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Report of The Study Group on Cod Stock Fluctuations.

Syntheses of North Atlantic Cod Stocks.

THE NORWEGIAN SKAGERRAK COASTAL COD

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## DESCRIPTION OF COD STOCKS, THEIR BIOLOGY AND ENVIRONMENT.

### THE COASTAL COD AT THE NORWEGIAN SKAGERRAK COAST.

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#### **History**

The coastal cod used to be the most important resource for the fishermen at the Skagerrak coast up to recently when its importance (at least from an economical point of view was surpassed by deep sea shrimp (Dannevig and van der Eynden 1986). The cod was fished in nets, various types of pots and by hook and line.

#### **General structure of the stock.**

The coastal cod seem to be clearly separated from the cod of the open Skagerrak. This is indicated by tagging experiments (e.g. Danielssen 1969, in prep) and by differences in recruitment patterns (Gjøsæter and Danielssen 1990). Genetical studies show that the Skagerrak coastal cod are different from the cod of other parts of Norway at least in some characters (Nævdal, Gjøsæter and Gjørstad in prep).

Dannevig (1954) suggested that the Skagerrak coastal cod could be subdivided into three groups:

1. "Deep cod" living at deep water in the fjords and in the skerries,
2. "Kelp cod" living at shallow waters in the skerries, and
3. "Fjord cod" living at shallow waters in the fjords.

These groups were based on pigmentation, but some differences in body proportions were also suggested. The separation in these three groups has not been verified, and nothing is known about the stability of the groups and about their genetical basis.

Tagging experiments (Dahl 1906, Løversen 1946, Moksness and Øyestad 1984, Danielssen 1969, in prep.) has shown that the coastal cod is very stationary. Most recaptures are made less than 1 nautical mile from the tagging location, and according to (Danielssen in prep.) more that 93% are caught less than 15 n.miles from the tagging location. These tagging

experiments and also studies showing that the growth rate may be different in different fjords and coastal areas (Dannevig 1933, Løversen 1946, Gjørseter and Danielssen in prep), suggest that the fjords can have separate populations. However, it is likely that they partly are recruited from a common pool of eggs (Dahl 1906), and they can not be regarded as separate stock units.

There are evidence of a vertical migration. As the surface water gets warm during summer the cod go deeper, and it come back to shallow waters at autumn when surface water gets colder. During winter cod go down again to avoid the cold surface water, but come back to the upper layers in spring (Dannevig 1966, unpublished data, Flødevigen marine research station).

### **Fishing pattern.**

The coastal cod are partly fished by professional fishermen, and partly for leisure and for private consumption. There are no data to say which are most important. Neither is it possible to give any reliable catch quanta. Fishing mortality is not known, but based on tagging experiments a total mortality around 1.7 (year<sup>-1</sup>) has been suggested (unpublished data, Flødevigen marine research station).

### **Environment**

The environment of the cod on the Skagerrak has been described by several authors, and will not be dealt with here.

### **Spawning**

The cod at the Skagerrak coast spawn from middle of February till May, usually mainly in March - April (Dahl 1906, Dannevig 1966, Dahl et al. 1983). Spawning takes place at temperatures between 4 and 6°C, and apparently the temperature is the main factor regulating the time of spawning.

Data on where the cod spawn is sparse, but apparently spawning takes place in many (most?) fjords along the coast, and probably in the skerries too (Dahl 1906, Dannevig 1966, Dahl et al. 1983).

Dahl (1906) described spawning migration from Søndeledfjorden in the Risør area: During autumn adult fish are found in the skerries off the fjords entrance. From September an migration towards the inner parts of the fjords starts. They stay in the inner parts of the fjords during winter, and there the spawning starts in February - March while the fjord is still covered with ice. After spawning most of the spent fish starts an outward migration towards the fjord entrance. It is not known how representative this pattern is for other fjords.

### **Egg- and larval stages**

The eggs are pelagic and are mainly found in the upper 50 m. The depth distribution varies, however with the hydrografic conditions, and when there is much freshwater, they may go deeper. Experiments has shown that cod eggs from the Skagerrak coast has a density of 1.0238 - 1.0271 g cm<sup>-3</sup> (Moksness unpubl.).

Dahl (1906) argues that eggs and larvae float with the current and that eggs from different spawning sites can mix.

