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FLUCTUATIONS IN THE ABUNDANCE OF COD IN THE BALTIC AND BOTHNIAN COASTAL AREAS

By

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SUMMARY

Year-to-year variations in the abundance of cod were studied in three coastal and shallow areas at the Baltic coast of Sweden and in two in the southwestern Bothnian Sea. The investigation was carried out with gill nets fished with constant effort. The fishing in the Baltic areas started in 1962 and 1963 and in the Bothnian areas in 1975 and 1976. The last year treated is 1982.

The catches in localities which are cut off from the open sea or deep waters by sills were compared with those in localities which have direct contact with such waters. The "sheltered" nets gave only some percent or even less of the catches in the "exposed" nets. The former gave insignificant catches even at the end of the investigation period, when the Baltic stock of cod increased considerably. This increase was clearly reflected, however, in another type of marginal habitat, i.e. shallow but "exposed" hard bottoms. Reasons for the habitat selection are discussed and the food availability is suggested to be the most important one.

The distance from the spawning grounds in the southern and eastern Baltic influences the abundance in coastal waters. In years with a small stock of Baltic cod, the species has been almost absent at the Bothnian coasts, which has not been the case at the coast of the Baltic proper. When the stock has been large, as in recent years, the difference between Baltic and Bothnian areas has been smaller in relative terms. One reason for this is probably successful spawning further northwards than is usually the case, which leads to a shortening of the transportation and migration of eggs and fry to the northern waters.

INTRODUCTION

In the Baltic Sea there are two stocks of cod (Schmidt 1930, among others); the Baltic cod (Gadus morhua callarias) dominating east of Bornholm and the Atlantic cod (Gadus morhua morhua) west of that island. The year-class size of the former is considered to be regulated mainly by the extension of water layers saline enough to keep the eggs floating. Some authors have also stressed the importance of nutrient supply for the production of food for cod larvae (Meyer and Kalle 1950, Otterlind 1984). The amount of water with favourable conditions varies widely between years and so does, consequently, the stock of cod. In the late 1970's there was a big increase in commercial catches, especially in the northern areas (Fig. 1). Undoubtedly this development was partly due to intensified fishing but the fundamental cause was generally considered to be an increased abundance of cod. This paper investigates how the increase was reflected in experimental gill net fishings at some coastal localities and in different biotopes within these localities.

MATERIAL AND METHODS

The investigations were carried out with gill nets fished at fixed stations with constant effort. Three areas along the Swedish coast of the central Baltic were studied and two in the southwestern part of the Bothnian Sea (Fig. 2). The fishing in the Baltic started in 1962 and has continued since then with the exception of the southernmost locality, Simpevarp, where the program was run in 1963 and 1964 and then from 1966 onwards. The program in the Bothnian Sea started in 1975 at Forsmark at the Swedish coast and in 1976 at Finbo in the Åland islands. The last year treated here is 1982 for all areas. The investigations are part of a monitoring system for thermal power plants at Simpevarp, Marviken and Forsmark.

The fishing in the Baltic was mainly undertaken with 1.8 m deep and ca. 30 m long bottom nets. They were made of nylon twine and seven different mesh sizes, from 21 to 60 mm mesh bar, were used. The nets were grouped in small areas, "stations", comprising eighteen nets. Four such areas were fished at Simpevarp, three at Åsvikelandet and two

at Marviken. An example of the placing of nets is shown in Fig. 3. One setting per station was carried out in the months of May, June, August, September and October. The stations were normally fished in different but adjacent days. The nets were set in the afternoon and lifted in the morning, the exposure time being 16-18 hours, always including sunset and sunrise. The catches are registered in number and total weight for each species and net. Since 1972 the water temperature at the bottom has been measured at each net at setting and lifting.

In the Bothnian Sea the fishing has been carried out with multi mesh-size nets made by monofilament nylon. Such nets have also been used at Simpevarp. They are 35 m long and 3, 6 or 9 m deep, composed of 7 m long sections of five different mesh sizes, 17-50 mm mesh bar. Both buoyant and bottom set nets were used. The fishing design is presented in Table 1 and for Forsmark also in Fig. 4. The aim has been to fish once a fortnight (twice a fortnight at Simpevarp during 1970-1977 and at station 4 at Forsmark) throughout the year at Simpevarp and Forsmark and during the period May - November at Finbo. Divergences from this program occurred especially during the ice season, December - April. In 1981 and 1982 the fishing at Simpevarp was interrupted in late summer.

