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Hypoxia and the Demersal Fish Stock in the Kattegat (IIIa) and Subdivision 22.

by

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1. Development of Hypoxia in the Kattegat.

Reduced values of oxygen content near the bottom have been observed in the autumn in the central and eastern Kattegat since 1921-40. In fig. 1.1 observations since 1904 and onwards according to month are shown (Ærtebjerg Nielsen et al 1981). Observations for 1987, 1988 and 1989 are added: The observations are made on or near a position (St. 13) 20 n.m. E-S of Anholt at a depth of 30-40 m.

It appears that since the period 1974-78 a downward trend is observed in 1987-1989, further the area with low oxygen content during autumn in the southern Kattegat has expanded also to shallow water (10-15 m). In fig. 1.2, 1.3 and 1.4 stations with an oxygen content ≤1ml/l ≤2ml/l and ≤3ml/l respectively in the autumn 1988 are shown. It appears that values ≤3ml/l are frequently observed in the northern Kattegat as well. (Ærtebjerg 1989).

2. Demersal Fish Stocks.

In the region of ICES yearly analytical assessments on cod and plaice are made. Reporting on yield and recruitment of sole is made, since 1984. A simple short-cut assessment was presented in 1989 and in 1990.

Data on the Danish yield of Norway lobster (Nephrops norvegicus) according to area are available since 1960.

In the following the development of stocks of cod, plaice, dab and Norway lobster shall be dealt with.

2.1. Cod in Kattegat.

2.1.1. Assessments.

The development of the cod stock in the Kattegat is given in table 2.1.1. Yearly landings, fishery mortality (F), spawning stock biomass, total biomass, and number of recruits, age I as estimated from VPA are shown.

It appears that the recruitment has been varying but applying means for 3 years, a clear downward trend is found with a reduction of 50% since the periods 1971-73 and 1974-76. (From 25 x 10^6 to 12.5 x 10^6).

The spawning stock biomass is reduced with about 70%. (35 x 10^3 tonnes to 9. 7 x 10^3 tonnes) In the same period F has increased from 0.8-1.28 or about 60%. F being proportional to the fishing effort.

It should be stressed that the reductions started after 1976

2.2. Cod in subdivision 22.

2.2.1. Assessments.

The development of the cod stock in subdivision 22 is given in table 2.2.1. Yearly landings, fishing mortality (F), spawning stock, biomass, total biomass and number of recruits age I as estimated from VPA is shown for each of the years 1971-89 and grouped as means of 3 years.

Compared to the period 1970-75 the landings in 1976-84 decreased with about 25% (33 x10^3 tonnes to about 25 x 10^3 tonnes) in the period 1985-87 the landings dropped with about 52%, in 1989 even with 80%. The spawning stock biomass was almost constant until the period 1979-81 and decreased then from about 27 x 10^3 tonnes to about 19 x 10^3 tonnes or about 30%. The lowest spawning stock biomass on record was found in 1986, 1987, 1988 and not least 1989 with a reduction of 60% compared to the mean of call preceding periods. The fishing mortality was almost constant on quite a high level until 1982-84, in 1985-87 an increase was observed. The recruitment of age I has dropped drastically to a level of about 20% (20 x 10^6) in 1985-87 compared to the period 1971-72. (about 130 x 10^6.) and in 1988 and 1989 to about 2 x 10^6 or a reduction of 98%.

2.3. Connections to other Cod Stocks.

The stock of cod in the Kattegat is connected with the Skagerrak stock and the stock in Subdivision 22, 23 and 24 by passive migrations of eggs and larvae and active migration of adult fish.

2.3.1. Eggs and larvae.

Eggs and larvae being pelagic are transported by the current from the Skagerrak to the Kattegat and from the Kattegat to Subdivision 22 and 23 and vice versa. In fig. 2.3.1 the distribution of cod larvae per 20 minutes in 2 m ringtrawl in spring 1959 in Subdivision 22, 23 and in the Kattegat is shown. It appears that concentrations of larvae are found in the Northern and Southern part of Subdivision 22 and in the northern part of subdivision 23, in the southwestern, the southeastern and the northern Kattegat. In the latter on a lower level because the peak spawning is earlier in this area. The concentrations in the southern Kattegat are possibly due to eddies created by the exchange of water masses between the Baltic and the Kattegat.

In fig. 2.3.2 the distribution of cod larvae in 1983 (Christensen et al. 1983) is shown. Compared with the distribution in 1959 (fig.2.3.1), it is seen that the distribution is changed and a concentration in the southwestern part of Kattegat is not found (the number of larvae is not to compare as different gears are used). In Subdivision 22 no Danish investigations on the abundance of cod larvae have been carried out since 1960, but investigations made by the Federal Republic of Germany, in the southern part of subdivision 22, in 1989 have shown a total absence of cod larvae. (A. Müller pers. comm.)

This means that the exchange of larvae between the Kattegat and Subdivision 22 and visa versa may be on a very low level. The southern Kattegat and subdivisions 22 and 23 is possibly now recruited mainly by larvae coming from the northern part.

2.3.2. Migrations of adult cod.

Tagging experiments in the Skagerrak and the North Sea have demonstrated an emigration of cod to the Northern Kattegat. Danielsen (1969) who tagged cod off the Danish Skagerrak coast (off Rubjerg) got 4.7% of the recaptured cod from the Northern Kattegat. Danish tagging experiments in 1971 in the North Sea on Monkey bank(52 n.m. WSW of Thorsminde), and 3 n.m. west of Thorsminde (Bagge 1973), showed migration of cod less than 70 cm to the western Skagerrak. 13 cod more than 70 cm were recaptured and 5 of those (38%) were recaptured near Skagen. In 1973 only cod more than 70 cm (Bagge not published) were tagged off Thorsminde. Of the recaptured cod 63, 26 (41%) was recaptured in the Skagerrak. 7 of those off Skagen (11%) indicating a moderate emigration to the northern Kattegat from the North Sea.

In the period 1959-85 about 55 tagging experiments have been carried out in Subdivision 22, 23 and 24 by Denmark, The German Democratic Republic, the Federal Republic of Germany and Sweden. Not all results are published.

A review of the results with respect to migrations to the Kattegat and to other areas is given by Bagge (1987) who concluded that the percentage of recaptured cod tagged in Subdivision 22, 24 and 23 and recaptured in the Kattegat, varied from 0-10%,(mean 3.0%) 0-9% (mean 1.5%) and 7-65% (mean 39.0%) respectively, the highest values when tagging was done in December-January (just before spawning), which means that the input of adult cod from Subdivision 22 and 24 to the southern Kattegat has not been very significant, while emigrations from Subdivision 23 have been important. As the stock of cod in Subdivision 23, being protected against trawling and seining has been on a high level with a biomass about 33% of the biomass of the Kattegat cod stock (Bagge 1981). The input of cod from this subdivision has been important. The stock of cod in subdivision 23 is since 1987 on a low level. The recaptures of cod tagged in subdivision 22 and in the western part of subdivision 24 and recaptured in the northern part of subdivision 22, varied from 1-20% (mean 3.0%) depending of the month of tagging. The main migration is in December-January. A review of cod migrations between the Baltic and the Kattegat and vice versa is given in Anon.(1990). The concentrations of cod larvae in the northern part of subdivision 22 and 23 fig. 2.3.1 indicate the migrations of cod to this area to be spawning migrations. The decline of the stock of cod in the Kattegat seems to be caused primary by unsuccesful spawning in the southern Kattegat and the northern part of subdivision 22 and by a missing exchange of larvae with subdivision 22 and 23, secondly by a reduced emigration of adult cod from subdivision 23 and to a lesser degree from subdivision 22 and 24.

2.4. Plaice in the Kattegat.

2.4.1. Assessment.

The development of the stock of the plaice in the Kattegat, yearly landings, fishing mortality, spawning stock biomass, total biomass and number of recruits age I as estimated from VPA and 3 years mean are shown in table 2.4.1.

In spite of a decreasing fishing mortality from 0.6 in the 70'ties to 0.3 in 1984-1988 the landings have decreased from 12600 tonnes in 1978 to 1700 tonnes in 1989.

In the period 1974-76 the highest recruitment on record is seen followed by the highest spawning stock biomass (1977-78). The spawning stock then decreased drastically from 27000 tonnes in 1978 to 8000 tonnes in 1982 due to poor recruitment (1978 and 1979). Since then the recruitment has been on that low level. No stock recruitment relation was observed.

2.4.2. Growth:

A decrease in the index for the yearly growth increment was found by Bagge and Nielsen (1987) using a rewriting of the von Bertalanffy equation (Beverton and Holt (1957)).

$$L\infty(a,y) = l(a+1, y+1)-l(a,y)*\exp(-K)/(1-\exp(-k))$$

Where l(a+1, y+1) and l(a,y) are length of the fish at age a and a + 1 in year y and y + 1 respectively.

The decreasing trend can be seen from table 2.4.2.

2.5. Plaice in Subdivision 22.

2.5.1. Assessment.

The plaice landings from subdivision 22, table 2.5.1., has had a decreasing trend since 1969 until 1989, which is the lowest landing in the period 1950-1989.

The level of landings in the middle of the 60'ties was the highest on record.

Analytical assessments have not been made regularily, but Bagge and Nielsen (1989) made VPA based on catch at age data sampled in Bagenkop (in the southern Belt Sea) and effort data from the cod fishery, plaice being a by-catch in the cod fishery.

The estimated stock size and recruitment are given in table 2.5.2. The spawning stock biomass has decreased from 5000 tonnes in the 1970'ties to 1000 tonnes in the 1980'ties caused by recruitment failures as in the Kattegat. An index from trawl surveys of plaice (all age groups) in 4 areas is given in table 2.5.3.

2.5.2. Growth.

The index of growth increment shows a slight decreasing trend from 1970-1977. And an astonishing increase is observed in the 80'ties, table 2.5.4. (Bagge and Nielsen 1989).

2.6 Connection to other plaice stocks.

The stock of plaice in the Kattegat is connected with the Skagerrak and the stock in Subdivision 22, by passive migration of eggs and larvae and active migration of adult fish.

2.6.1 Eggs, larvae and juvenile.

The spawning areas and nursery grounds are shown on fig. 2.6.1. Earlier Larval surveys (Anon 1989) (Fig. 2.3.2) indicate drift of larvae from the Skagerrak to the northern part of the Kattegat and from the Belt Sea into the Kattegat and vice versa. The level of drifting depends of the hydrographic condition. The input of larvae from the Skagerrak and the Belt Sea can also be demonstrated from meristic characters (mean number of anal finrays). In the northern part of the Kattegat Area 2 (fig. 2.6.1) the newly settled 0-group plaice shows a high mean number of anal finrays indicating "Skagerrak characters". In the southern part of the Kattegat Area 7 (fig. 2.6.1) the mean no of anal finrays is smaller indicating Belt Sea characters. (Nielsen and Bagge, 1985). Area 5 (fig. 2.6.1) shows also a high mean no of anal finrays, but with a high standard deviation (year 1950 and 1955) (table 2.6.1.), which indicate that a mixing of the stocks take place. A local Kattegat component in the center of the Kattegat, Fig. 2.6.1. was pointed out by Nielsen and Bagge (1985).

2.6.2. Migration of adult plaice.

Tagging experiments carried out on adult plaice, Trybom (1903), Johansen (1907) and Bagge (1978) in the Skagerrak and the northern Kattegat showed that no important migration of adult plaice take place from the Skagerrak to the Kattegat and vice versa.

Blegvad (1939) and Bagge (unpublished data 1957-1963) showed from tagging experiments in the northern Belt Sea a migration into the Kattegat in the early spring of about 40% of recaptured fish which has been in the sea more than 200 days. Blegvad found a migration of 20%, but that figure also includes tagging experiments from the "southern Belt Sea", where the plaice are more stationary. Fig. 2.6.2. and 2.6.3. show some of Blegvads results of tagging experiments in the Belt Sea on local plaice stocks.

Simonsen et al (1988) also showed a mixing of the plaice stocks in landings from the southern Kattegat. A change in meristic characters as anal finray from quarter to quarter indicated a mixing of adult fish. A low mean number of anal finrays observed in the spring (the first quarter) confirms the migrations of Belt Sea plaice into the Kattegat.

2.7. Dab in the Kattegat

No analytical assessment has been carried out.

2.7.1. Landings and growth

The landings in the Kattegat has fluctuated (table 2.7.1), but the present level about 1000 tonnes is lower than in the 70'ties 1700 tonnes

Only indices of stock size is available. The catch in kg per 1 hour hauls with standard trawl from the Kattegat survey is shown below.

Year	1984	1985	1986	1987	1988	1989
Catch kg.	92.6	62.3	110.2	212.6	154.1	226.0

It is seen that the dab-population in the Kattegat has increased from 1984 to 1989.

The yearly growth increment has been estimated (Bagge and Nielsen, 1987) and a decrease has been observed (Table 2.7.2.).

2.8 Dab in Subdivision 22

No analytical assessment has been carried out.

2.8.1. Landings and growth.

The landings figures shown are in table 2.7.1. The Danish landings has increased from 928 tonnes in 1978 to 1993 in 1985, and the level of landings have been on that high level onwards. Temming (1983) made a V.P.A. and found an increase in the stock by number in the period 1960-1980. Bagge and Nielsen (1986) showed from trawl surveys a drastic increase from 1982 to 1983 and 1985. (Table 2.8.1). In the Belt Sea a decrease in the yearly increement $L\infty(a,y)$ between the periods 1972-74 and 1983-85 has been shown by Bagge and Nielsen (1989) (Table 2.8.2).