At temperatures around 6 °C the eggs hatch after 14 days (Iversen and Danielssen 1984).

### **Juveniles**

#### **Distribution and growth**

Larvae are pelagic till they reach an age of 2 - 3 months and a length of about 30 mm. Then they settle in shallow waters. Apparently few settle deeper than 20 m (Dahl 1906). The first juveniles settle in April - May, and generally they stay in the littoral zone till October - November, but in warm years they can stay even longer before they go deeper (Gjørøseter et al. 1989).

A study in the Risør area showed the density of 0-group cod was highest in protected fjord areas (exposure 4) and decreased gradually towards the most exposed areas (exposure 1)(Fig. 1) (Gjørøseter and Danielssen 1990).

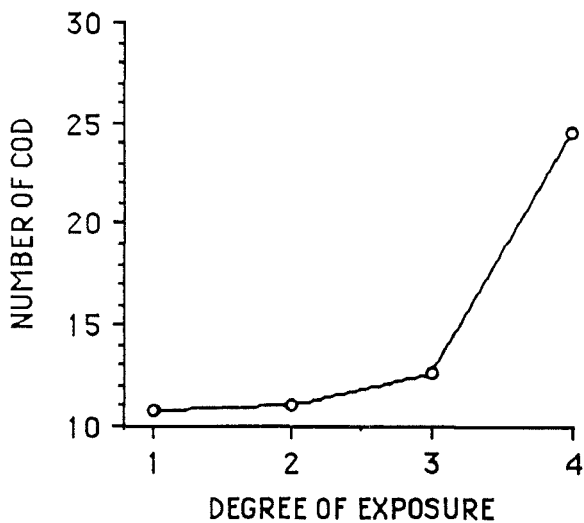


Fig. 1. Relation between number of 0-group cod pr. haul and degree of exposure. 1 most exposed, 4 most protected (Data from Gjøsæter and Danielssen 1990)

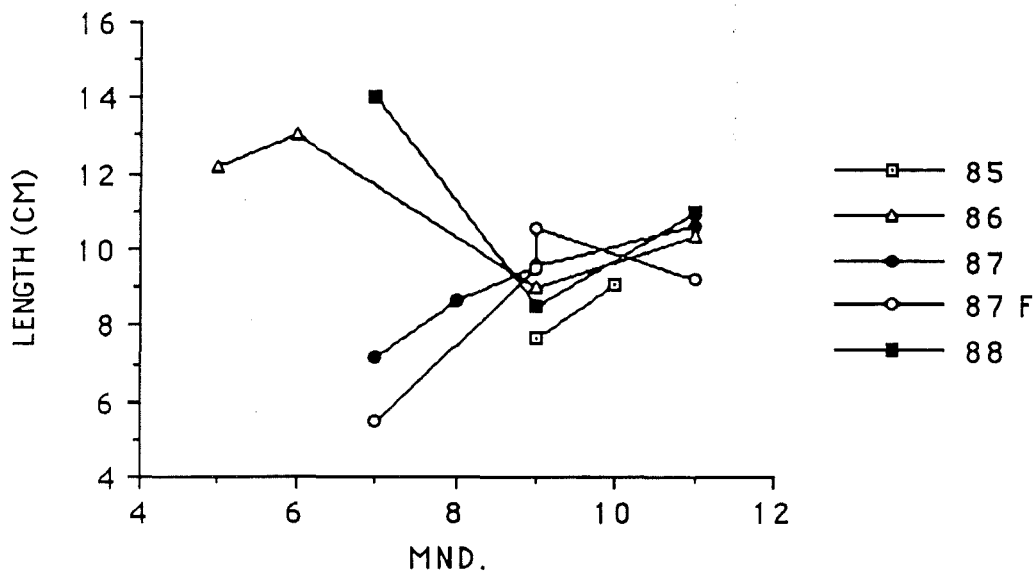


Fig. 2. Mean length of juvenile cod (15 cm or less) from beach seine catches in the Risør and Flødevigen (F) areas. The figures in the legend indicate years (Gjøsæter and Danielssen in prep)

From the cod settles at a size of about 3 cm in May - June it grow rather fast, but simultaneously new recruits settle (Dahl 1906, Gjøsæter and Danielssen in prep.). Therefore, the increase in mean length in the catches (Fig. 2), gives a underestimate of growth. It should also be noted that the smallest fish are not caught representatively with the beach seine

used. During autumn the 0-group reach a mean size of about 12 cm and a maximum size of 15 cm.