The multi mesh-size nets were set and lifted in accordance with the routine described above for the 1.8 m bottom nets, the exposure time being somewhat longer at Forsmark and Finbo, however. The catches were registered according to species and number within length groups of 5 cm (total length) and to station. The vertical position of the fish was also noted, by means of colour bands dividing the nets into 1.5 m deep sections. When the nets are stretched in the water the height of the sections decreases to about 1.25 m. Water temperature was measured both when the nets were set and when they were lifted. At each station the measurements were made at the surface, at 2.5, 5, 7.5 m, and so forth to the bottom. More detailed descriptions of the fishing routines have been made by Thoresson (1976).

For both types of nets, catches are compared between "sheltered" and "exposed" net sites. Localities which are cut off from the open sea and deep water by sills are considered as sheltered, while those in direct contact with deep water are regarded as exposed. At Simpevarp

16 net sites are sheltered and 32 exposed, while 24 are difficult to classify and are excluded from the comparison in question. At Åsvikelandet (Fig.3) 27 nets are placed at sheltered localities, i.e. station 1 and the two southernmost sites with nine nets at station 3, which are separated from deep and open waters by sills at a depth of 3-4 m. The northern nine nets at station 3 and station 2, together 27 nets, are exposed. The groups have the same composition of mesh-sizes. Sheltered and exposed sites are often situated close to each other, as in station 3 at Åsvikelandet or as at Simpevarp, where they may lie on the landward or seaward side of the same small island.

The whole Marviken area is far from open and deep water (ca. 20 km) and highly sheltered. At Forsmark stations 1, 2, and 3 are sheltered and 4 and 5 exposed (Fig. 4). Station 1 at Finbo is considered as sheltered and station 3 as exposed, while station 2 has an intermediate character.

The classification of the catches into length-groups adopted for the multi mesh-size nets was used to identify rich year-classes. For this purpose the following data on the length-age relation from the Deep of Gdansk and the Gotland basin were used (combined by Thurow 1974):

Age group	1	2	3	4	5	years
Length	20.4	28.1	37.1	45.1	54.6	cm

RESULTS

The total catches of cod used in this paper are presented in Table 2. It is evident that cod is practically absent in the sheltered Marviken area. In Table 3 mean catches are compared for sheltered and exposed nets in the other areas (see "Material and methods"). For Åsvikelandet two comparisons are made, one for localities within the archipelago (station 1 versus 2) and one for localities close to the open sea (southern versus northern nets in station 3). In all areas the catches were much smaller in sheltered than in exposed nets. At Åsvikelandet the sheltered sites within the archipelago gave less cod than those closer to open water. Both types of localities gave smaller catches at

Forsmark than at Finbo. The total catch - in all seasons and depths - at the three sheltered stations at Forsmark was 4 cods.

The variations in the abundance of cod at Simpevarp and Åsvikelandet in 1962-1982 are shown in Fig. 5. Sheltered nets are excluded. The nets at Simpevarp are split in two depth-groups, 0-5 m and 5-15 m (18 and 29 nets respectively). The groups have been made comparable by giving the different mesh-sizes the same weight. For Åsvikelandet the nine northern nets at station 3 are chosen. They are set at depths between 7 and 14 m. In order to make the variations in the different net groups comparable, the catches were normalised in relation to the mean catches during the period of low and stable catches during 1970-1973.

Fig. 5 shows catch minima during 1962-1964 and 1970-1973 and maxima in 1966 and during 1979-1982. The "5-15 m level" shows rather smooth variations and good agreement between the two areas. The variations were somewhat greater at Åsvikelandet, however. The maximum levels there were about six times higher than the minimum level to be compared with four times at Simpevarp. The shallow nets at Simpevarp show the same overall picture, but the catches were smaller and the variations bigger, especially in the latest years.

Reflections of the big increase in cod abundance in recent years were also looked for in unsuitable habitats. The catches at Simpevarp in 1979-1982 were calculated for the nets which gave no cod in the years of minimum abundance, 1970-1973. All these fifteen nets were situated in water shallower than 6 m and nine of them were sheltered. Only five of totally 44 cods were caught in the sheltered nets; the other 39 came from six rather exposed nets.

As was shown in Table 3, very few cods were caught at station 1 at Åsvikelandet. In 1970-1973 one single fish was taken, in 1979-1982 totally nine. All of them were caught at rather deep localities, 7-10 m. Seven of the southern nets at station 3 missed cod completely in 1970-1973, but gave nineteen cods in 1979-1982.

In the investigated areas cod has been shown to avoid high temperatures (Neuman 1977 and 1979). If scarcity of food arises, when the abundance of cod is high, this might possibly lead to an appearance in higher temperatures than normally. In order to test this possibility, the temperature measurements made at each net since 1972 at Simpevarp and Åsvikelandet were used to calculate mean catch per temperature interval (2°C). This was done separately for the years 1972-1982 (values based on less than 10 net-catches have been excluded). Averages of these means were calculated for periods with small and large catches (see Fig. 5), and the distribution along the temperature scale are compared in Fig. 6. No tendency to a higher tolerance for high temperature when the abundance is high can be seen.