2.9. Sole in the Kattegat.

2.9.1. Assesments and growth.

The landings from 1975 to 1988 are shown in table 2.9.1. The landings fluctuated and was on a high level in the late 70'ties and again from 1985 and onwards. The Danish landings constitute about 70-80% of the total landings. The sole landings are mainly by-catch in the Norway lobster fisheries. 80% of the sole catch in IV quarter is taken by trawl.

About 15% of the total catch is taken by sole gill nets. An analytical assessment has not been made yet, because the time series of catch at age data is too short.

Recruitment figures were available from 1960 to 1973 and again from 1984 to 1988. Table 2.9.2. The mean recruitment in the period 1960-65, 1966-1970 and from the most recent period 1984-1988 are shown below. The level of recruitment has increased from the 60'ties to the recent period with a factor 7.

	Total landings	Sole recruit I group survey data
Mean 1960-1965	400.8	1.11
1966-1970	311.0	.80
1984-1988	620.60	7.69

The mean weight and mean length for the most important age groups have been compared between years (table 2.9.2 and table 2.9.3) shows a decrease in growth from 1984-1988.

The fishermen found an increase in the gillnet catches when a low level of oxygen was detected in the area.

2.10. Discussion

2.10.1. Failing recruitment.

The reproduction of cod, plaice, dab and sole shows some common features. They have pelagic eggs and pelagic larvae which take nourishment from a yolk sac the first 6-8 days after hatching. Active feeding may start 2-3 days before the yolk sac is emtied. Cod, plaice and dab are spawning in February-March in the Kattegat and in March-April in Subdivision 22 but the dab extend the spawning time until May and June in Subdivision 22 and Kattegat respectively. The spawning time further coincide with or are close to the Phytoplankton spring bloom, but the dab is still spawning in the following period.

The sole differs being an early summer spawner and thus spawning when primary production is reduced to the summer level.

2.10.1.1. The pelagic stage.

When the pelagic stage is finished after about 2 months, all species in the area in question have their early bottom stage in shallow water. Plaice and sole in very shallow sandy areas (0.5-2.0 m). Cod in 2-6m in areas with eel grass and brown algae and dab on soft bottom in areas with a depth of about 10 m.

The load of nutrients to the Kattegat and Subdivision 22 has increased heavily during the last 20 years in fig. 2.10.1 and 2.10.2 the amounts of phosphate and nitrate found in the surface water at Fladen (Kattegat) in the winter month 1965-87 is shown Engström and Fonselius (1989), (Swanson 1984) and (Ærtebjerg 1986). A significant increase of primary production is not possible to show due to large gaps in the data set and varying techniques used (Anderson and Rydberg 1988) but must be expected as Ærtebjerg (1986) on a more complete data set from the Great Belt indicates a pronounced increase during he 1970'ties. In the same period a decrease of oxygen in the bottom water has been observed and especially after 1980 (fig.1.1). Anderson and Rydberg (1988) found that the mean oxygen concentration decreased from 4.58 ml/l to 4.08 ml/l (1971-82) corresponding to an increased oxygen consumption of 50%. It is not proved whether this effect is caused by the increased load of nutrients, by climatic changes or other factors, but most evidence point at the eutrophication. (Anon. 1987).

Low oxygen values are not found during the pelagic phase of eggs and larvae of cod, plaice, dab and sole, anyway not at the depths where eggs and larvae are found 0-15 m, mainly over depths of 30m, which means that the depletion of oxygen has no direct effect on the survival of eggs and larvae.

2-3 days before the pelagic larvae have exhausted their yolk sac they start active feeding on phytoplankton and copepod nauplii. This stage is a critical one, Shelbourne (1962) because if the proper "start food" (species, size and density) is not available combined with the proper temperature, the larvae is supposed to die from starvation, which may contribute to recruitment failure.

Investigations of the "start food" of cod, plaice and dab in the southern North Sea (Last, 1978) have shown that cod larvae of 3.0-3.9mm prefer diatoms (67% of the food), and dab larvae of 2.0-2.9 mm prefer dinoflagellates (45%), while plaice larvae prefer zooplankton mainly the appendicularian Oikopleura dioica (85%) on a later stage cod and dab feed on juvenile stages of Copepods. In the northern North Sea cod larvae starts on Copepod nauplii (Rab and Hislop 1980) (Pihl and Ulmestrand 1988).

A change in the composition of groups of species in the Phytoplankton has been demonstrated during the period 1962-82 by Berg and Radach (1988) who found a significant four folds increase of phytoplankton-C made up by flagellates and a not significant decrease af diatoms. In the same period nitrate increased four times and phosphate by a factor 1.5.

In the Dutch Wadden Sea similar increase of flagellates in the period 1969-85 has been shown by Cadée (1986). A decrease of diatoms was found from 1969-74 followed by an increase to values above the 1969 level in recent years.

Similar investigations have not been made in the Kattegat or in Subdivision 22 but if similar or more pronounced trends may be supposed in these areas, the failing recruitment of cod and plaice may be related to that. It should be mentioned that Møhlenberg (1990, Pers. Comm.) has demonstrated a decreasing biomass of copepods in the southern Kattegat and the northern Subdivision 22 and 23 in July 1979-88.

The increased stock of dab and sole may be due to the fact that sole is an early summer spawner and dab has an extended spawning period, which means that spawning happens after the spring bloom where the amounts of nutrients is reduced very much, but still on a higher level than in earlier years, which may benefit the spawning success, on that stage.

2.10.1.2. The early bottom stage.

When the pelagic stage is finished, cod, plaice, dab and sole are found in shallow water. Plaice and sole on sandy bottom 0.5-2.0 m, cod between vegetation 2-6 m and dab on muddy bottom at depth $\geq$ 10m.

Due to eutrophication the growth of rapid growing algae with a life span of only one year as Ectocarpis silicolosus and Chatomorpha linum have increased heavily along the coasts of the southern Kattegat and in Subdivision 22 between 0 and 6m covering the bottom as a carpet during late spring and summer Rask (1990).The algae replace algae with a larger life span and Zostera and prevent the young bottom stages of plaice and cod from feeding on Harpactisids being their main food, which may introduce an extra mortality. This phenomenon is also observed in the Baltic and along the Swedish Westcoast (Pihl 1988), but not in the Laholms Bay (Wennberg 1987) possibly due to outflow of fresh water from two rivers.

The bottom stage of sole appears in late summer when the algae have disappeared in depths less than 2.0m in the Kattegat and the young bottom stages of dab settling in depths $\geq$ 10m is not affected. An extra mortality on these species is not necessarily introduced.

2.10.2. Growth.

In the southern Kattegat and in Subdivision 22 the area and the time period with a still decreasing oxygen content in the bottom water have expanded affecting the bottom invertebrates and the distribution and growth of demersal fish stock.

In section 2.4 and 2.7, 2.8 and 2.9 a decrease in growth has been dealt with.

Two main factors in an area with a low oxygen content may influence the growth of fish

1) Change in the bottom fauna.
2) Change in metabolism resulting in a reduced consumption.

A change in the bottom fauna in the Kattegat has been observed by Pearsson et al (1985) who in 1983 repeated the bottom sampling made by Petersen 1911-12 using the same methods. They found a decreased biomass, a reduced mean size of animals and a changed composition of species (a decrease of bivalves and an increase of short living, fast moving deposit feeding polychaets, further an increase of brittlestars). The change was related to the increased eutrophication followed by oxygen dificiency. Rosenberg et al (1988) found from 1984 to 1985 a decreasing biomass of the brittlestar, Amphiura filiformis but the biomass of Amphiura chiajei was unchanged, but the total biomass of all species decreased with about 75%, which means that the brittlestar mentioned constitute with 26% of the total biomass in October 1985 but with 64% in November 1985.

Preliminary results from bottom sampling in the southern part of the Kattegat Bagge et al (unpublished data) compared with data from Blegvad and Petersen 1916-1930 combined (unpublished data) (fig. 2.10.3) also indicate a change in the bottom fauna.

Low oxygen content in autumn results in a decrease in numbers and biomass, but with a recolonisation soon after. (Bagge et al, preliminary results, unpublished data). Similar results was found by Murawski et al (1989) off New Jersey.

The preliminary results of stomach samples of plaice and dab in the southern Kattegat (Bagge et al unpublished data) indicate no food competition between plaice and dab, and the species composition in the stomach is not the same as in the bottom samples, which indicates a selective feeding, and that may result in lack of food in periods with low oxygen content. The stomach content of plaice distributed on taxonomical main groups in 1987-1988 (preliminary unpublished data) compared to Blegvad (1916) are shown on Fig. 2.10.4. In the food of plaice the bivalves in 1916 constituted 50% of the stomach content (by weight). In 1987-88 the fraction of bivalves has been reduced to 20%, the polychaets have increased from about 45% to about 70% and the species composition has changed.

Using the mean weight of the stomach content as percentage of the body weight as an index for consumption a decrease for plaice from 5% in 1916 (Blegvad 1916) to 0.5% in 1987-88 was found. In the Sound (Subdivision 23) 0.5% was found by Degel and Gislason (1988).

The distribution of taxonomical main groups in % of the stomach content of dab (fig. 2.10.5) in the same period showed the Polychaets as the dominating food in 1916 (45%) followed by echinoderms (brittlestars) and bivalves with about 28% and 22% respectively. In 1987-1988 the stomach content was dominated by brittlestars constituting nearly 70%. The polychaets and bivalves about 18% and 8% respectively.

The consumption has in the same period decreased from 2-3% of the body weight in 1916 to 0.3-0.5% in 1987-88. In the Sound (subdivision 23) 0.5% (Degel and Gislason, 1988). The availability of polychaets increases at low oxygen saturations because they move up from the sediment, Barker Jørgensen (1980). In 1988 large quantities of polychaets and other invertebrates were taken in trawl hauls. The low consumption indicates a reduced capability of consumption. Very low indices were found at oxygen saturations below 50%. It should further be mentioned that at low oxygen tensions more is spent on ventilation (Steffensen et al. 1982).

It is assumed that the same factors explains the decrease in growth for Sole.

In Subdivision 22 the main food item (Abra alba) is still available and the biomass of the species has even increased in the northern area (Bagge and Nielsen (1989)). The increasing growth increment of plaice may be explained by that.

2.11. Nephrops norwegicus (Norway lobster)

No analytical assessment is made.

2.11.1 Landings

The landings in the Skagerrak and Kattegat by country are shown in table 2.11.1.

In the Kattegat the Danish landings have decreased since 1984 and the Swedish since 1982. In the Skagerrak the Danish landings show the same tendency while the Swedish landings have increased slightly.

2.11.2 Effort and catch per unit of effort

In Fig. 2.11.1 Swedish landings per unit of effort (LPUE) is shown. In the Kattegat the LPUE increased until 1982 to about 12 kg per hour and decreased there after to a level of 3.0 kg in 1989 or to about 25% indicating a decreasing stock.

In the Skagerrak the Swedish LPUE decreased from 1984, about 11 kg per hour to about 6 kg per hour in 1989, even the total landings increased indicating an increasing effort and a decreasing stock.

Danish catch statistics on effort are available but not reliable, therefore a short description of the development in the Danish fishery on Nephrops is given below:

The development of hypoxia in subdivision 22 and especially in the southern Kattegat has restricted the fishery on finfish in these areas to the winter months, which transfers the Danish effort to other areas and species, plaice in the North Sea in April-June, and Norway lobster in July-December in the Kattegat and Skagerrak being the only non quotated species. Fishery on Baltic sprat and herring for consumption is not profitable since the opening of the herring fishery in the North Sea, vessels from that fishery have also switched to Nephrops fishery. At the same time the overcapacity of Danish vessels in the North Sea has transferred part of that fleet to a periodically fishery on that species in Kattegat and Skagerrak. which means that the number of fishing vessels fishing on Nephrops has almost doubled, and at the same time the size of the vessels and the amount of hp per vessel have increased. Further, sonar is common equipment in order to exploit areas not earlier fishable.

A further increase in effort since 1984 has developed as 2/3 of the trawlers have changed to the double trawl system. This implies, that each vessel is fishing with 2 trawls, which almost double the catch compared to vessels using the single trawl system.

A conservative estimate of the increase in Danish effort 1984-89 compared to the years earlier than 1980 is by a factor 4, which compared to the Danish landings indicates a significant decrease in stock size. The Swedish effort in the Kattegat has in the period 1980-89 increased by a factor 1.4 in the Skagerrak by a factor 2.5 Anon. (1990).

2.11.3. The catchability of Norway lobster

The catch of Norway lobster according to month of the year in the Kattegat has been shown by Høglund (1939). Poulsen (1945) and Jensen (1956), they suggested that the animal periodically were hiding in burrows. That suggestion was proved by Thomas (1954), Dybern et al (1965) and Rice and Chapman (1974). It was suggested that temperature, Jensen (1956) and light intensity, Thomas (1954), Dybern (1956) and Rice and Chapman (1974) were the governing factors. Bagge and Munch Petersen (1979) demonstrated a significant negative correlation between the catch per hour and the oxygen saturation near the bottom together with a negative correlation between the percentage of females in the catch and the oxygen saturation (fig. 2.11.2 and 2.11.3)

It appears that the catch per 1 hour of males and females increases 4 times when the oxygen saturation is reduced from 90% to 60% and at lower saturations exponentially, further that the percentage of females increases from 20% - 35%.