### Interactions

A list of the most abundant species occur together with cod in shallow waters are given in Table 1.

Table 1. Species caught in beach seine in the Arendal area 1985 -87. Only species giving an average of more than 1 fish haul<sup>-1</sup> are included (Gjørseter et al. 1989).

Species	Number pr haul
<i>Gobiculus flavescens</i>	40.51
<i>Gasterosteus aculeatus</i>	26.58
<i>Ctenolabrus rupestris</i>	20.26
<i>Gadus morhua</i> O-group	16.56
<i>Merlangus merlangus</i> O-group	12.90
<i>Gobius niger</i>	11.33
<i>Platichthys flesus</i>	9.39
<i>Gadus morhua</i> I-group	6.32
<i>Sprattus sprattus</i>	4.44
<i>Zoarches viviparus</i>	4.24
<i>Pomatoschistus minutus</i>	3.82
<i>Spinachia spinachia</i>	3.57
<i>Siphonostoma typhle</i>	3.26
<i>Pollachius virens</i>	2.90
<i>Pholis gunellus</i>	1.82
<i>Acanthocottus scorpius</i>	1.67
<i>Pleuronectes platessa</i>	1.13

The correlation between abundance of 0-group cod and abundance of some other species caught in the littoral zone was studied by Gjørseter and Danielssen (1990). They used a material from 22 stations in the Risør area, sampled each year from 1945 till 1985. No significant correlations were found (Table 2).

Table 2. Spearman rank correlations,  $\rho$ , between annual mean number of 0-group cod and abundance indices of other species (N = 41). P = probability (Gjøsæter and Danielssen 1990)

Species		$\rho$	P
Goldsinny wrasse	<i>Ctenolabrus rupestris</i>	0.072	>0.50
Other labridae	<i>Labridae</i>	-0.017	>0.50
Gobidae	<i>Gobidae</i>	-0.001	>0.50
Stickleback	<i>Gasterosteus aculeatus</i>	0.307	0.10>P>0.05
Flounder	<i>Plattichthys flesus</i> (L.)	0.309	0.10>P>0.05
Herring	<i>Clupea harengus</i> L.	0.063	>0.50
Sprat	<i>Sprattus sprattus</i>	-0.305	0.10>P>0.05
Mackerel	<i>Scomber scombrus</i> L.	-0.188	0.50>P>0.20
Sand eel	<i>Ammodytes lancea</i> Yar	-0.255	0.20>P>0.10
Pipe fish	<i>Siphonostoma typhle</i>	-0.044	>0.50
Other fish		-0.13	0.50>P>0.20
Crab	<i>Carcinus meanas</i>	-0.203	0.50>P>0.20

Interactions between juveniles and older cod and between juvenile cod and other fish from the littoral zone, have been studied by Gjøsæter (1987a, 1987b, 1988, 1990). He showed that 0-group cod avoid habitats occupied by older cod. If they cannot avoid the larger cod, they prefer to stay close to algae where they can hide. Presence of alga seem to reduce the predation from larger cod considerably, although large cod prefer small cod to most other littoral fishes, at least under experimental condition.

It was also shown that 0-group cod and 0-group whiting generally prefer the same habitats, but they have different feeding habits. The whiting take pelagic food more efficiently than cod, while cod is better in finding food at the bottom or hidden among algae.

### **0-group abundance and recruitment**

Tveite (1971) has shown that there is a close correlation between the number of 0-group caught in the littoral zone during autumn and subsequent abundance of that year-class along the Norwegian Skagerrak coast.



Beach seine hauls has been taken annually since 1917 (except 1940 - 44) in September at more than 100 stations from Kristiansand to the Swedish border. Average number of cod in these hauls has been taken as an indication of recruitment. Tveite (1971, 1984) presented data for the period 1917 till 1983. He concluded that there was a period with relatively low recruitment in all areas from 1930 to 1950. The best period for the open areas was from 1950 till 1970, while for the more landlocked areas the abundance of 0-group was highest before 1930 and after 1970.

