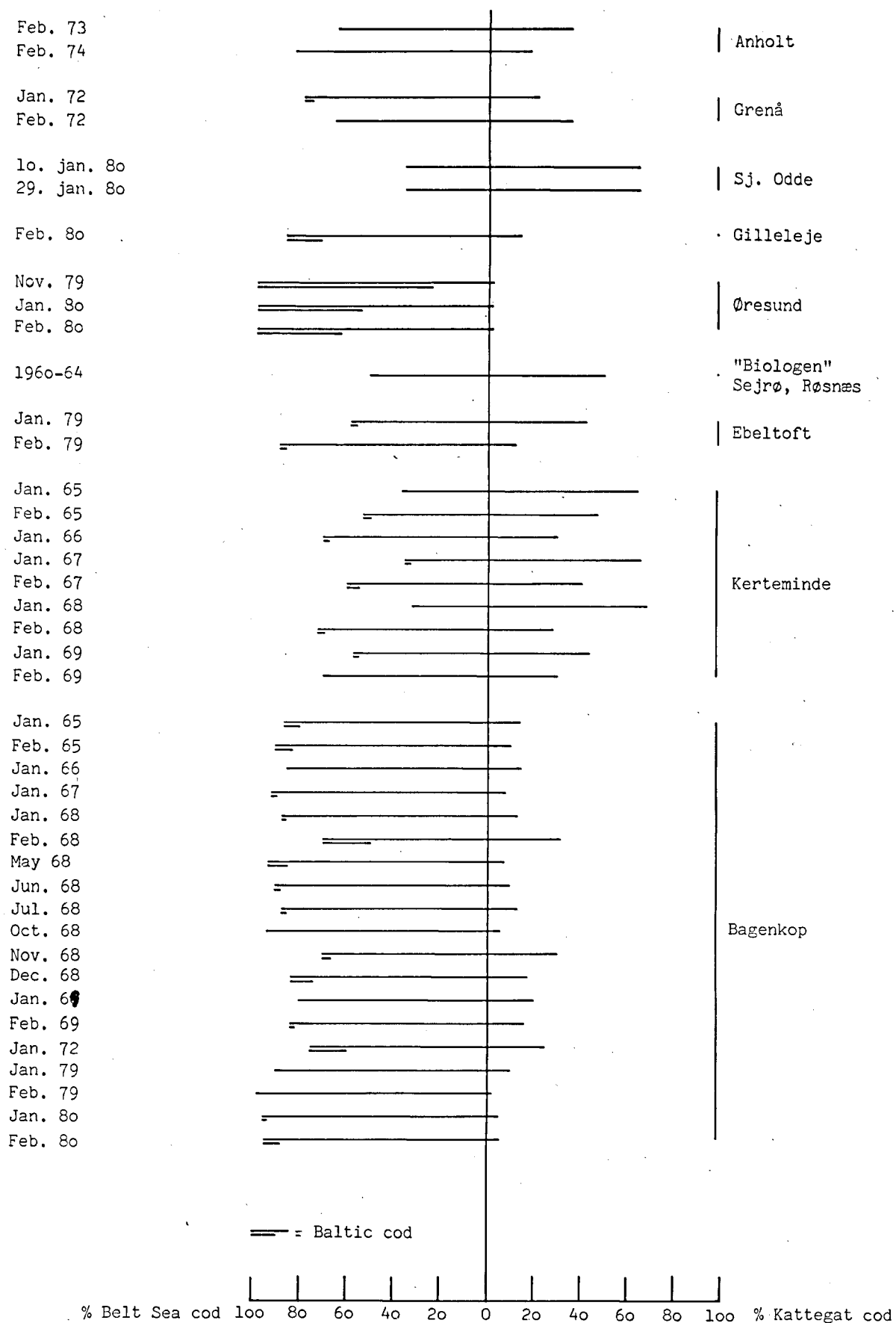


Fig. 3. Percentual distribution of Kattegat cod, Belt Sea cod and Baltic cod according to locality, month and year as estimated from otoliths. Age groups III and IV.