The low oxygen regime makes the Norway lobster more vulnerable to the trawl fishery and reduces the protection of females carrying the eggs, which together with the increased effort put a heavy stress on the stock of Nephrops.

The fishery has moved northward in Kattegat and since 1988 there has been no Danish commercial fishery in the Kattegat on Nephrops south of latitude 56°40'N.

2.12. Oxygen deficiency and fish diseases.

The investigations of fish diseases in the Kattegat dab population involve the regisration of the frequencies of certain infretious diseases. It is one disease of viral origin, lymphocystis, one of presumed viral origin, epithelial papillomas and one often bacterial associated, ulcerations.

These diseases are widely disributed among dab populations. However, the impact of stress, for example caused by oxygen deficiency or food deficiency evntually caused by the latter, will result in a decrease in the efficiency of the fish's immune defence against infectious diseases. This can lead to an increased disease level in the affected fish stocks. 1987. In the Kattegat, the investigations of fish diseases in the dab populations were initiated in May 1984 (Mellergaard & Nielsen, 1985) an have been carried out annually in May. During the first three years of the investigations the disease level in the Southern Kattegat kept at a relatively constant level of appr. 5%. The first intensive oxygen deficiency in the latter area took place in late summer 1986 and has been an annually event since that time. In the following years the disease levels have gradually increased to appr. 18% and have not yet culminated (Fig. 2.12.1). As illustrated in this figure only the viral diseases respond to the environmental stress while the frequency of ulcerations seems to be at a constant level.

A rapid spread of disease among the young age groups of dabs seems to be responsible to the marked increase in disease level from 1986-87. In an non-stressed population only few fish among the two and three year old fish are affected by disease while diseases are more common in the older age groups. If a dab stock is affected by stress, for example caused by oxygen deficiency, the young fish will be seriously affected by disease. In a non-stressed fish population the frequency of the viral diseases, lymphocystis and epidermal papillomas, is increasing with increasing age (Mellergaard & Nielsen, 1984; 1985). The increase in the disease rate in the southern Kattegat is primarily due to a serious spread of diseases in a, under normal conditions, healthy population of young fish (Fig. 2.12.2). Secondarily, as the disease rate in the young fish population initially is high the disease rate in this population will be even higher with increasing age of the population.

Therefore, a decrease in the disease rate of the southern Kattegat dab population will be registered until the area has been without oxygen deficiency for approximately four years. During this period, a new and healthy fish stock will be built up, as the new population is not influenced by stress. In the same period, the diseased stock will gradually die out due to fishery and natural mortality.

13. References.

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Table 2.1.1. Assessment of cod in the Kattegat.

Year	Landings 1000 tonnes		F (3-9)		Spawning stock biomass 1000 tonnes		Tot. bio-mass 1000 tonnes	No. of Recruits in millions	
1971	15.7		0.60		29.2		66.1	37.2	
1972	17.4	17.3	0.56	0.70	37.9	35.0	68.7	22.7	25.1
1973	18.8		0.95		38.0		65.2	15.5	
1974	21.9		0.98		36.4		68.7	30.3	
1975	15.5	17.9	0.65	0.30	24.2	32.9	63.8	26.0	25.3
1976	16.3		0.78		31.6		57.9	11.0	
1977	20.1		1.04		32.4		60.9	29.5	
1978	13.4	16.8	0.83	0.83	20.7	26.5	58.4	23.4	21.2
1979	14.8		0.62		26.3		50.5	10.8	
1980	13.5		0.68		26.5		44.3	14.4	
1981	15.3	10.4	0.86	0.92	21.9	21.3	41.3	17.1	17.4
1982	12.5		1.21		15.6		38.7	20.6	
1983	12.8		1.09		15.7		40.3	20.5	
1984	11.9	12.5	1.16	1.16	16.4	16.1	36.5	11.4	13.6
1985	12.7		1.22		16.3		29.4	8.8	
1986	9.1		1.22		12.5		28.6	17.4	
1987	11.5	8.9	1.42	1.28	9.1	9.7	21.6	5.5	11.0
1988	5.5		1.20		7.9		16.8	10.0	
1989	8.5				8.3		19.6	6.3	

Table 2.2.1 Assessment of cod in Subdivision 22.

Year	Landings 1000 tonnes		F (3-7)		Spawning Stock biomass 1000 tonnes		Total biomass	Number of recruits VPA I group in millions	
1970	31.4		0.72		19.2		70.8	120.5	
1971	32.1	32.1	0.91	0.81	30.0	27.0	78.1	112.2	127.6
1972	32.8		0.80		31.8		82.0	150.2	
1973	38.2		0.99		34.5		83.0	33.2	
1974	31.3	33.8	1.16	1.08	37.1	32.0	70.5	151.2	85.2
1975	31.9		1.10		24.3		76.1	71.2	
1976	33.4		1.28		37.1		75.5	57.0	
1977	29.5	28.4	1.13	1.07	23.8	26.3	53.6	82.9	64.2
1978	24.2		0.80		19.0		51.1	52.6	
1979	26.0		0.76		29.9		48.1	24.8	
1980	22.9	25.1	1.06	.96	29.9	28.8	46.5	69.4	39.4
1981	26.3		1.06		23.6		42.1	27.9	
1982	21.0		1.15		21.0		34.9	51.7	
1983	24.5	24.2	1.03	1.06	16.6	21.3	35.8	75.4	47.0
1984	27.1		1.00		26.4		36.9	13.8	
1985	22.1		1.37		26.7		32.1	9.9	
1986	12.0	15.4	1.27	1.21	14.8	19.2	19.6	47.3	21.9
1987	12.1		0.98		16.2		25.6	8.4	
1988	9.7		0.93		13.2		15.3	2.3	
1989	5.7		0.79		9.8		10.7	1.7	

Table 2.4.1. Summary Table Plaice in the Kattegat.(See text).

Year	Landing 1000 tonnes		F (3-9)		Spawning Biomass 1000 tonnes		Total Biomass 1000 tonnes	Recruits VPA I-group in millions	
1968	11.6		.56		21.2		47.0	67.9	
1969	9.8	10.8	.54	.55	23.7	24.7	47.2	48.5	53.6
1970	10.9		.56		29.2		47.7	44.3	
1971	15.0		.88		29.7		42.5	17.1	
1972	15.8	13.7	.73	.72	23.6	21.8	37.3	56.8	33.2
1973	10.2		.56		12.2		29.2	25.7	
1974	11.7		.70		17.2		32.1	54.5	
1975	10.5	10.6	.60	.58	12.1	14.2	40.7	94.5	49.7
1976	9.7		.45		13.3		46.7	54.4	
1977	11.9		.60		30.0		47.0	28.7	
1978	13.1	11.7	.59	.62	27.5	25.9	36.9	17.2	18.1
1979	10.0		.67		20.2		24.6	8.5	
1980	5.8		.62		13.9		16.8	7.4	
1981	4.0	4.2	.55	.53	10.1	10.8	14.2	14.4	13.8
1982	2.9		.42		8.4		17.0	19.5	
1983	3.5		.52		8.1		18.3	18.5	
1984	3.6	3.5	.74	.53	8.3	8.5	17.2	17.3	15.5
1985	3.4		.33		9.2		16.3	10.7	
1986	2.7		0.49		7.7		11.0	5.2	
1987	3.2	2.6	0.56	.50	7.7	6.7	11.0	6.3	9.0
1988	2.0		.62		4.7		10.2	14.5	
1989	1.7		0.46		4.3		9.4	5.3	

Table 2.4.2. (L_∞) a,y of Plaice in the Kattegat (sex combined) (Bagge and Nielsen (1987)

Year/age	IV	V	VI	VII	mean
71	78.966.	84.08	104.9.	109.44.	94.34.
72	75.48.	78.85	.82.33	87.17	80.50
73	83.74.	91.90	97.35	100.22	93.30.
74	57.96.	84.72	78.91	94.46	79.01.
75	74.35	83.76.	84.45	90.99	83.38.
76	64.89.	72.58.	86.07.	86.19	77.43
77	73.13	90.59.	92.63	88.09.	86.11
78	61.37	(58.91)	(49.44)	85.76.	
79	69.75	73.21	84.92	99.41	81.82
80	64.61	74.59	80.51	84.78	76.12.
81	74.42	79.79	80.57.	78.85	78.4
82	66.86	69.76	66.19	(62.62)	66.35
83	68.83	67.87	65.32	66.26	67.07
84	69.15	79.45	83.33	83.83	78.94
85	66.02	69.20	69.22	78.71	70.78

Table 2.5.1. Landings of Plaice in Subdivision 22

Year	Denmark	Germ. Dem. Rep.	Germ. Fed. Rep.	Total
1968	4.5	.01 x	.15 x	4.66
1969	4.4	.01 x	.15 x	4.56
1970	3.8	.01 x	.20	4.01
1971	3.4	.01 x	.16	3.57
1972	2.7	.01	.15	2.87
1973	3.4	.002	.16	3.56
1974	3.4	.036	.17	3.61
1975	2.7	.011	.30	3.01
1976	3.3	.011	.30	3.61
1977	3.4	.005	.35	3.76
1978	3.9	.033	.35	4.28
1979	3.5	.010	.20	3.71
1980	2.2	.005	.08	2.33
1981	1.2	.016	.07	1.21
1982	0.7	.006	.04	0.75
1983	0.9	.005	.04	0.95
1984	0.8	.007	.02	0.83
1985	0.6	.068	.03	0.70
1986	0.6	.034	.03	0.66
1987	.4	.004	.01	0.45
1988	.2	.003	.01	0.21
1989	-2	-	.01	0.21

x No data available assumed figures.

Table 2.5.2. Spawning stock Biomass in Subdivision 22 and Recruitment (Bagge og Nielsen, 1989)

Year	SSB	Recruit.
1968	8207	17140
1969	7173	10393
1970	5943	14310
1971	3932	7390
1972	3254	25130
1973	2600	6426
1974	4468	14093
1975	2197	24817
1976	2336	29586
1977	4358	20045
1978	6527	9758
1979	6607	1208
1980	3540	1741
1981	1894	5057
1982	1064	2962
1983	1483	1619
1984	1080	4579
1985	978	2066
1986	1139	-

Table 2.5.3. The estimated index* of plaice (all age-groups) in subdivision 22 per 1 hours haul per area per year. Bagge and Nielsen, 1989.

	Area			
	10	11	12	13
	I	I	I	I
Year				
1953	17.49	74.50	475.55	39.05
1954	14.94	26.72	55.49	31.73
1955	16.71	11.25	60.31	20.18
1956	47.32	18.00	67.35	70.92
1957	16.09	5.50	8.88	12.58
1958	17.53	9.23	33.43	9.43
1959	15.23	49.37	34.47	18.73
1960	113.41	78.01	28.69	63.52
1961	62.96	35.62	47.55	47.35
1962	94.44	25.56	33.87	129.34
1963	39.22	48.30	92.96	43.39
1964	62.80		3.38	
1979			17.00	
1980				
1982	2.00	0.73		6.92
1983	5.11	0.75		10.61
1985	1.05		1.63	3.24

* Pennington index

Area 10 = North of Fyn
Area 11 = Little Belt
Area 12 = "Ferskvandet"
Area 13 = Aarhus Bay

Table 2.5.4 (L_∞)a,b, for plaice (sex combined) in subdivision 22. Bagge and Nielsen 1989)

	Mean age 2-4	Age 3	Age 2
1970	45.05	46.15	
1971	38.88	39.97	
1972	44.72	45.38	
1973	37.93	32.24	
1974	37.56	34.92	
1975	36.79	40.05	
1976	-	35.30	
1977	36.38	37.33	
1978	48.01	47.89	
1979	39.90	39.46	
	-	-	
1982	30.50	27.61	
1983	39.37	39.69	
1984	44.22	39.67	

Table 2.6.1. Mean no. of anal finrays of 0 group (See fig. 2.6.1).

Area		1950	1955	1985	1988
Area 2	M	53.50	53.93	54.88	54.08
N.f.	Sdev	2.43	2.06	1.99	2.49
Sæby	N	195	87	121	99
Area 5	M	53.06	53.33	54.17	53.94
Hov-	Sdev	3.45	2.34	1.86	1.98
Åsa	N	17	6	76	36
Area 7	M	51.62	50.37	54.80	52.18
North of	Sdev	3.32	1.54	2.17	1.94
Djursland	N	39	16	44	17

Year selected in which all the three areas are represented.

Table 2.7.1. Danish landings of dab from the Kattegat and Subdivision 22.

	Kattegat	Subdivision 22
1978	1688	28
1979	1878	1413
1980	1614	1593
1981	1674	1601
1982	1669	1863
1983	1836	1920
1984	1264	1796
1985	1901	1993
1986	911	1655
1987	1150	1706
1988	1219	1846
1989	1073	1722

Table 2.7.2. (L∞) a,y, (see text) of Dab in the southern part of the Kattegat. (Bagge and Nielsen (1989)).

Year/age	II	III	Mean
33	42.81	38.62	40.71
34	55.28	81.20	68.24
35	61.55	62.31	61.83
Mean 1933-35	53.21	60.71	
60	27.29	28.65	27.87
61	31.05	37.25	34.15
62	40.26	60.73	50.49
63	33.81	46.97	40.39
Mean 1960-63	33.10	43.40	
84	38.81	35.19	37.0
85	34.57	17.82	26.19
1984-85	36.69	26.51	

K = .1075.

Table 2.8.1. The estimated index* of dab (all age-groups) in subdivision 22 per 1 hours haul per area per year. (Bagge and Nielsen (1986)).