Fig. 7 presents the catches at some multi mesh-size net stations at Simpevarp, Forsmark and Finbo. In order to make these areas comparable with each other and with Fig. 5, only catches in the six lowest sections (up to 7.5 m from the bottom) in May - October are presented. Results from an experimental gill net fishing at Lovisa situated in the middle of the northern coast of the Gulf of Finland have been inserted in the figure (Salmela pers. comm.). The development at Simpevarp is very similar to that for the bottom nets in the 5-15 m interval except for the increase in 1980, when the bottom nets showed a decrease. Normally the catch level is clearly higher at Simpevarp than in the Bothnian Sea areas. The biggest relative differences occur when the catches are low; the cod may be almost absent in the northern localities, which never is the case at Simpevarp. The rate of increase 1976-1979 must be regarded as similar in all the areas. In 1981 and 1982, however, the expansion continues at Finbo, while it has ended in the other areas, including Lovisa.

The classification of the catches into length-groups adopted for the multi mesh-size nets was used to identify rich year-classes using literature data on the length-age relation (see "Material and methods"). In Table 4 the catches in the multi mesh-size nets at Simpevarp, Forsmark and Finbo are presented as the quotient between the actual catch per day within a length-group each year and the average catch within this group all the years investigated. The length distribution for all years is also included in the table. The first really strong year-class

seems to be that of 1976. The following year-classes are difficult to separate; all or most of them might have been good, especially that of 1980. The time of appearance of a rich year-class varies between years and areas. At Simpevarp they have always been rather well represented already at the age of one year (15-25 cm). At Finbo practically no cod shorter than 20 cm has been caught and also the length-group 20-25 cm has been rare. Forsmark takes an intermediate position; the occurrence already in 1977 of the year-class 1976 is noteworthy. This year-class did not show up in significant amounts at Finbo until the age of four, while the year-class of 1980 gave good catches here already in 1982.

DISCUSSION

In the introduction it was noted that the commercial catches of cod in the Baltic increased considerably in the late 1970's (Fig. 1). A comparison with the experimental gill net catches in the corresponding areas (Fig. 7) shows a somewhat earlier and less drastic increase at Simpevarp, Forsmark and probably Lovisa. This difference may be explained by a selection for older fish in the commercial fishery and by a more intense fishing in recent years caused by the enlargement of the stock. The development at Finbo has been more similar to that of the commercial fishery in the Bothnian Sea than to that of the gill netting at Forsmark. This may be due to the fact that cod from the comparatively large stocks in the deep areas of the Bothnian and Åland Seas, which are most important for the fishery in this region, more frequently move into the Finbo area than into the more isolated Forsmark area. The latter seems to be more dependent on occasional immigration of very young fish. It must be concluded, however, that all materials reflect the same remarkable increase of the abundance of cod. This expansion can be used to discuss how the distribution of cod in coastal areas is influenced by the distance from the spawning grounds and the character of the biotope.

Simpevarp, at the central west coast of the Baltic proper, shows a higher level of catch than Forsmark and Finbo at the southern Bothnian Sea. The difference is largest, in relative terms, in bad years, when cod is almost absent in the northern localities, including Lovisa at the Gulf of Finland. The total Baltic catch east of Bornholm, by far

the greater part taken in the southern and eastern Baltic proper, was doubled from 1978 to 1980. The catches in the northern areas, i.e. the northernmost Baltic proper including the Archipelago Sea, the Gulf of Finland, the Bothnian Sea and the Bothnian Bay, however, increased much more drastically from a very low level before 1978. Bigger fluctuations in abundance in marginal areas than in the distribution centre of the population are to be expected. Furthermore, rich year-classes are formed when the eggs survive in larger areas than usually, which means that fry hatch further northwards. The resulting shortening of the transportation and migration to the northern areas may be one reason for the very strong manifestation of a good year-class here, as the migration into these waters is considered to take place in young stages (Otterlind 1966 and 1983).

Whereas rich year-classes of the Baltic cod migrate far away from the distribution centre, there are obviously coastal habitats even rather close to this, which are seldom or never utilized. These are barred from open and deep waters by shallow sills. The reasons for the avoidance of such localities are not known. Direct effects of hydrographic factors on the behaviour of cod are no likely explanation. There are no significant salinity gradients within the investigation areas. The preference for low temperatures (Fig. 6) may be of some influence, as the "sheltered" localities often are too warm in summer. This is hardly the main reason, however, as they are avoided in all seasons.