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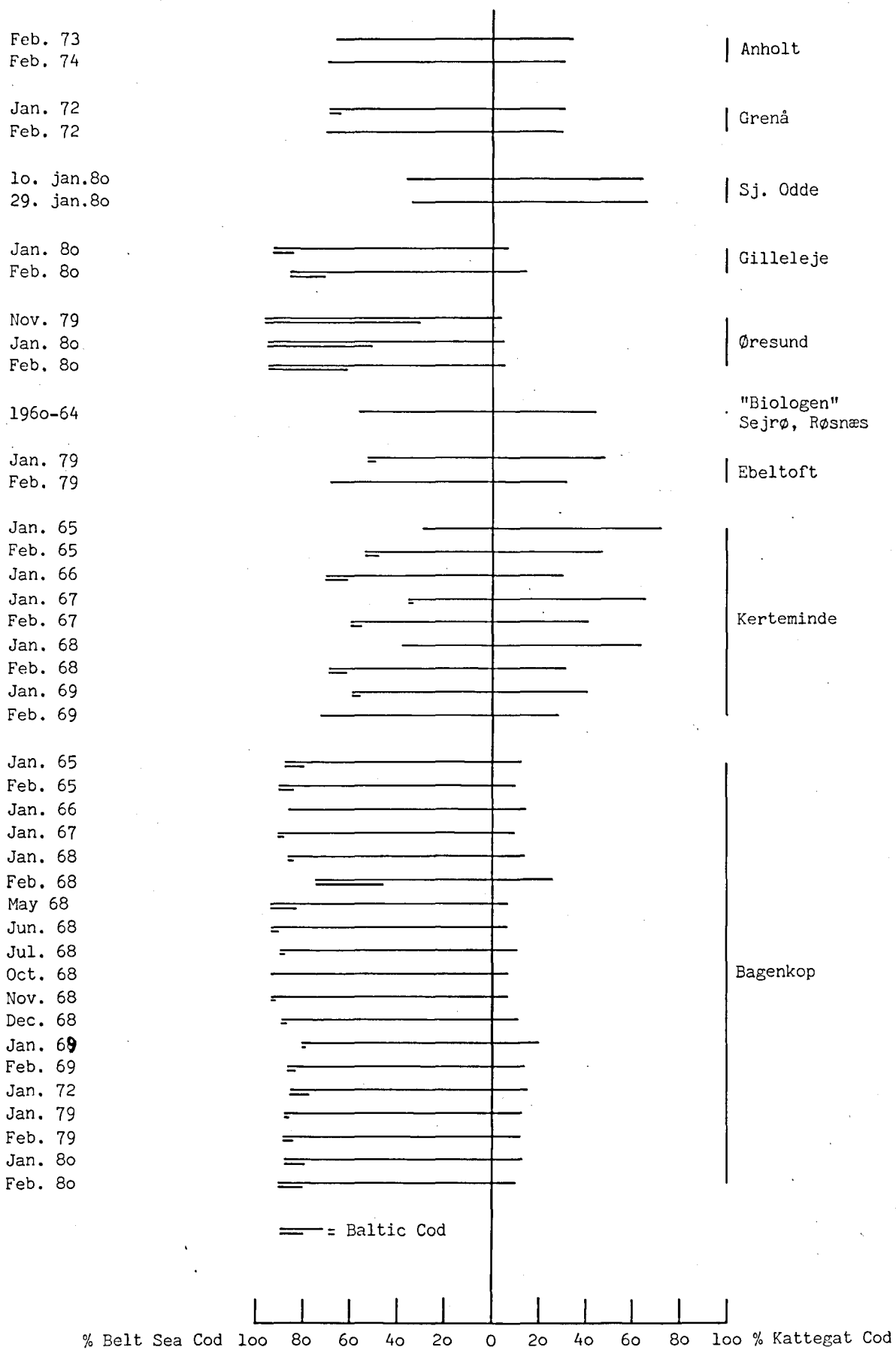


Fig. 4. Percentual distribution of Kattegat cod, Belt Sea cod and Baltic cod according to locality, month and year as estimated from otoliths. All age groups.