	Area			
	10	11	12	13
	I	I	I	I
Year				
1953	92.29	101.00	31.68	460.31
1954	175.65	34.21	26.60	162.34
1955	397.64	41.78	51.92	300.03
1956	505.23	25.00	111.47	303.90
1957	78.11	17.00	47.88	104.07
1958	255.47	28.88	56.75	157.17
1959	222.23	83.46	46.56	171.77
1960	210.04	61.09	26.11	192.91
1961	150.82	34.39	63.81	200.56
1962	264.90	36.95	114.06	249.24
1963	214.89	50.09	144.56	606.11
1964	224.71		8.73	
1979			89.00	
1980				
1982	163.00	103.99		241.60
1983	1253.82	507.32		1110.88
1985	1304.44	257.94	361.70	1312.00

* Pennington index

Area 10 = North of Fyn
Area 11 = Little Belt
Area 12 = "Ferskvandet"
Area 13 = Aarhus bay

Table 2.8.2. (L_∞') a,y of dab in Subdivision 22 (sex combined) (Bagge and Nielsen (1989)),

Year	Age	2	3	4	5
1962	-	-	44.37	44.18	47.66
1963		37.23	31.06	48.69	-
1964	-	-	32.38	27.34	35.54
Mean 1962-1964		37.23	35.94	40.07	41.60
1972	-	41.48	56.65	-	-
1973	-	42.15	59.32	-	-
1974	-	41.85	65.43	-	-
Mean 1972-1974	_	41.83	60.47		
1983	-	41.72	44.52	43.82	-
1984	-	40.93	28.34	(22.28)	-
1985	-	36.55	55.36	-	-
Mean 1983-1985	-	39.73	42.74	43.82	-

Table 2.9.1. Sole in the Kattegat and the Skagerrak

	Sole landings tonnes		Sole recruit I gr.survey data
	total	DK	
1975	498	459	
1976	611	422	
1977	815	517	
1978	661	502	
1979	475	376	
1980	344	316	3.19
1981	295	271	
1982	224	210	
1983	319	262	
1984	406	326	8.19
1985	548	396	18.25
1986	783	645	1.73
1987	714	623	2.12
1988	652	550	8.17
1989	814	793	9.16

Table 2.9.2. Sole in the Kattegat estimated mean length and the yearly growth increment ($L\infty$).

Meanlength

Year/ Age	1984	1985	1986	1987	1988
2	25.25	24.83	24.408	24.16	23.33
3	26.55	27.39	27.27	25.74	25.30
4	28.53	29.45	29.53	28.08	27.02

K = .27

$L\infty(a,b)$

Year/ Age	84-85	85-86	86-87	87-88
2-3	33.81	34.65	29.61	28.57
3-4	38.26	35.92	30.26	30.71

Table 2.9.3. Mean weight by age per year of Sole in the Kattegat

Mean weight

Year/ age	84	85	86	87	88
2	183	174	165	160	144
3	213	234	231	194	184
4	257	283	287	245	218
5	294	291	257	274	248

Table 2.11.1. Nephrops in Skagerrak and Kattegat.
Landings in tonnes by country 1979-89.

	Skagerrak				Kattegat		
Year	Denmark	Norway	Sweden	Tot.	Denmark	Sweden	Tot.
1979	361	9	295	665	1446	131	1577
1980	643	18	332	993	1542	122	1664
1981	609	8	375	992	1568	161	1729
1982	1090	8	372	1470	1611	216	1827
1983	1589	51	564	2204	1330	148	1478
1984	1749	97	830	2676	1842	194	2036
1985	1334	72	785	2191	1609	189	1798
1986	1054	64	900	2018	1593	214	1807
1987	1385	80	975	2440	1454	151	1605
1988	1260	89	1000	2349	1204	160	1364
1989	1795	70	743	2608	1222	87	1309

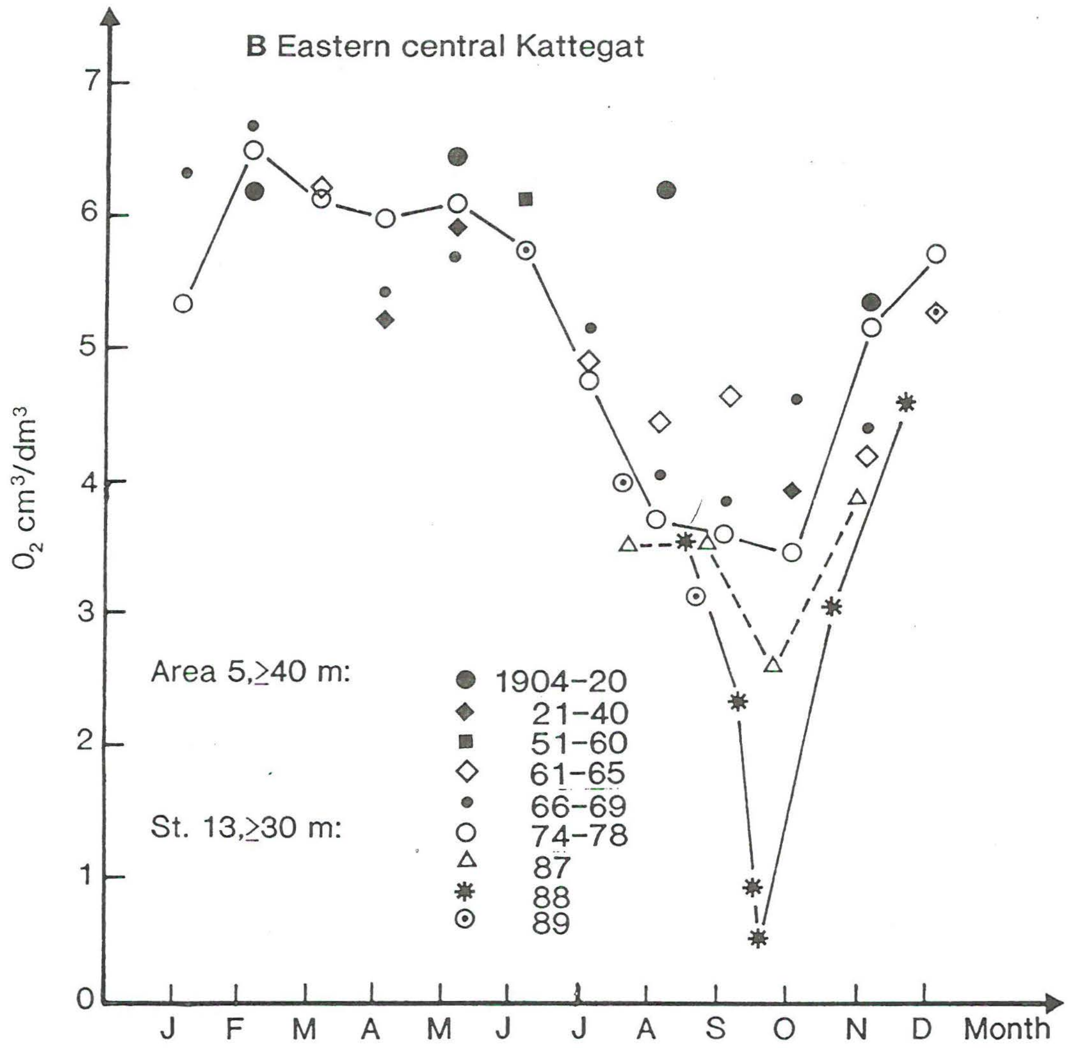


Fig. 1.1.

The seasonal variations of the monthly mean concentrations of oxygen near the bottom within different time periods.

(Ærtebjerg, Nielsen et al 1981 and Ærtebjerg 1987-89, not published).

Fig. 1.2. Oxygen in the near bottom water, summer and autumn 1988.
(Ærtebjerg 1988).

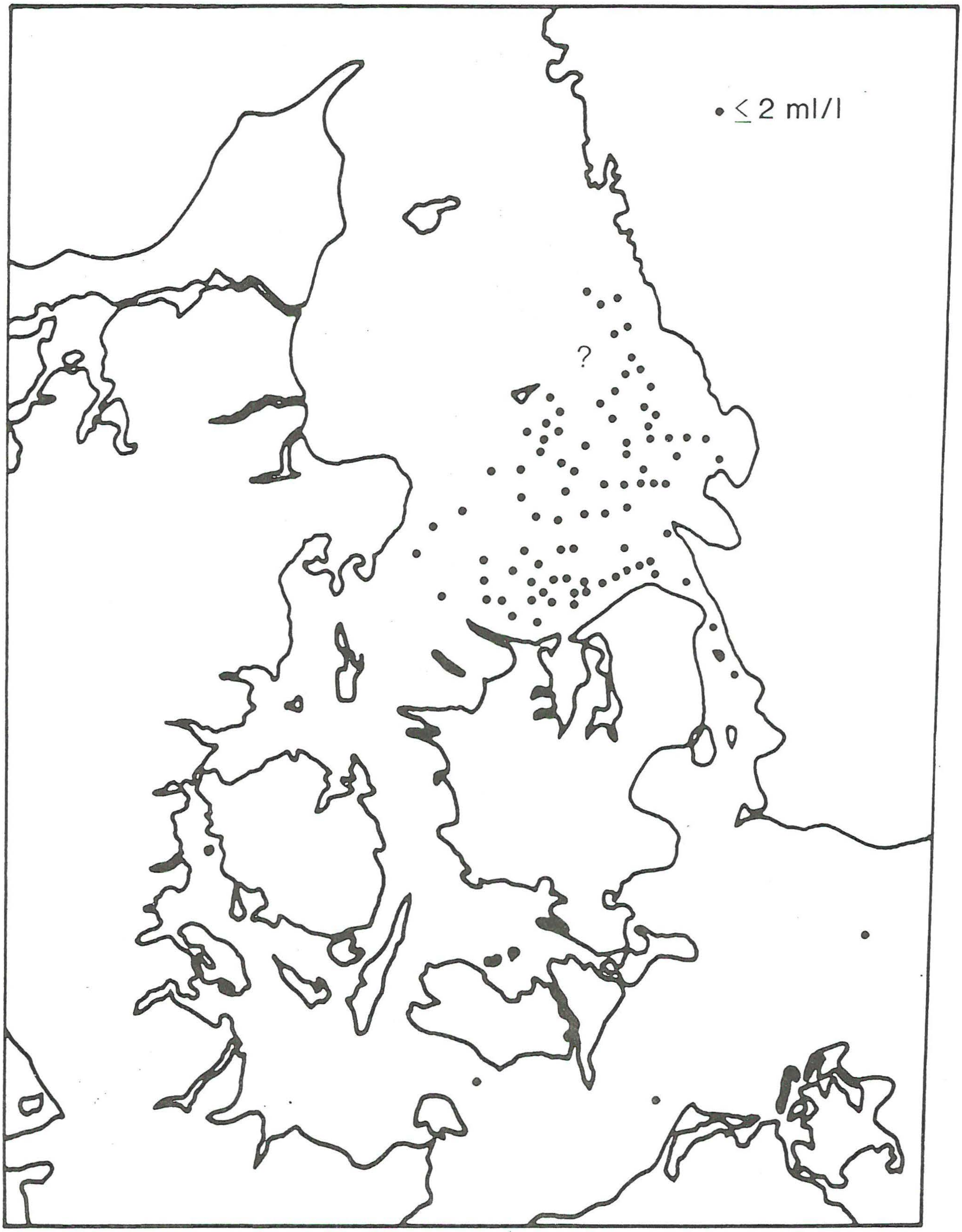


Fig. 1.3. Oxygen in the near bottom water, summer and autumn 1988. (Ærtebjerg 1988),