Gjøsæter and Danielssen (1990) studied data from the Risør area 1945 - 1985 in more details, and found no general trend in abundance (Fig. 3). They found no correlation between the abundance of 0-group cod and other gadoids from the same area. The correlation between abundance of 0-group cod in the Risør area and on the Skagerrak coast in general was strong.

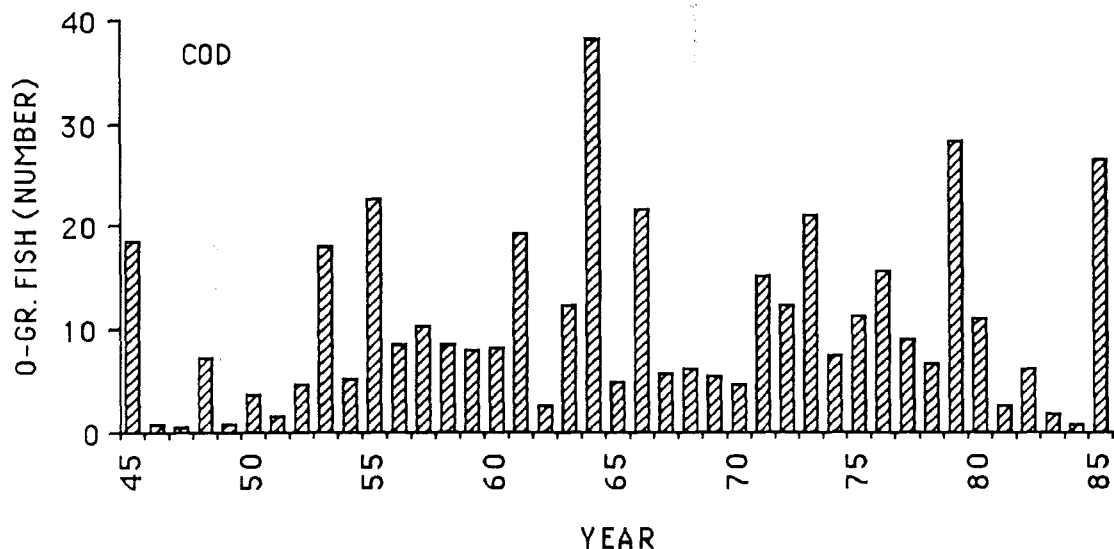


Fig. 3. Average number of 0-group cod in 22 beach seine hauls in the Risør area 1945 - 1985. (From Gjøsæter and Danielssen 1990)

Johannessen and Tveite (1989) studied the relationship between abundance of 0-group and environmental factors, and concluded that the wind direction and the stability of the water masses was the most important factors.

**Adults**

**Feeding**

Some preliminary data on food content of stomachs from cod from the Risør area caught during winter were given by Hop, Danielssen and Gjørseter (1988). Fish, mainly Gobidae, was an important part of the diet (Fig. 4, 5), and so were shrimps, crabs and other crustacea. The diet is, however, highly variable both geographically and with season, and a more detailed analyses of these variations is in progress.