Locality	Month/Year	Total N			%			III+IV N			III+IV %			
		K	BS	EB	K	BS	EB	K	BS	EB	K	BS	EB	
"Biologen")
Sejrø, Røsnæs	1960-64	30	38		44.1	55.9		14	14		50.0	50.0)
Ebeltoft	Jan. 79	45	47	2	47.9	50.0	2.1	25	42	1	36.8	61.8	1.5)
"	Feb. 79	45	94		32.4	67.6		12	86		12.2	87.8)
Kerteminde	Jan. 65	46	19		70.8	29.2		28	16		63.6	36.4)
"	Feb. 65	22	23	2	46.8	48.9	4.3	14	15	1	46.7	50.0	3.3)
"	Jan. 66	20	40	6	30.3	60.6	9.1	16	37	1	29.6	68.5	1.9)
"	Jan. 67	45	23	1	65.2	33.3	1.5	36	18	1	65.5	32.7	1.8)
"	Feb. 67	30	41	3	40.5	55.4	4.1	23	32	3	39.7	55.2	5.2)
"	Jan. 68	41	24		63.1	36.9		34	16		68.0	32.0)
"	Feb. 68	19	39	4	30.7	62.9	6.5	14	35	1	28.0	70.0	2.0)
"	Jan. 69	30	41	2	41.1	56.2	2.7	26	34	1	42.6	55.7	1.6)
"	Feb. 69	17	44		27.9	72.1		15	35		30.0	70.0)
	Mean 65-69				46.6	50.5	3.1)
Bagenkop	Jan. 65	20	118	11	13.4	79.2	7.4	19	107	6	14.4	81.0	4.6)
"	Feb. 65	9	76	5	10.0	84.4	5.6	8	65	5	10.3	83.3	6.4)
"	Jan. 66	7	42		14.3	85.7		6	35		14.6	85.4)
"	Jan. 67	7	63	1	9.9	88.7	1.4	5	53	1	8.5	89.8	1.7)
"	Jan. 68	16	94	1	14.4	84.7	0.9	11	73	1	12.9	85.9	1.2)
"	Feb. 68	19	35	20	25.7	47.3	27.0	19	31	12	30.7	50.0	19.4)
"	May 68	6	76	9	6.6	83.5	9.9	6	69	6	7.4	85.2	7.4)
"	June 68	9	110	3	7.4	90.2	2.5	6	52	1	10.2	88.1	1.7)
"	Jul. 68	15	115	1	11.5	87.8	0.8	10	67	1	12.8	85.9	1.3)
"	Oct. 68	11	137		7.4	92.6		2	33		5.7	94.3)
"	Nov. 68	10	132	1	7.0	92.3	0.7	9	20	1	30.0	66.7	3.3)
"	Dec. 68	13	101	2	11.2	87.1	1.7	4	17	2	17.4	73.9	8.7)
"	Jan. 69	19	77	1	19.6	79.4	1.0	19	75		20.2	79.8)
"	Feb. 69	17	100	3	14.2	83.3	2.5	16	80	1	16.5	82.5	1.0)
"	Jan. 72	19	99	11	14.7	76.7	8.5	19	45	11	25.3	60.0	14.7)
"	Jan. 79	30	198	3	13.0	85.7	1.3	12	110		9.8	90.2)
"	Feb. 79	21	152	7	11.7	84.4	3.9	2	101		1.9	98.1)
"	Jan. 80	26	163	16	12.7	79.5	7.8	7	128	2	5.2	94.8	1.5)
"	Feb. 80	20	166	21	9.7	80.2	10.1	7	114	10	5.3	87.0	7.6)
	Mean 1965-69				14.9	79.6	5.5)

Tabel 1. Distribution of Kattegat, Belt Sea and Baltic cod according to number and percentage in subdivision 22.

Locality	Month/Year	Total N			%			III+IV N			III+IV %		
		K	BS	EB	K	BS	EB	K	BS	EB	K	BS	EB
Anholt	Feb. 73	21	40		34.4	65.6		21	38		35.6	64.4)
"	Feb. 74	14	31		31.1	68.9		6	27		18.2	81.8)
Grenå	Jan. 72	23	49	3	30.7	65.3	4.0	13	44	2	22.0	74.6	3.4)
"	Feb. 72	19	44		30.2	69.8		15	28		34.9	65.1)
Sj.Odde	10.jan.80	116	64		64.4	35.6		113	61		64.9	35.1)
"	29.jan.80	110	56		66.3	33.7		101	54		65.2	34.8)
Gilleleje	Jan. 80	3	35	4	7.1	83.3	9.5		4	1		80.0	20.0)
"	Feb. 80	20	98	19	14.6	71.5	13.9	16	84	17	13.7	71.2	14.5)
Øresund	Nov. 79	10	87	169	3.6	31.5	61.2	3	36	117	1.9	23.1	75.0)
"	Jan. 80	15	162	143	4.7	50.6	44.7	6	148	120	2.2	54.0	43.8)
"	Feb. 80	6	74	41	5.0	61.2	33.9	2	63	35	2.0	63.0	35.0)

S. Kattegat

Subd. 23

Table 2. Distribution of Kattegat, Belt Sea and Baltic Cod according to number and percentage in southern Kattegat and subdivision 23.

Table 3.

Number of recaptures in the Belt Sea and Kiel Bay 1969.

Date	Kiel Bay	Middel and North Belt Sea ^{x)}
23/1 - 1/2	99	-
2/2 - 21/2	125	60
22/2 - 23/3	134	53
24/3 - 22/4	15	9
23/4 - 22/5	8	3
23/5 - 21/6	5	1
22/6 - 21/7	6	1

Tagging experiment carried out 21st - 23rd January 1969 - 12 nautical miles WSW of Bagenkop

x) Of the above recaptures were 4 recaptured in subdivision 24 and 1 in subdivision 25.