If hydrographic conditions are not the main reason for the observed distribution, the access to food is the most probable factor. According to Hessle (1923), Uzars (1969), and others the big crustacean Mesidothea entomon is a very important food item for Baltic cod longer than 20 cm, i.e. the sizes discussed here. An unpublished study in the Forsmark area indicates a clear dominance for Mesidothea, too. Bottom fauna investigations have shown low abundances of this species at all stations at Marviken and at the innermost station (1, Fig. 3) at Åsvikelandet (Grimås 1979) and no Mesidothea at all at a station at Forsmark close to the fishing stations 1-3 (Fig. 4) (Smith pers. comm.). The reason for this may be that the species is cold stenothermal (Demel and Mulicki 1958), and therefore is rare on shallow bottoms behind sills, which may trap them in warm water.

The bottom substrate is probably important for the food availability. Practically all fishing stations giving small catches in this investigation have "soft" bottoms (organogenic matter, clay or sand), while the biotopes preferred by the cod mostly have hard bottoms. Also Hessle (1923) noted that the best catches of cod along the east coast of Sweden are made on hard bottoms; the cod avoids clay, sand and ooze. The hard bottoms offer a richer and more varied food supply, especially as regards crustaceans; e.g. Gammarus locusta is an important food item in shallow waters (Hessle 1923).

Whatever the reasons for the habitat selection of cod may be, it is interesting to follow the expansion of the stock in recent years in different habitats. Not surprisingly, the increase of cod in relative terms is big in some sheltered localities, but the absolute catches are still very small in all such habitats. Small numbers of cod caught at unusual places attract much attention, however, which gives the impression that cod occurs everywhere. A quantitatively much more important expansion has occurred in another type of marginal habitats, i.e. shallow but exposed localities with hard bottoms. The catches decrease with decreasing depth and are normally small above 5 m (Neuman 1977 and 1979). At least at Simpevarp the expansion has been clearly greater, in relative terms, at depths above than below 5 m. This fact indicates some sort of "crowding" at deeper localities in recent years. The increase in shallow water probably would be still greater if the cod did not avoid high temperatures. When a summer thermocline develops, the cod is shut out from shallow waters.

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Table 1. Fishing design

	Maximum depth m	3 m bottom nets	6 m buoyant nets	9 m bottom nets	9 m buoyant nets
Simpevarp					
Station 1	15			2	
2	10	2	1		
3	13	2	1		
4	15				2
Forsmark					
Station 1	2	2			
2	5	3			
3	8			2	
4	14			3	3
5	40			3	6*
Finbo					
Station 1	5	3			
2	8			2	
3	40			3	6*

* Three at the surface and three at 10 m and downwards

Table 2. Total catches in the different areas

	Simpevarp	Åsvikelandet	Marviken	Forsmark	Finbo
Bottom nets	11,339	7,491	96		
Multi mesh-size nets	9,949			1,481	1,289

Table 3. Catches in sheltered and exposed nets (Number/net and night)

	Simpevarp	Åsvikelandet stn 1/2	Åsvikelandet stn 3	Forsmark*	Finbo*
Sheltered nets	0.10	0.02	0.06	<0.01	0.16
Exposed nets	3.0	2.6	2.7	0.83	1.7

* May - October, bottom sections

Table 4. Yearly catch per day within length-groups related to averages for all years

Simpevarp, total material

Age group	1		2		3		4	
	15	20	25	30	35	40	45	50 cm
1970	0.6	0.4	0.1	0.1	0.2	0.3	0.4	
1971	1.3	1.0	0.5	0.5	0.2	0.2	0.2	
1972	0.2	0.4	0.8	0.5	0.5	0.4	0.3	
1973	0.8	0.7	0.4	0.3	0.2	0.3	0.3	
1974	1.0	0.8	1.1	1.1	0.6	0.4	0.4	
1975	0.3	0.6	0.8	1.0	1.1	0.9	0.6	
1976	0.3	0.2	0.4	0.7	0.9	0.8	0.4	
1977	1.0	1.2	0.8	0.8	0.6	0.8	0.5	
1978	0.8	1.7	1.3	1.3	1.0	1.2	1.1	
1979	2.1	0.9	1.1	1.5	2.2	2.0	1.9	
1980	2.4	1.6	1.7	1.1	1.6	1.8	2.2	*
1981	1.1	1.3	0.7	0.8	1.9	2.4	2.8	
1982	1.2	2.2	3.3**	3.5**	2.1	1.6	1.9	
Length distri-	<15							>50
bution %	0.4	3.1	8.6	17.6	20.1	14.8	17.2	8.8	9.4