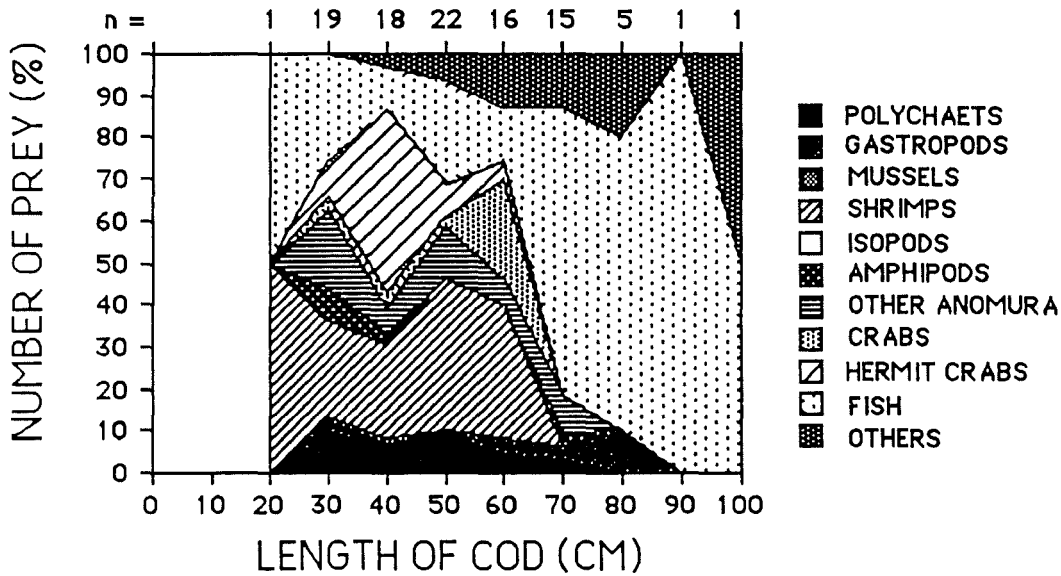


Fig. 4. Stomach content of cod from the Risør area during winter (From Hop, Danielssen and Gjørseter 1988).

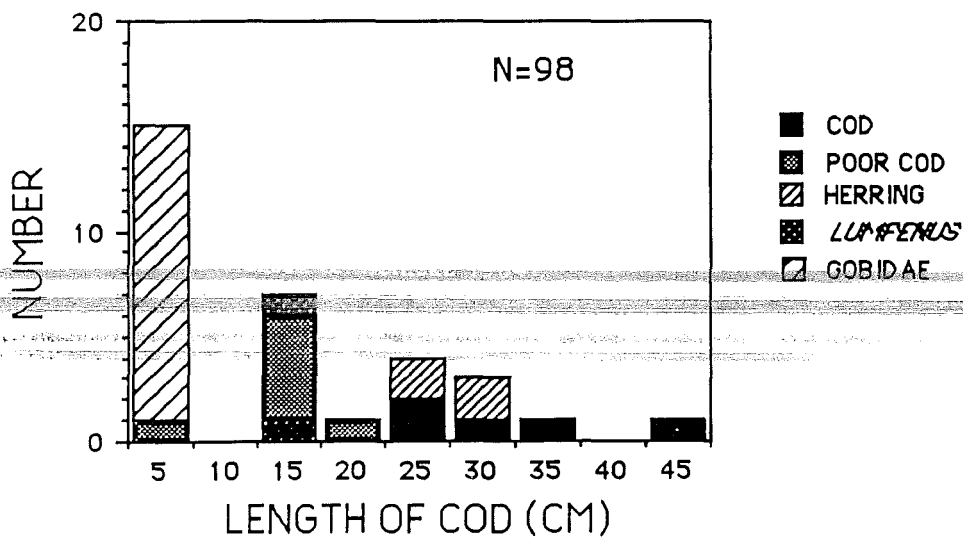


Fig. 5. Fish species in the stomach content of cod from the Risør area during winter (From Hop, Danielssen and Gjørseter 1988).

### Growth

Age and growth of the cod from the Norwegian Skagerrak coast have been studied by i.a. Dannevig (1933, 1953), Løversen (1946) and Gjørseter and Danielssen (in prep). They showed that growth was generally fast compared to other areas, and that it varied between different fjords and coastal areas (Fig 6). The average growth for the areas studied by Gjørseter and Danielssen (in prep.) is