Number of recaptures in the Belt Sea and S. Kattegat.

November)	1979	1
December)		4
January)		16
February)		17
March)	1980	14
April)		
May)		2

Danish recaptures of cod in the Belt Sea and the Southern Kattegat tagged by the Federal Republic of Germany in Kiel Bay November 1979.

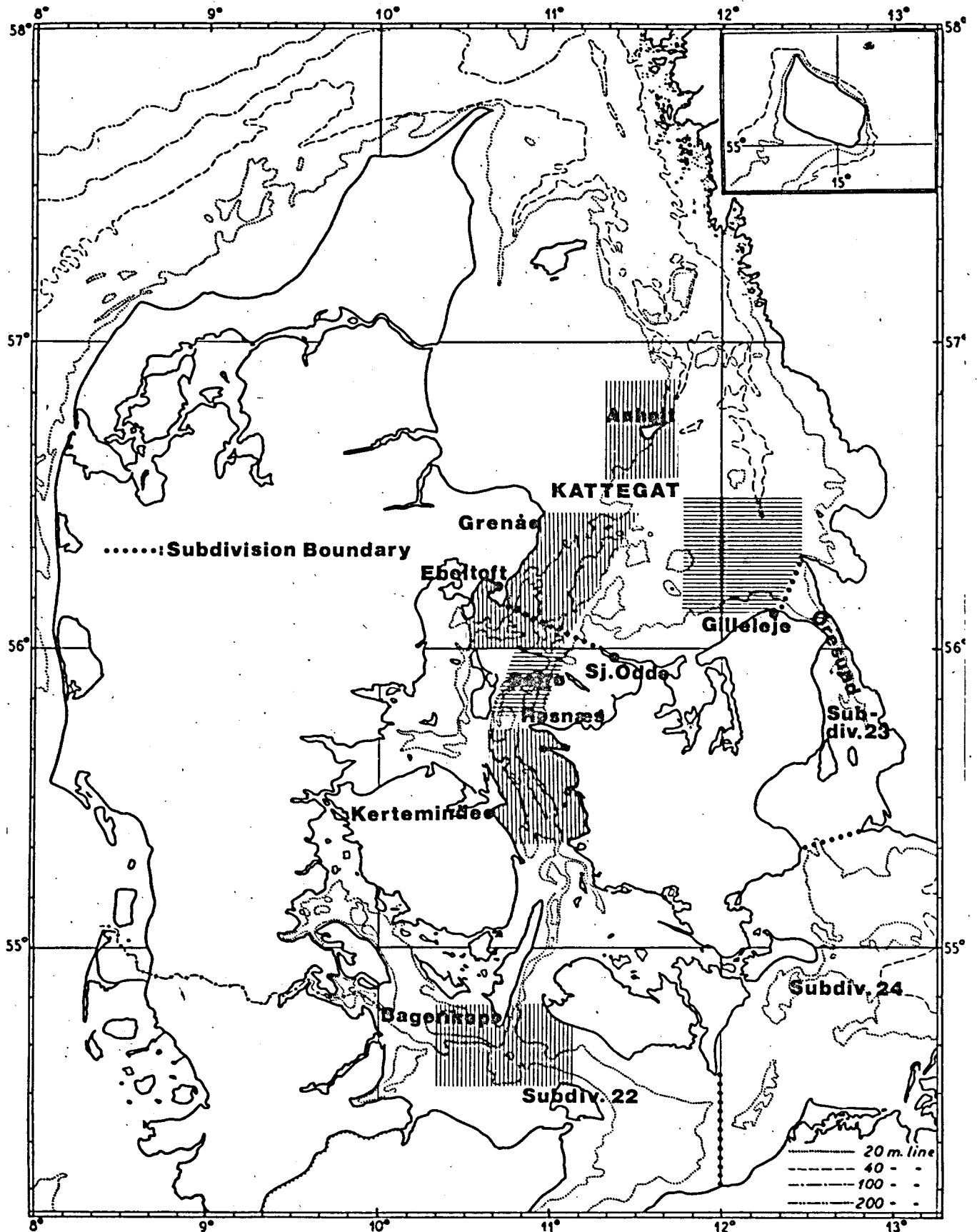


Fig. 1

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Appendix to C.M. 1980/J:12 - Growth Pattern in Cod Otoliths.

Page 4: Text should read:

Fig. 2a: Belt Sea Cod. Length 42 cm
Age group III. Caught in February.

Fig. 2b: Kattegat Cod. Length 42 cm
Age group IV. Caught in February.

Fig. 2c: Baltic Cod. Length 52 cm
Age Group V. Caught in April.