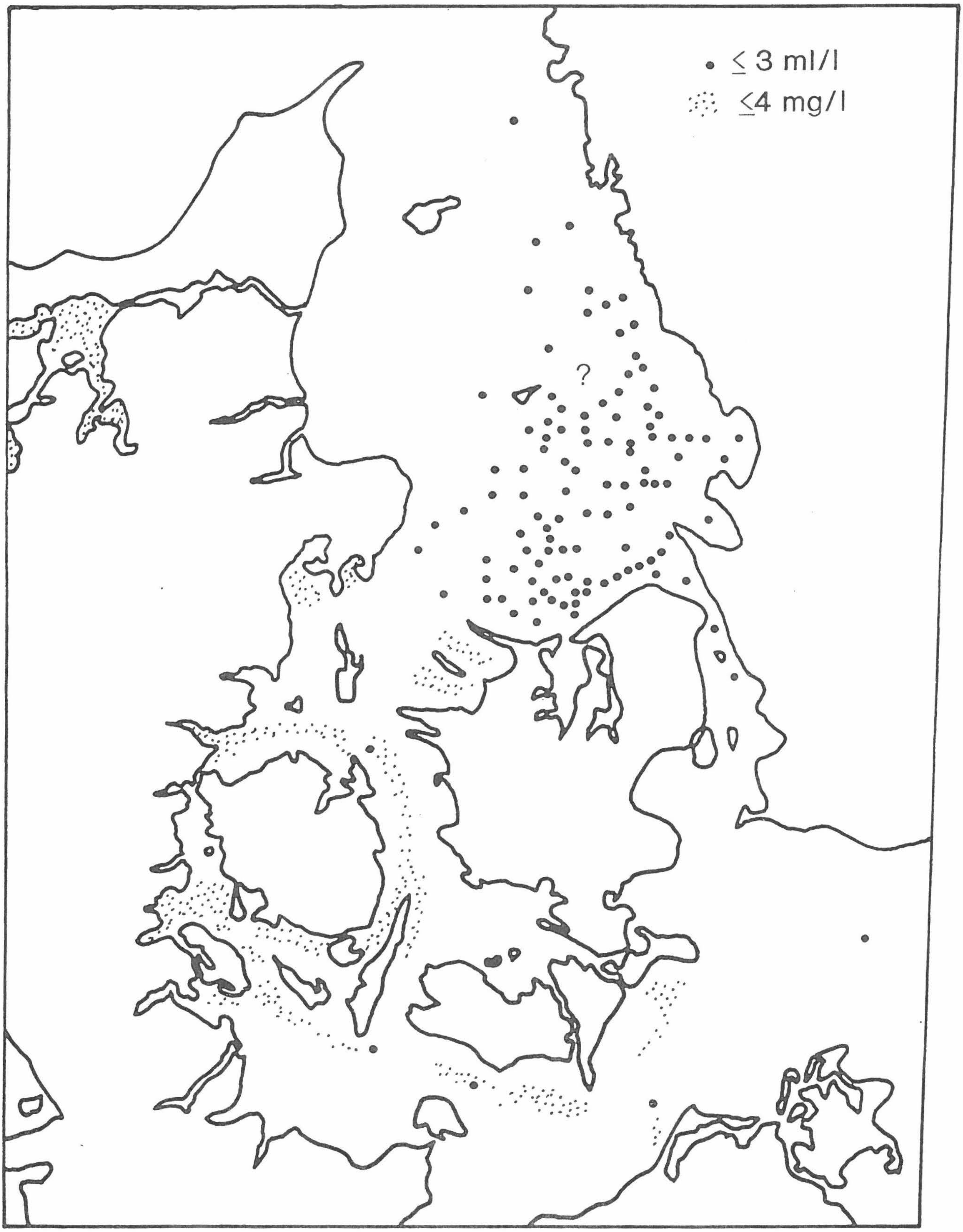


Fig. 1.4. Oxygen in the near bottom water, summer and autumn 1988.
(Ærtebjerg 1988).

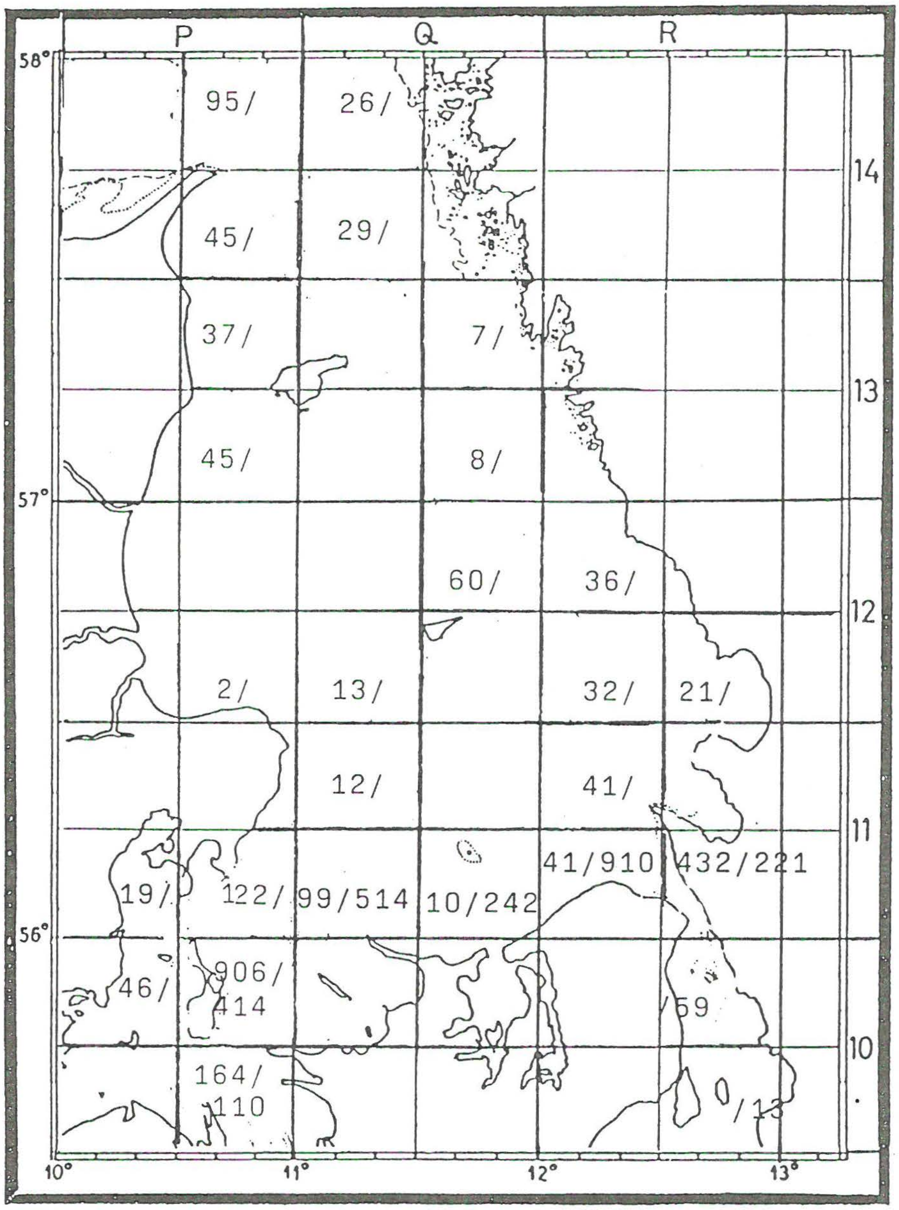


Fig. 2.3.1. The distribution of cod larvae in the Kattegat and Subdivision 22 in March 4-23 and April 7 - 22 1959. (Number per 20 minutes in 2 m ringtrawl). (Danish unpublished data).

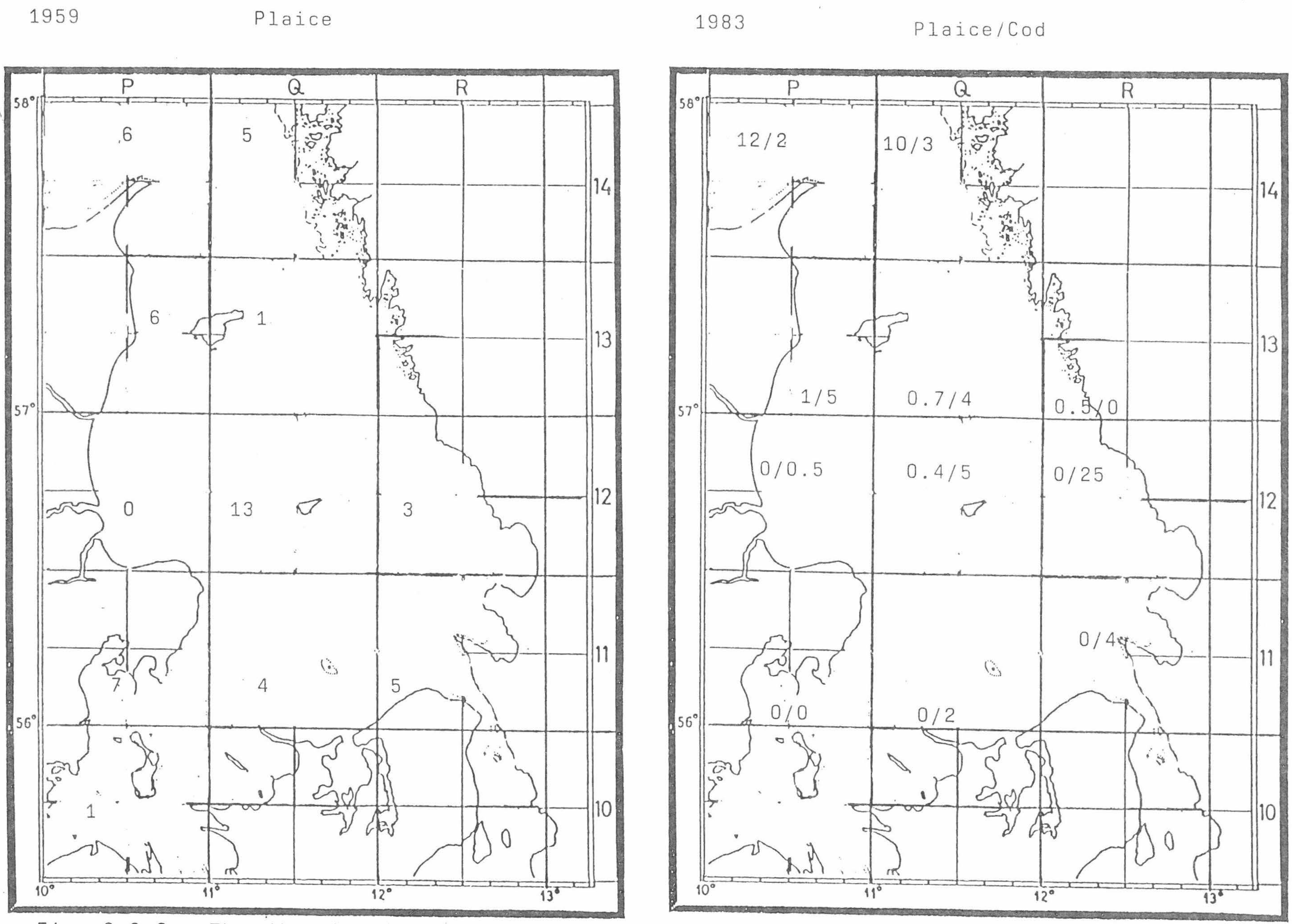
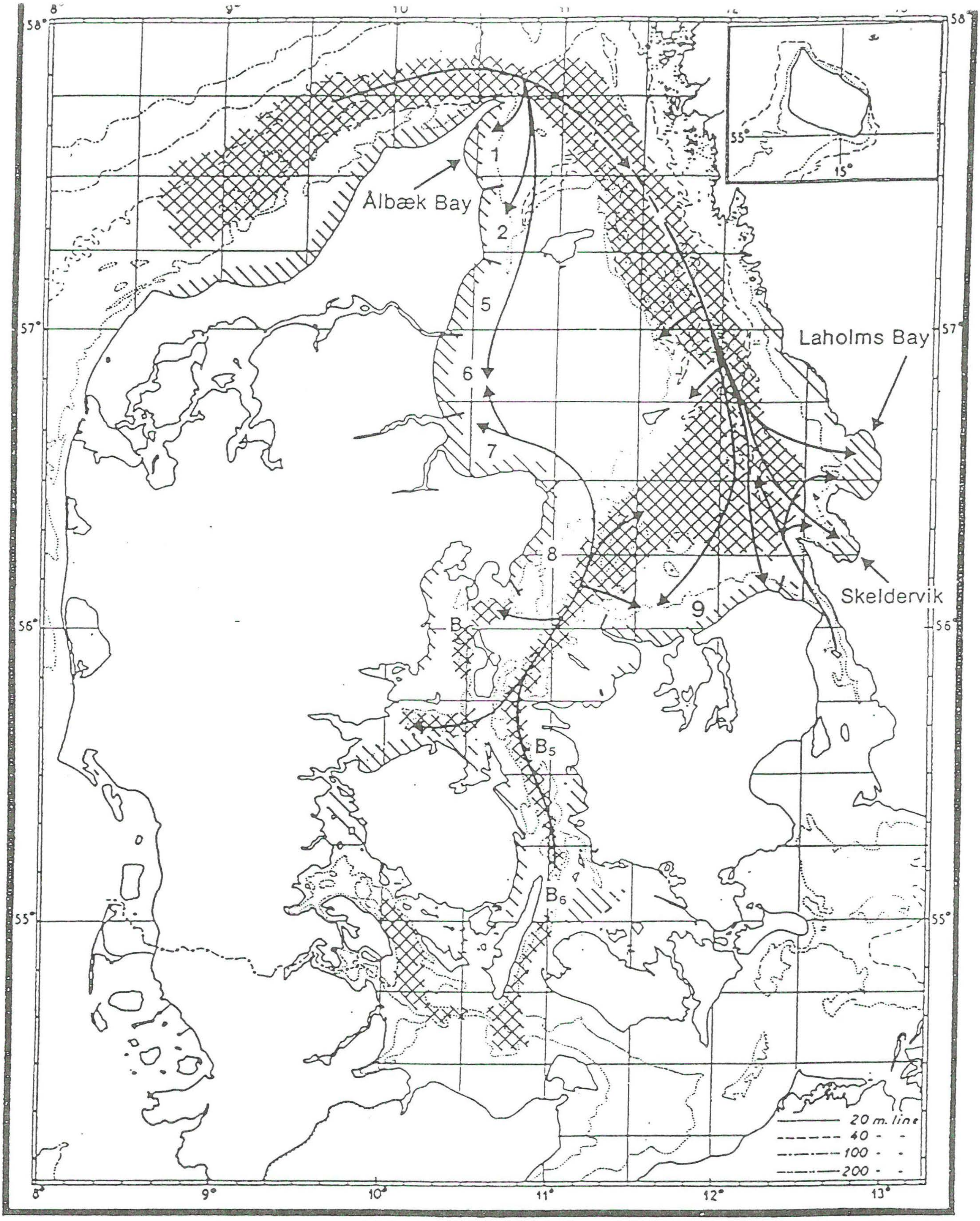


Fig. 2.3.2. The distribution of plaice larvae in the Kattegat in 1959 and of plaice and cod larvae in 1983. (Christensen et al. 1983).