Forsmark, the six bottom sections at station 4 and 5

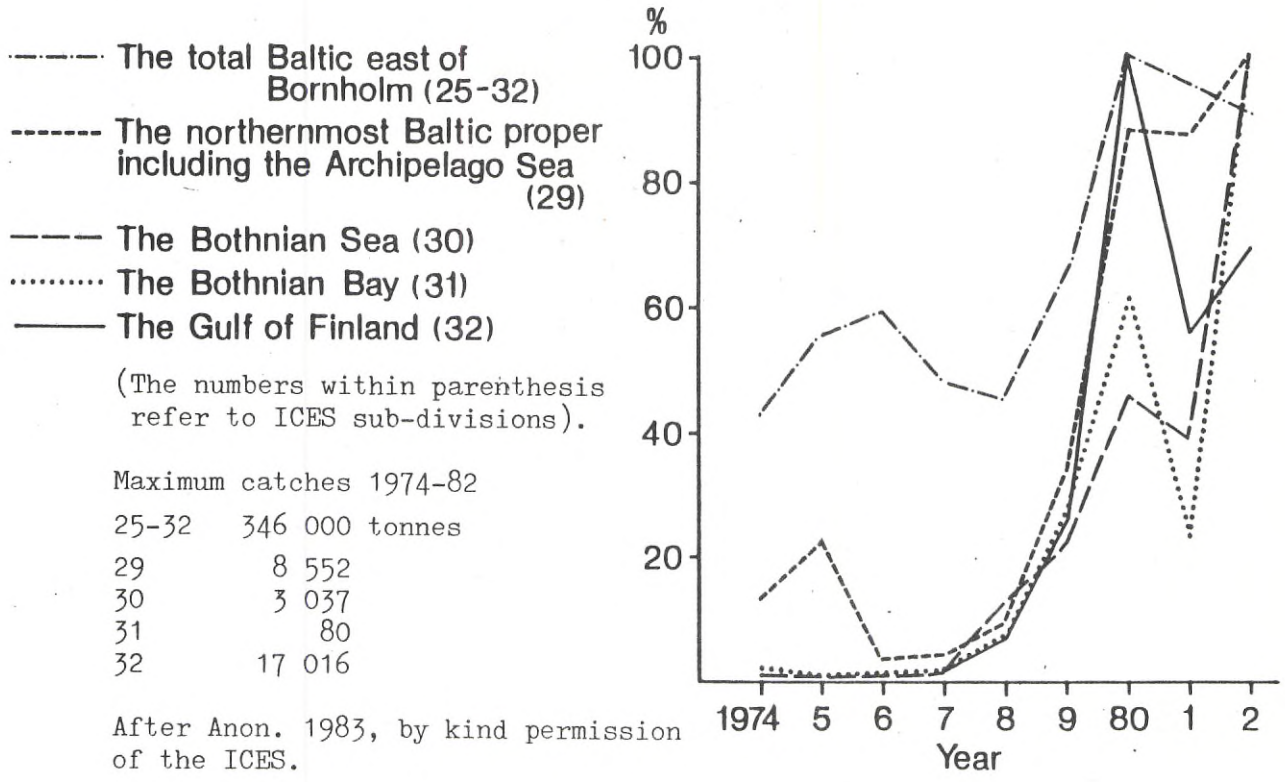
1975	0	0	0	0	0	0.3	0.5	
1976	0	0.6	0.2	0.6	0.2	0.1	0	
1977	5.6	2.8	1.1	0.3	0.2	0.1	0.2	
1978	0	0.6	2.4	2.9	1.5	0.5	0.3	
1979	0	2.2	0.7	1.1	1.6	1.9	2.6	
1980	1.1	0	1.6	1.1	1.1	1.3	1.6	*
1981	1.1	0.6	0.6	0.5	1.3	2.2	1.2	
1982	0	1.1	1.5**	2.1**	2.2	1.6	1.6	
Length distri-	<15							>50
bution %	0	4.2	6.0	15.9	9.9	14.5	21.4	15.2	12.8

Finbo, the six bottom sections at station 3

1976	0	0	0.1	0	0	0.1	0	
1977	0	0.6	0	0.1	0.1	0.1	0	
1978	0	0.6	0.2	0.3	0.3	0.4	0.4	
1979	0	0.3	0.7	0.6	0.3	1.0	0.7	
1980	0	0.8	0.6	1.2	1.5	1.8	3.4	*
1981	0	0.8	1.4	2.4	2.9	2.3	0.5	
1982	0	3.9	4.0**	2.5**	2.0	1.4	2.0	
Length distri-	<15							>50
bution %	0	0	3.6	18.5	22.7	24.9	13.7	6.6	9.9

* Probable border between year-classes 1975 and 1976
** Year-class 1980

Fig. 1 Commercial catches of cod in different parts of the Baltic expressed as percent of the 1974 – 82 maximum.