$$l_t = 76.01(1 - \exp[-0.30(t - 0.26)]).$$

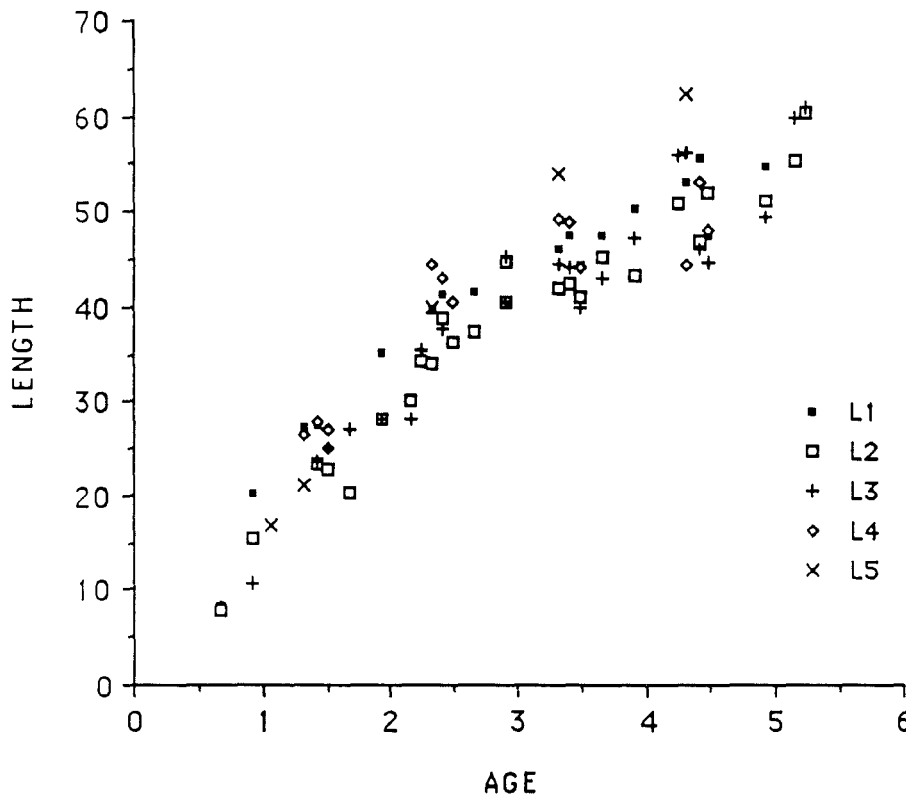


Fig. 6. Length at age of cod from the five areas: L1, Risør skerries, L2, Outer part of Søndeledfjord, L3 Inner part of Søndeledfjord, L4, Sandnesfjord, L5, Flødevigen. The symbols give average length for each age. Only lengths based on five or more observations are shown. (From Gjørseter and Danielssen in prep.).

To analyse possible density dependence in the growth rates, otolith diameters were measured and used as an indicator of length at age (Gjørseter and Lønnhaug 1990). The results suggest that there is no

correlation between the length increments and year-class strength (Fig. 7) (Gjørseter and Danielssen in prep.).