Nursery Grounds
Spawning Grounds
Drift of eggs and larvae from Spawning Grounds

Fig. 2.6.1. **Nursery and spawning grounds in the Belts, Kattegat and Skagerrak.**

(Nielsen and Bagge, 1985)

Fig. 2.6.2. Results of tagging experiments in 1932 (Blegvad 1934).

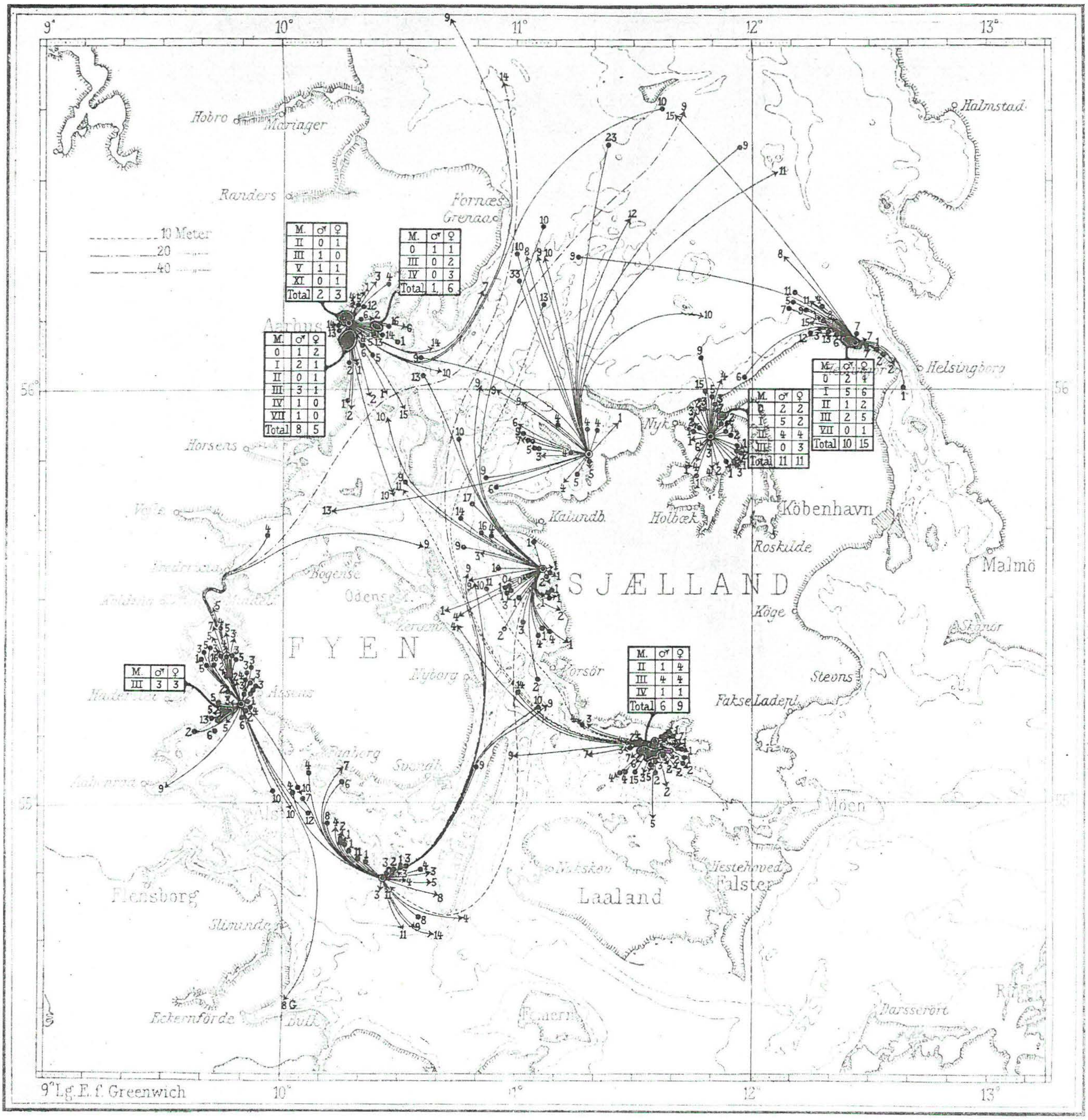


Fig. 2.6.3. Results of tagging experiments in 1929 (Blegvad 1934).

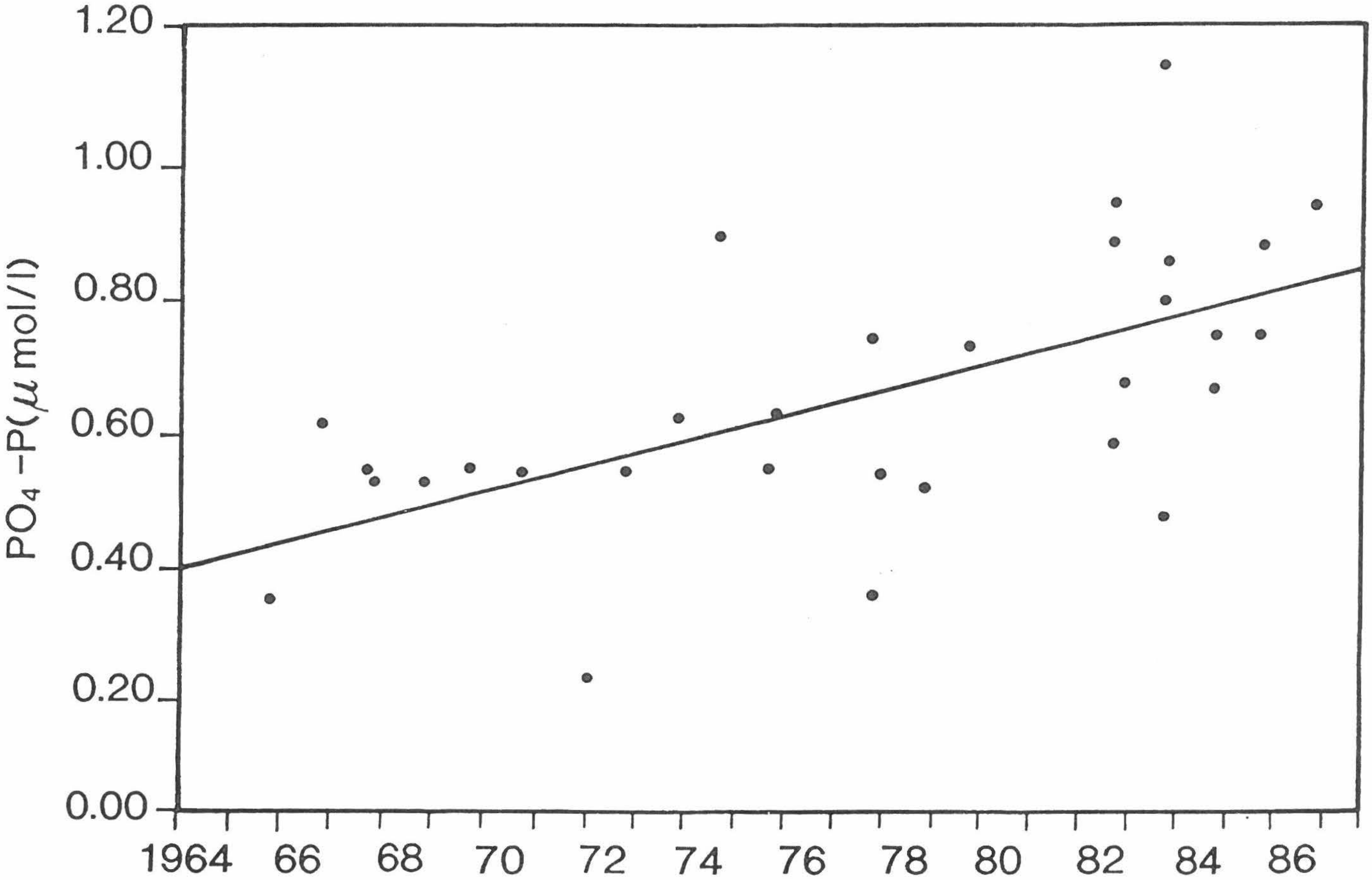


Fig. 2.10.1. Amounts of phosphate in the surface water at Fladen. (Engström and Fonselius 1989).

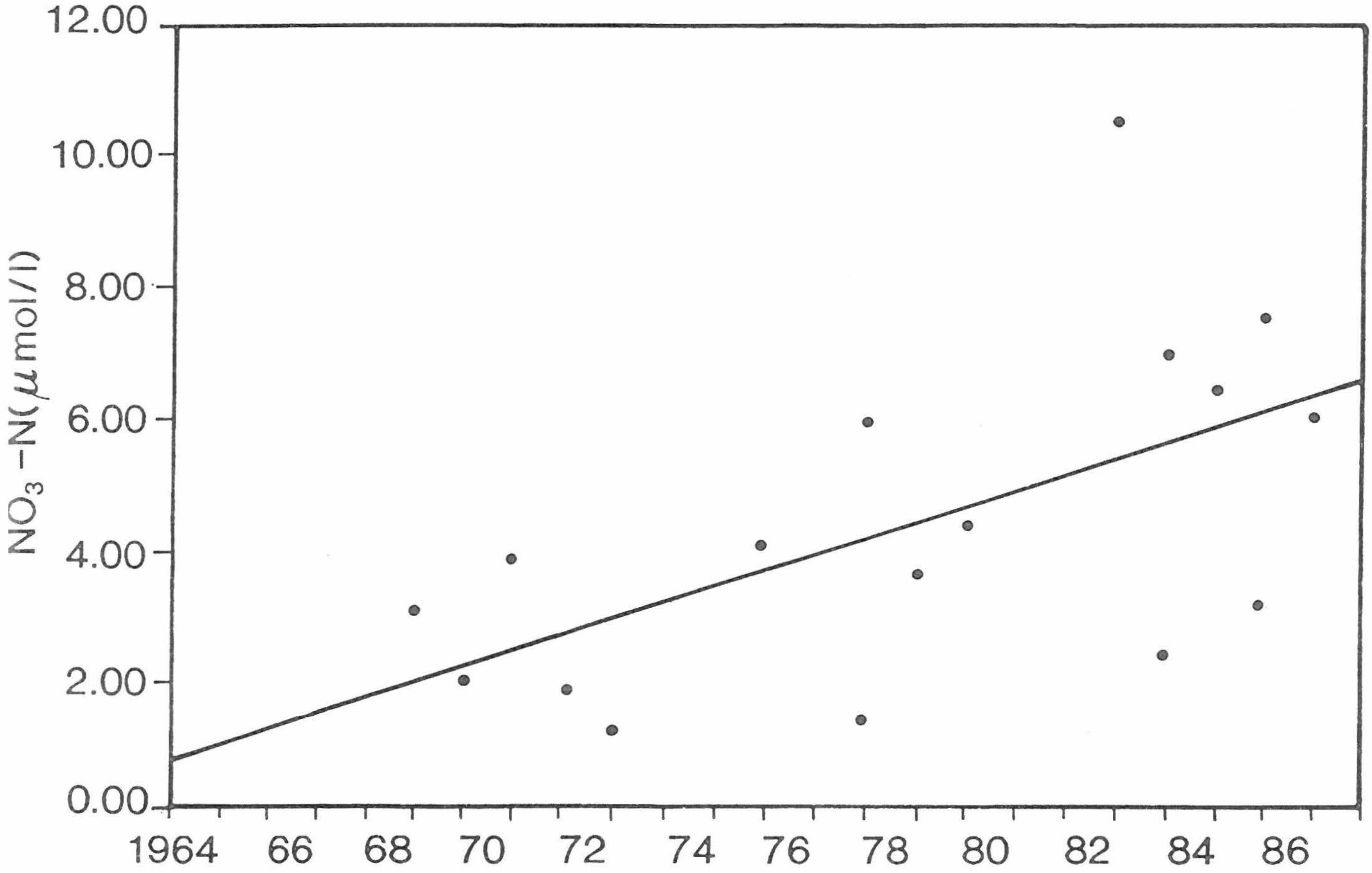


Fig. 2.10.2. Amounts Nitrate in the surface water at Fladen (Engström and Fonselius 1989).