(The numbers within parenthesis refer to ICES sub-divisions).

Maximum catches 1974-82

25-32	346 000 tonnes
29	8 552
30	3 037
31	80
32	17 016

After Anon. 1983, by kind permission of the ICES.

Fig. 2. The investigation areas

Fig. 3. Fishing stations at Åsvikelandet

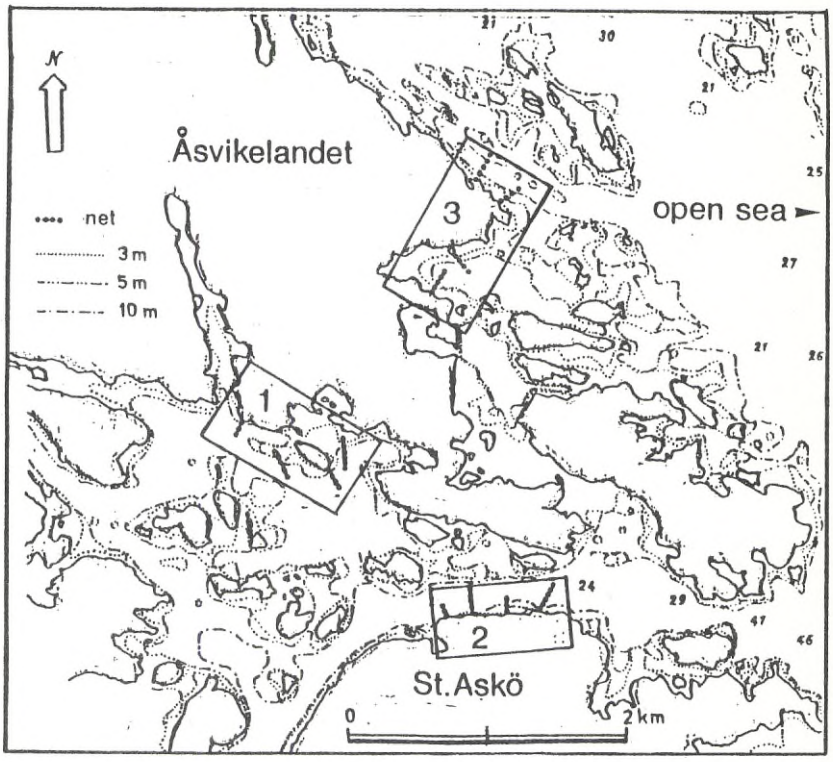


Fig. 4. Fishing stations at Forsmark

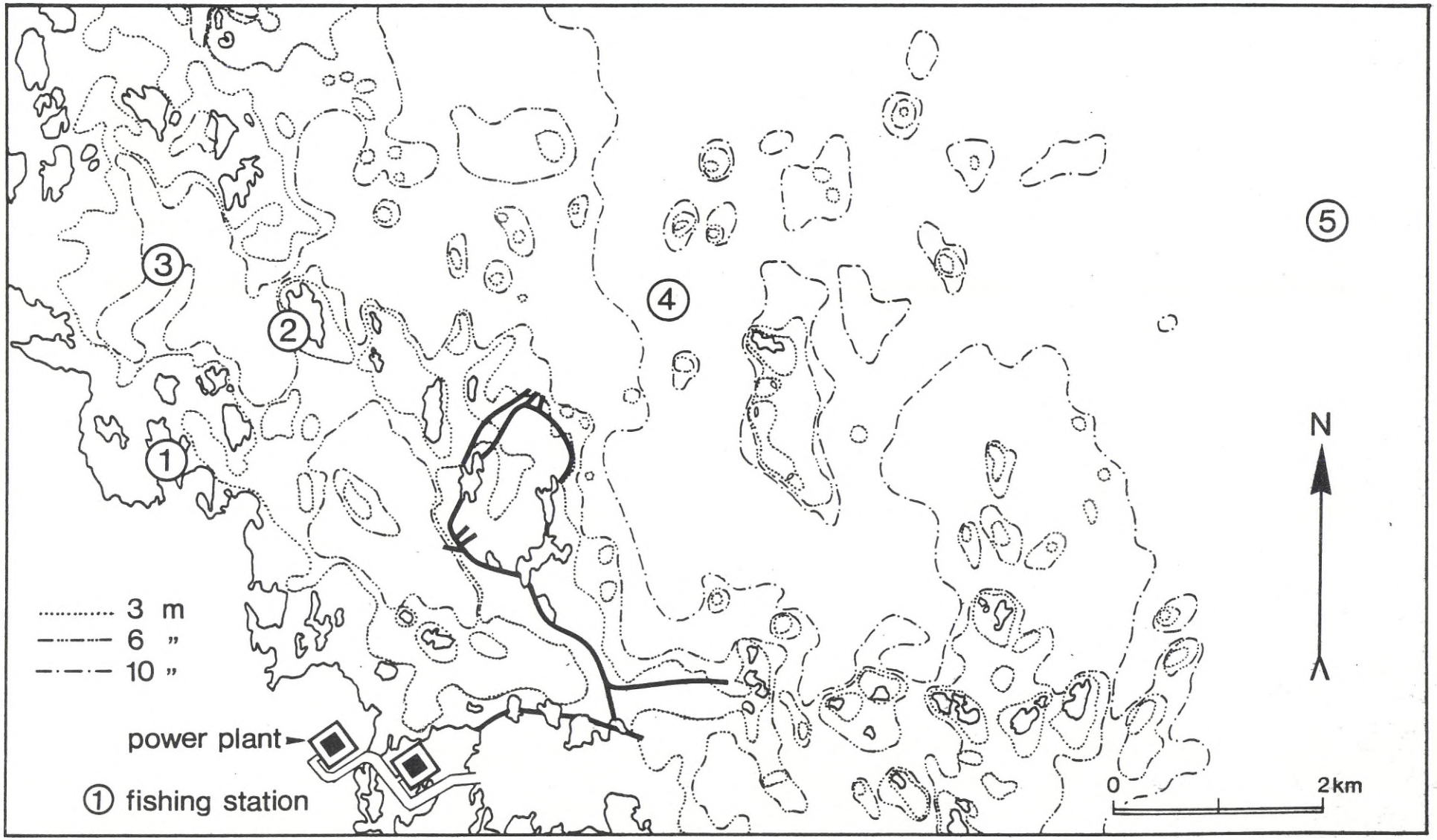


Fig. 5 Catches in exposed nets related to the 1970-1973 level.