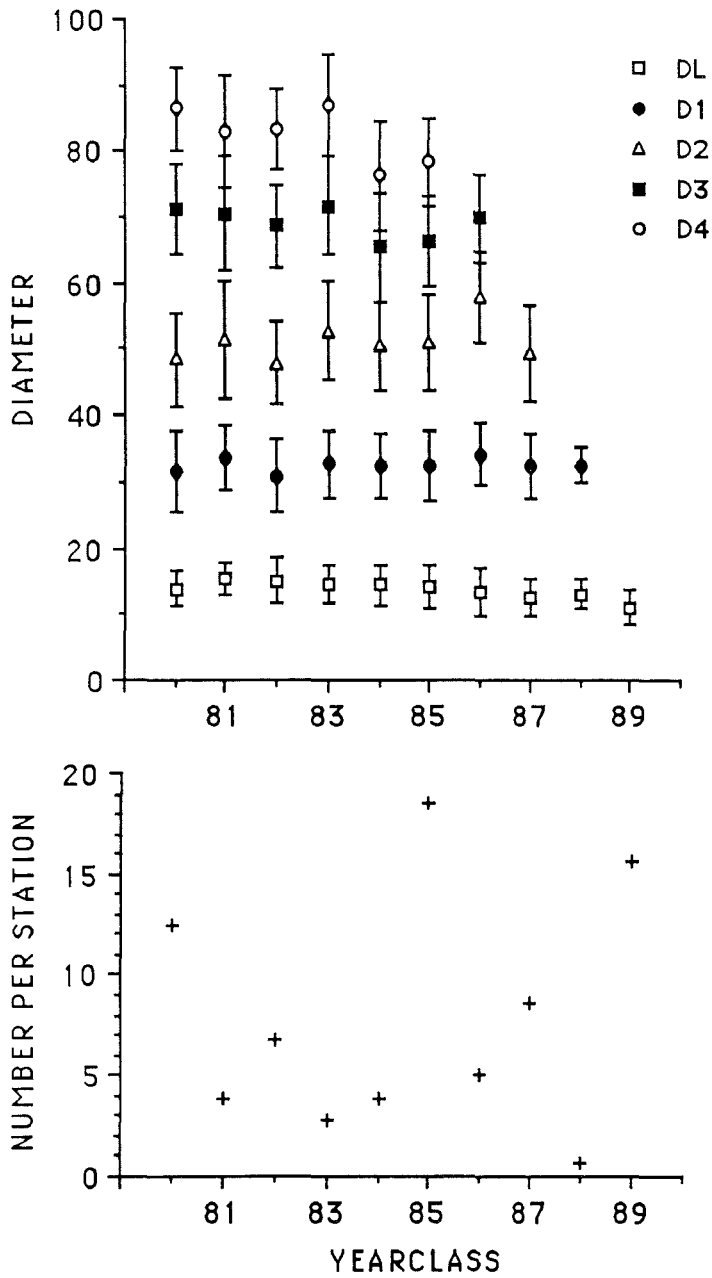


Fig. 7. Diameters of otolith zones in the year-classes 1980 - 89. Year-class strength at the 0-group stage is also indicated. (From Gjørseter and Danielssen in prep.).

**Age composition**

Few data are available on age composition, but results from a series of surveys with trammel nets in the Risør area suggests that few cod live for

more than five years, and catches are usually dominated by 2 years old fish (Fig. 8) (Gjørseter and Danielssen in prep.).

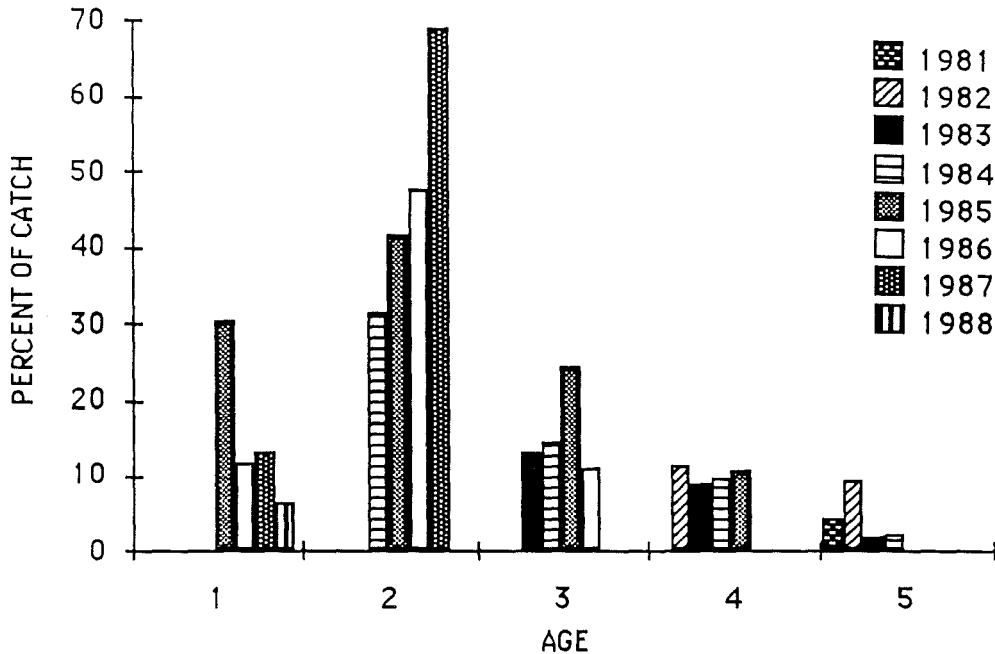


Fig. 8. Relative abundance of year-classes 1981 - 1988. The legend indicate year-class. (From Gjørseter and Danielssen in prep.)

#### **Maturation, fecundity and sex ratio.**

The Skagerrak coastal cod mature at an age of 3 - 6 years. There seem to be some geographical variations and the fish from the inner parts of the fjords mature at a lower age and a smaller size than fish from the open areas (Dannevig 1954). Off Flødevigen Sivertsen (1935, 1937) found that few cod were mature at an age of 3 years while 85 - 90% of the 4 and 5 year old fish were mature. According to Dannevig (1954) about 50% of the 3 years old fish mature.

Sivertsen (1937) found 337 males and 548 females in a material from the Flødevigen area during 1934-35, while unpublished data from 1985-88 gave 341 males and 326 females.

The fecundity has not been studied.

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