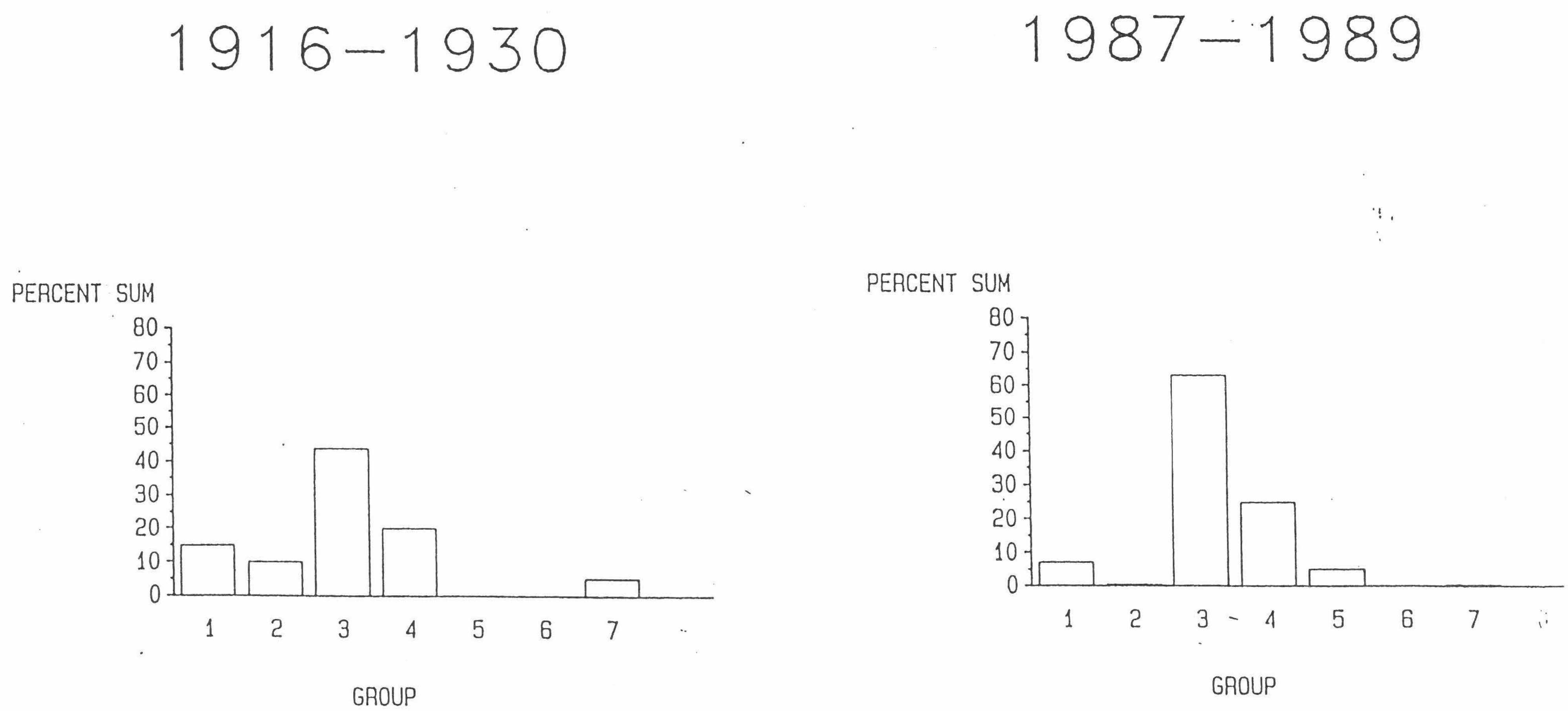


Fig. 2.10.3. Preliminary distribution of the most important taxonomical groups in the bottom sample (Petersen and Blegvad 1916-1934 and Bagge et al (unpublished data).

Group no. see fig. 2.10.5.

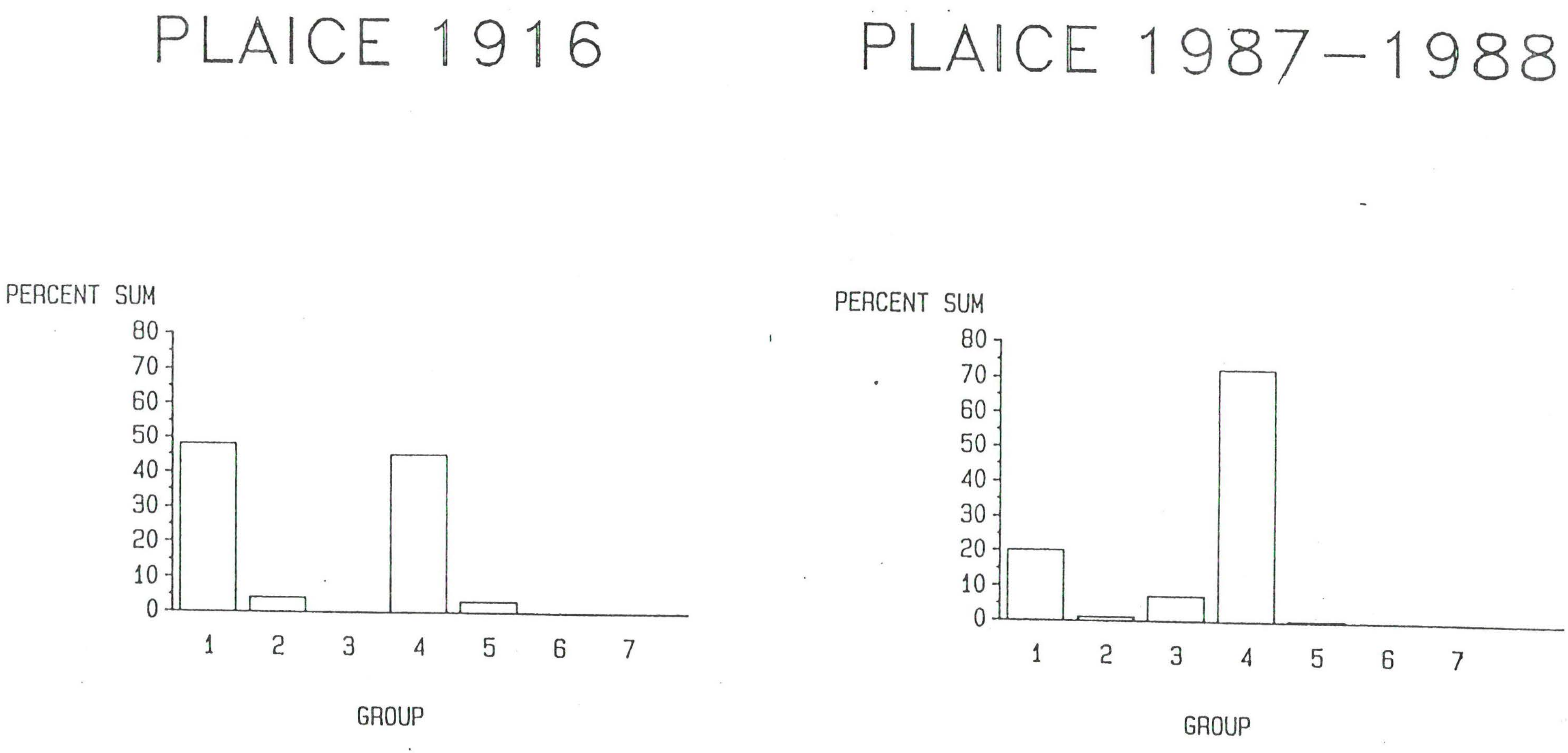
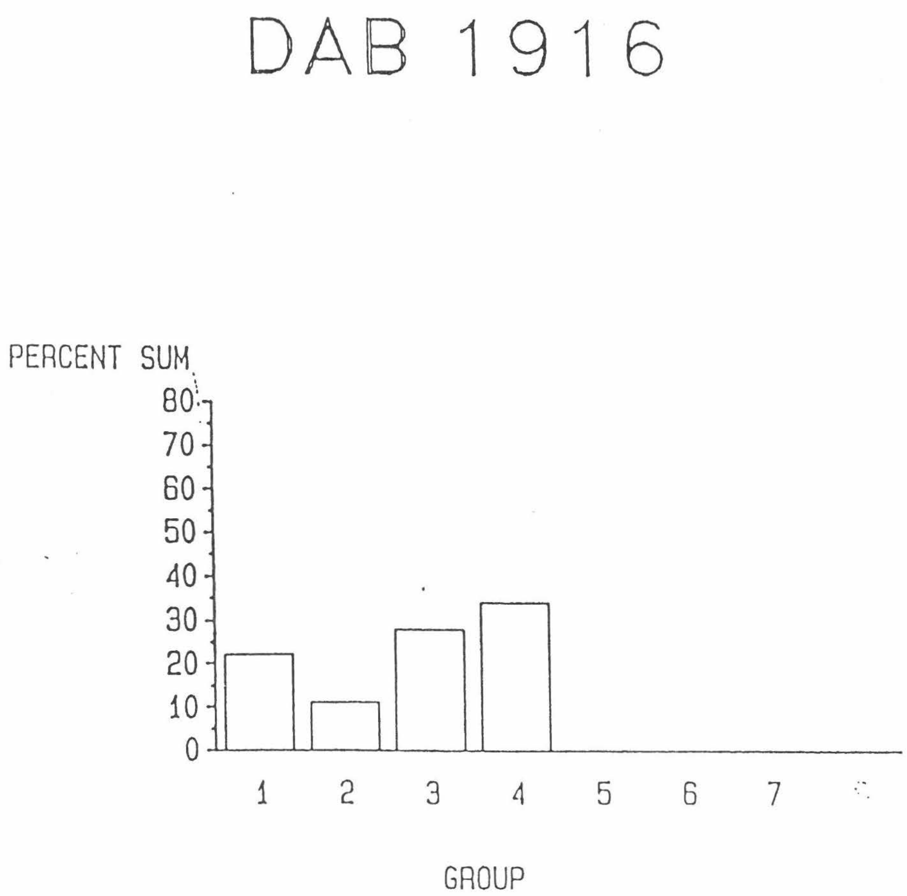
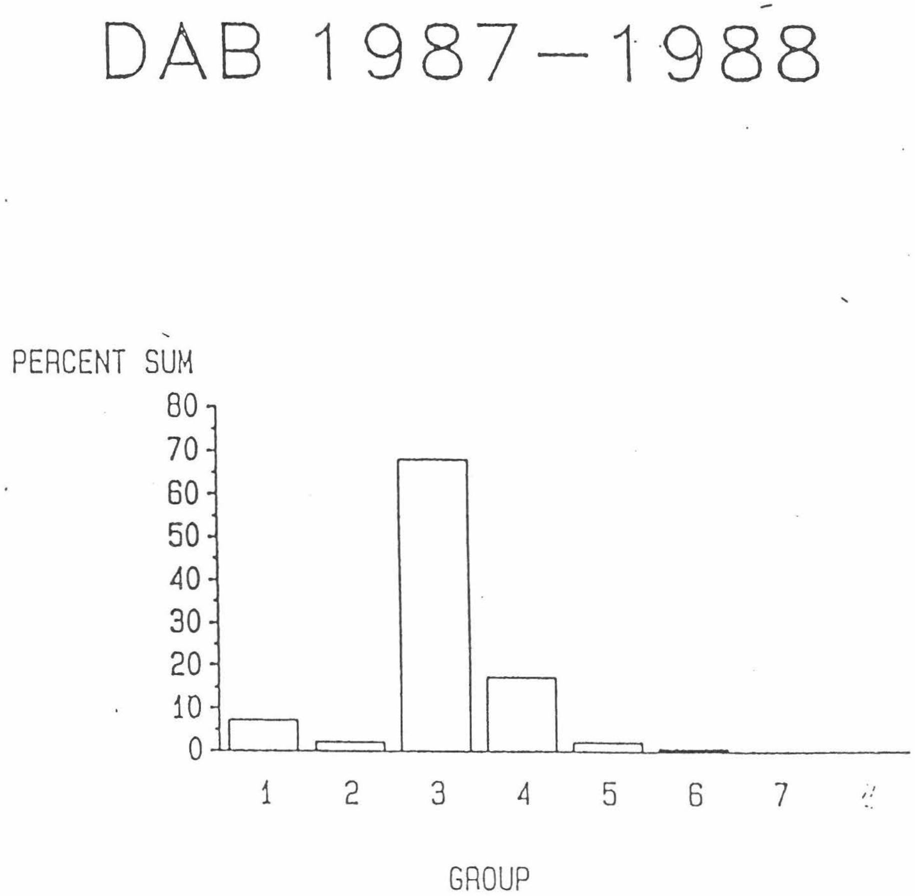


Fig. 2.10.4. Preliminary distribution of the most important taxanomical groups in stomachs of plaice in 1916 (Blegvad) and 1987-1988 (Bagge et al unpublished data).





Group 1	Bivalvia	Group 7	Grastropoda
Group 2	Crustacea		
Group 3	Echinodesmata		
Group 4	Polychaets		
Group 5	Other		
Group 6	Pisches		

Fig. 2.10.5. The percentual distribution of the most important groups in the stomachs of dab 1916 and 1987-88.