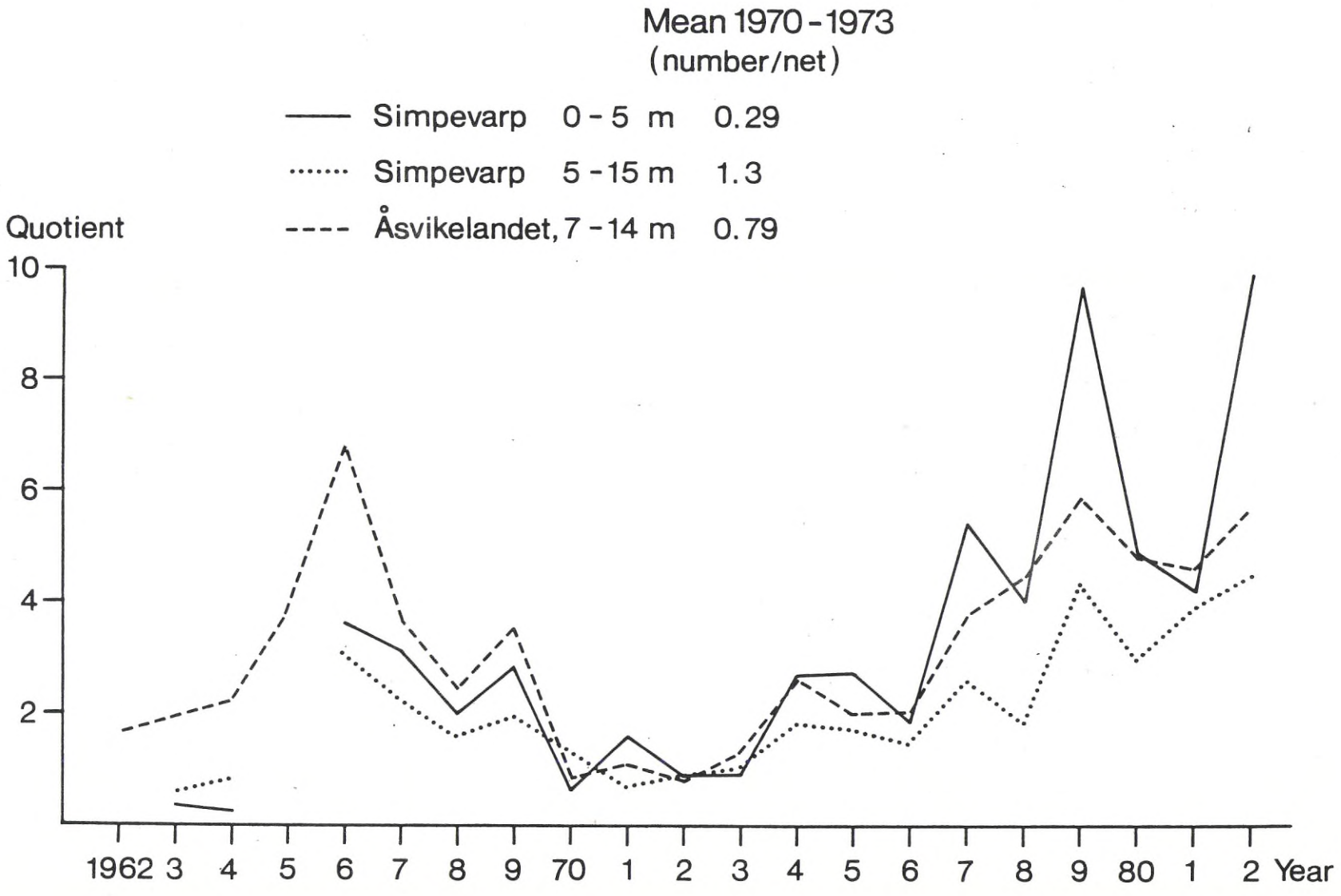


Fig. 6 Catches within intervals (2°C) of temperature in periods with low and high abundance of cod.

The catches are related to the mean catch (=1) for each material.