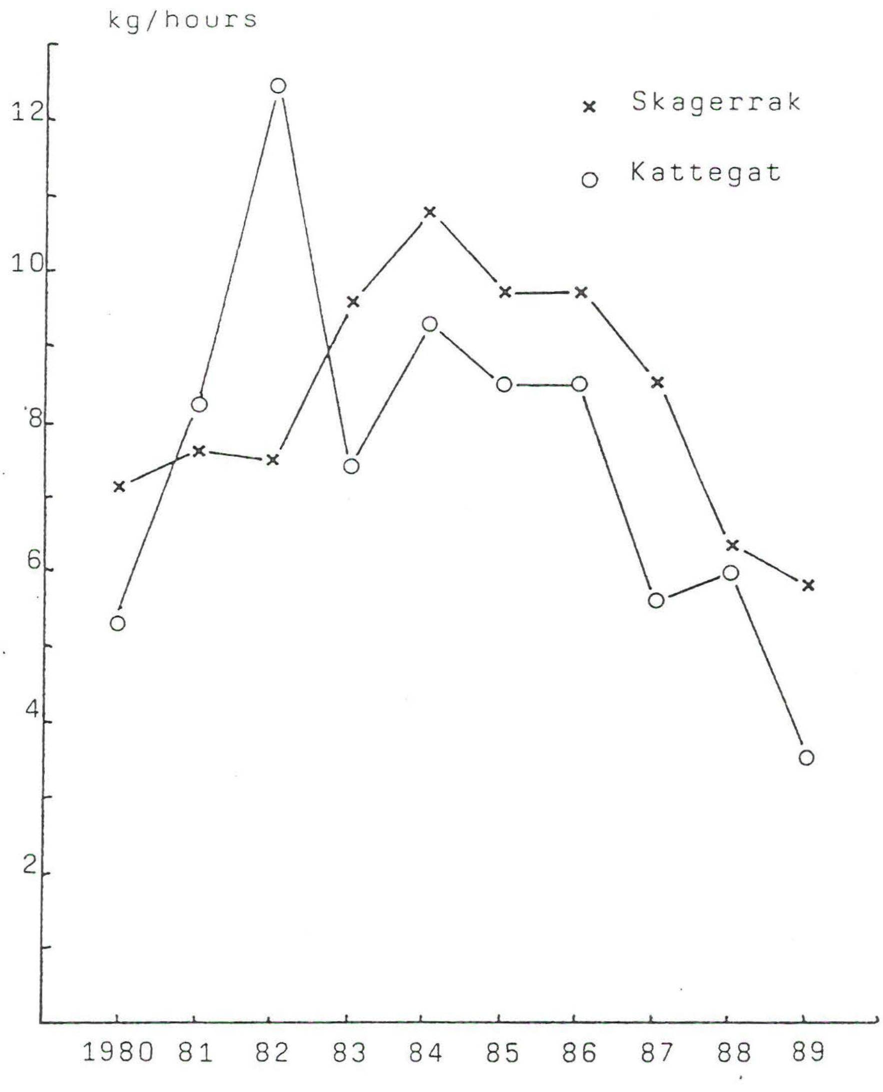


Fig. 2.11.1.

LPUE (in kg/hours trawling) of swedish specialist Nephrops trawlers in 1978-89. in Skagerrak and Kattegat (Anon. 1990).

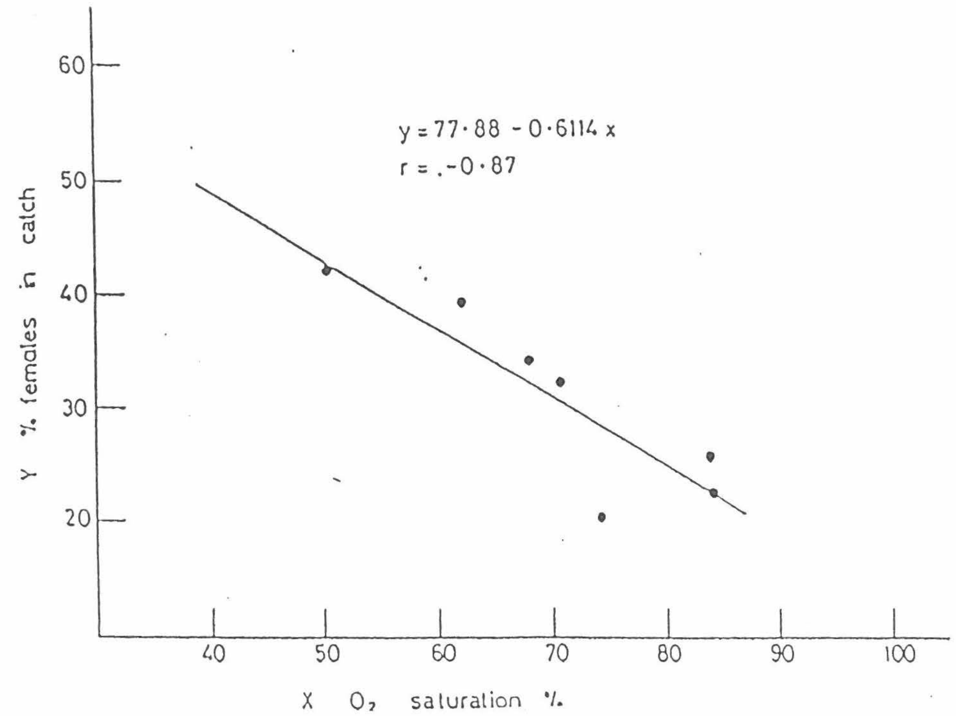


Fig. 2.11.2.
The percentage of females in relation to the mean oxygen saturation near the bottom.
(Bagge and Munch Petersen (1979).

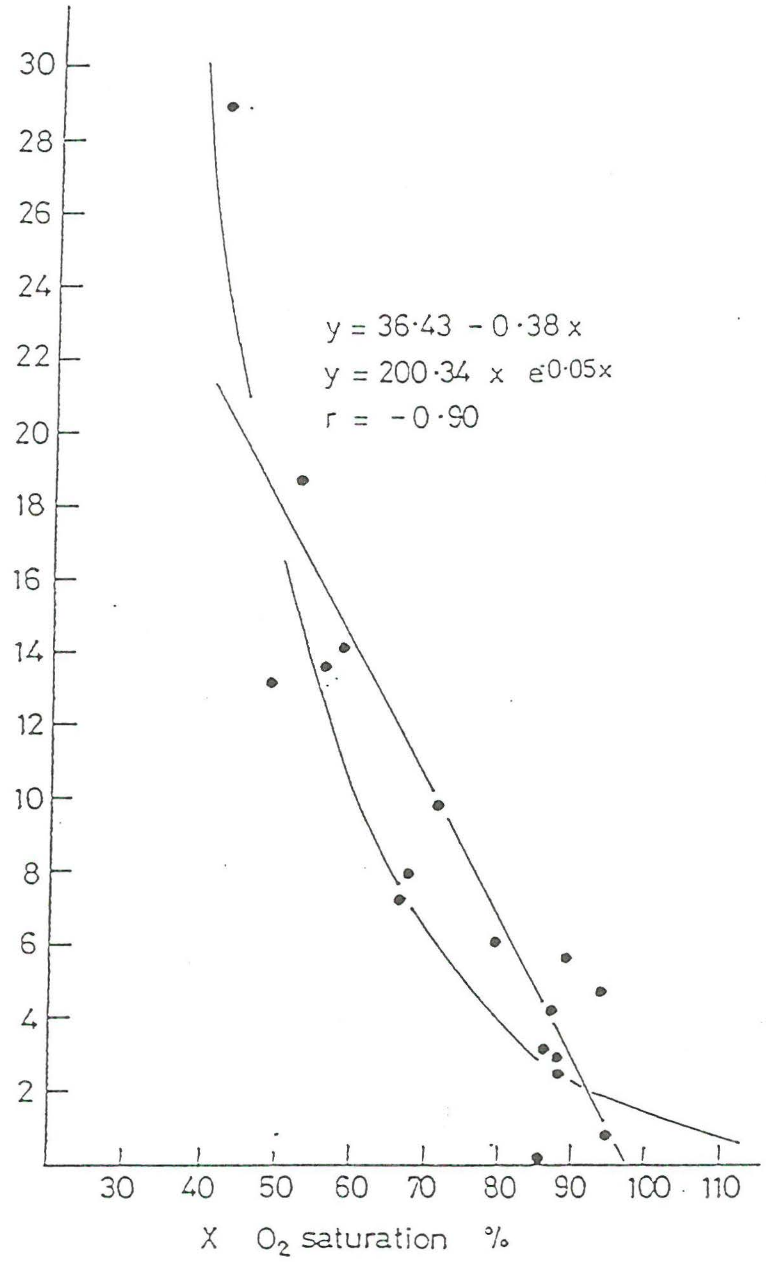


Fig. 2.11.3.
Catch per hour of Norway lobster in relation to mean oxygen saturation near the bottom.
(Bagge and Munch-Petersen 1979).

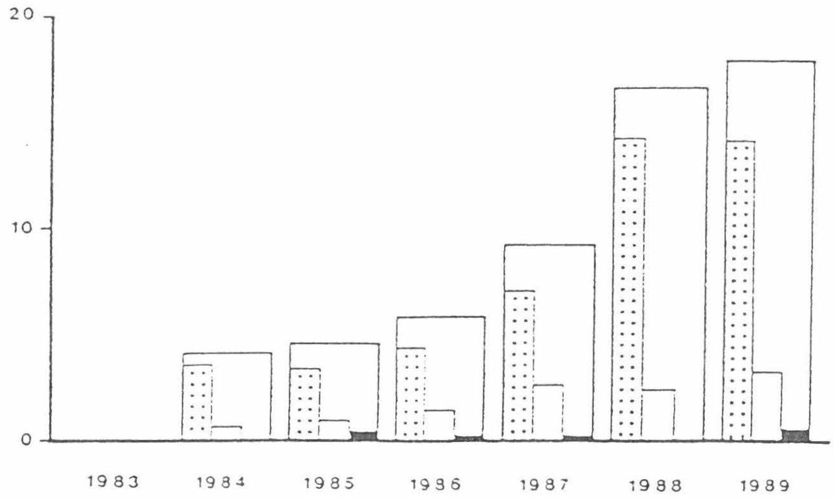
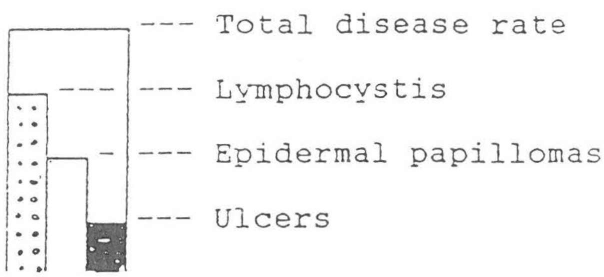


Fig. 2.12.1. Development of fish diseases in the Kattegat dab population.



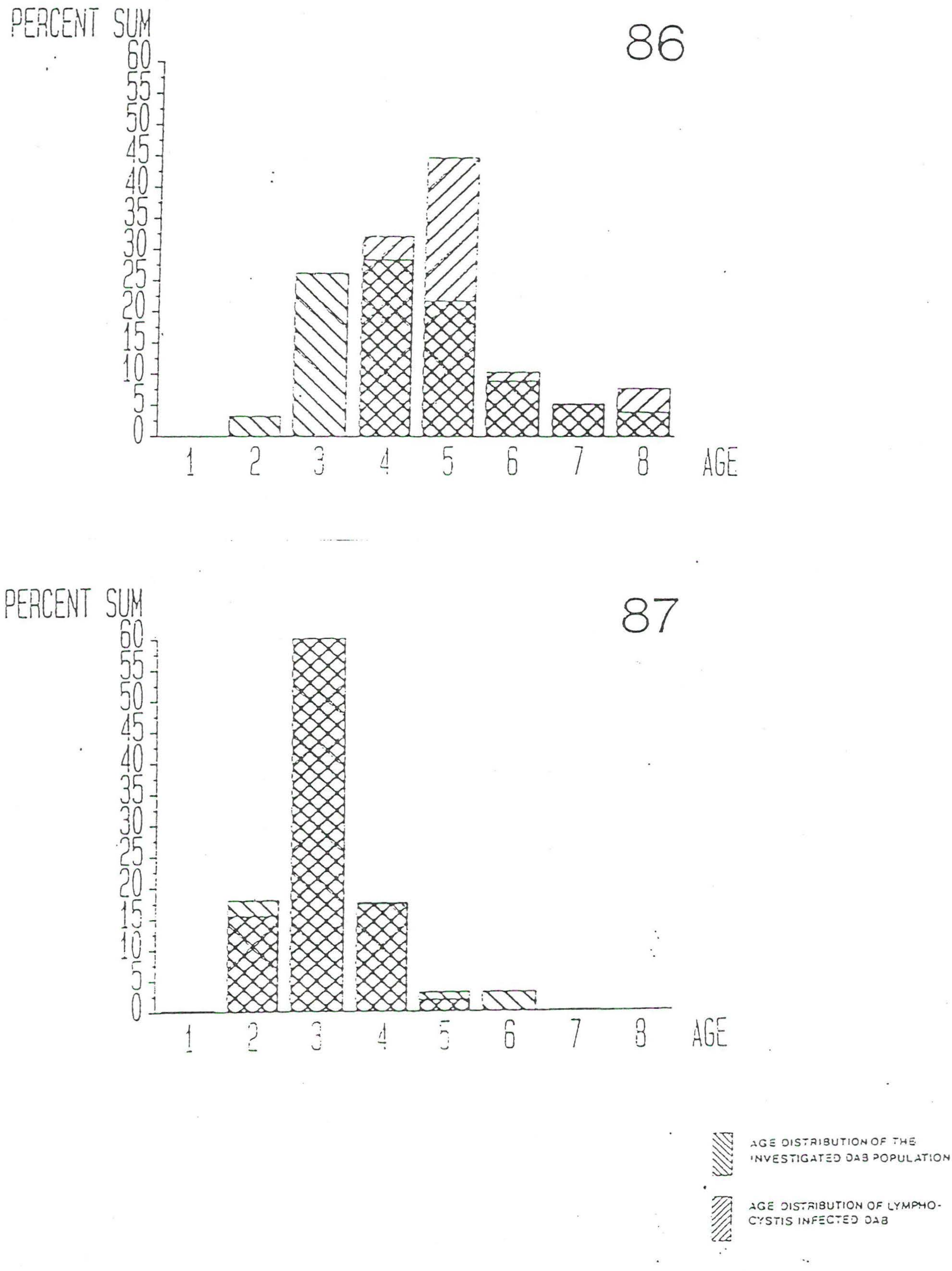


Fig. 2.12.2. Age distribution of the total and diseased dab population before (1986) and after (1987) the oxygen deficiency in the Kattegat.