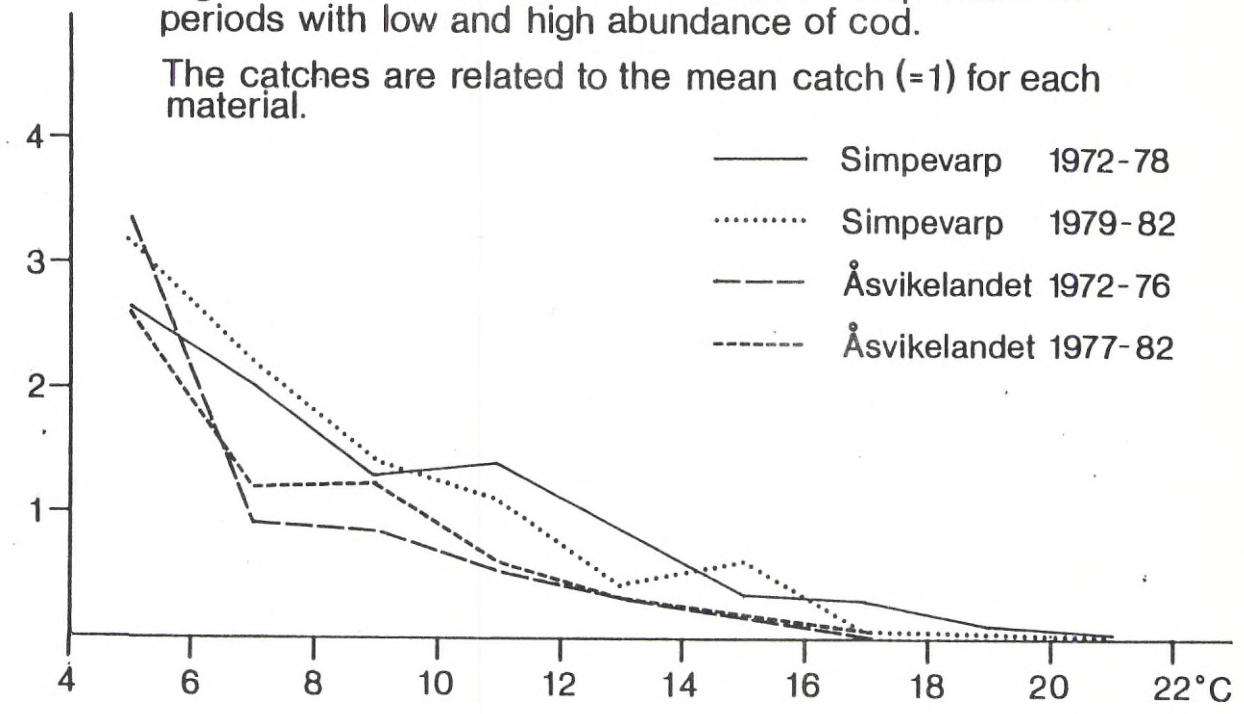


Fig. 7 Catches in exposed multi mesh-size nets at Simpevarp, Forsmark and Finbo. (May-October, six bottom sections)