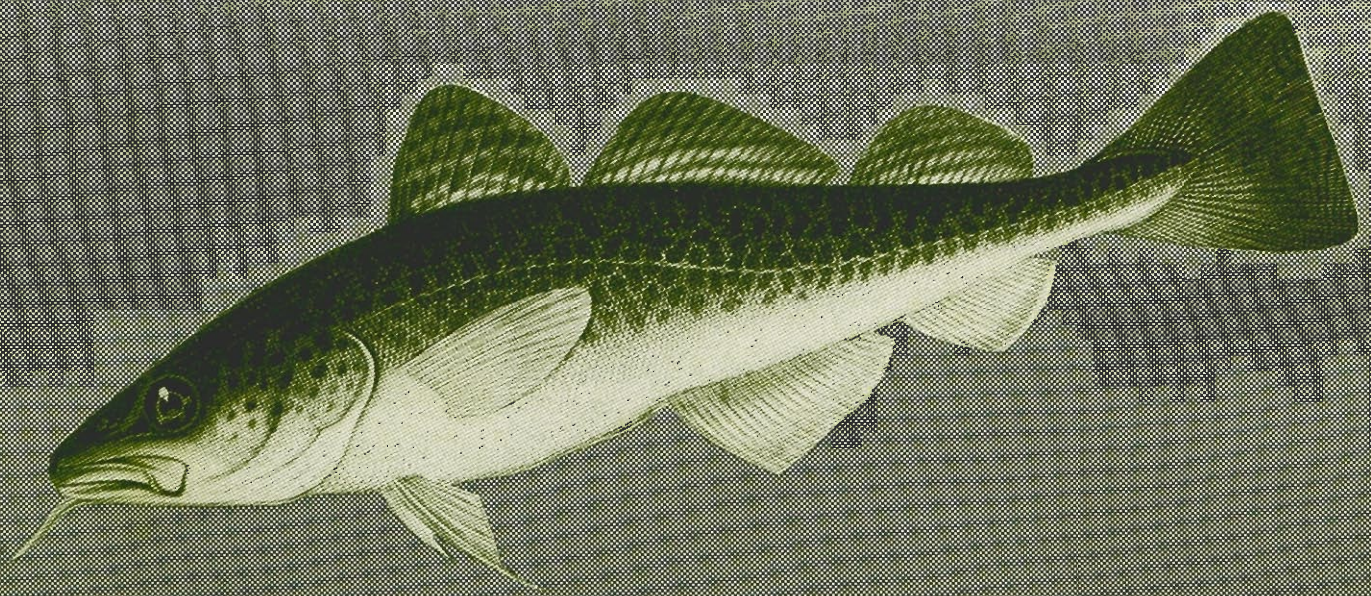
MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH

THE NORTH SEA COD AND THE ENGLISH FISHERY



By C. T. Macer and M. W. Easey

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by C. T. Macer and M. W. Easey

1. INTRODUCTION

Since the international adoption of 200 mile exclusive economic zones in the late 1970s, English* catches of cod from distant waters, such as the NE Arctic, Iceland and Newfoundland, have been drastically reduced and supplies from near waters, especially the North Sea, have become increasingly important. Thus, whereas in the 1950s and 1960s the North Sea accounted for less than 10% of total English landings of cod, currently this region contributes over 80% of the total.

After increasing in the late 1960s, the biomass of cod (the total weight of fish in the sea) has subsequently declined and this, coupled with a rising trend in fishing mortality, is causing concern. The purpose of this leaflet is briefly to review the biology of cod in the North Sea, to describe the recent history of the English fishery, and to assess the present state of exploitation of the stock.

2. THE BIOLOGY OF NORTH SEA COD

2.1 Life history

Although some 2-year-old males as small as 25 cm can be mature, the majority of cod spawn for the first time when they are between 3 and 4 years of age, at a length of approximately 50 cm. Spawning takes place between January and April, and at that time the eggs, which are about 1.4 mm in diameter, can be found floating in the surface layers over large areas of the North Sea, although in certain areas there are particularly dense concentrations (Figure 1(a)). The incubation period depends on temperature but typically the eggs hatch in about 2 to 3 weeks at a length of approximately 4 mm. The baby fish grow in length to between 20 and 80 mm by June, when they are mainly concentrated in the eastern and northern parts of the North Sea (Figure 1(b)). By the following winter, the fish are between 13 and 26 cm in length and have become concentrated in the shallow coastal waters of Denmark, Germany and the Netherlands (Figure 1(c)). It is not known whether this concentration includes fish from both of the main patches of juveniles shown in Figure 1(b). The patch found off the north-west Danish coast almost certainly ends up in the south-eastern North Sea. The fate of those found east of Shetland is less clear, although the drift of the currents is such that they could be transported to the Danish coast. A similar, though less pronounced, pattern of distribution can also be detected one year later in the 2-year-old fish (Figure 1(d)), though there is a summer migration offshore in the intervening period. The distribution of ages 3 and older in winter is shown in Figure 1(e). These ages are relatively more abundant in the northern North Sea than are the younger ages, and there is much less concentration of fish in the south-eastern North Sea.

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*In this Leaflet, the term 'English' refers to UK vessels landing at English ports.

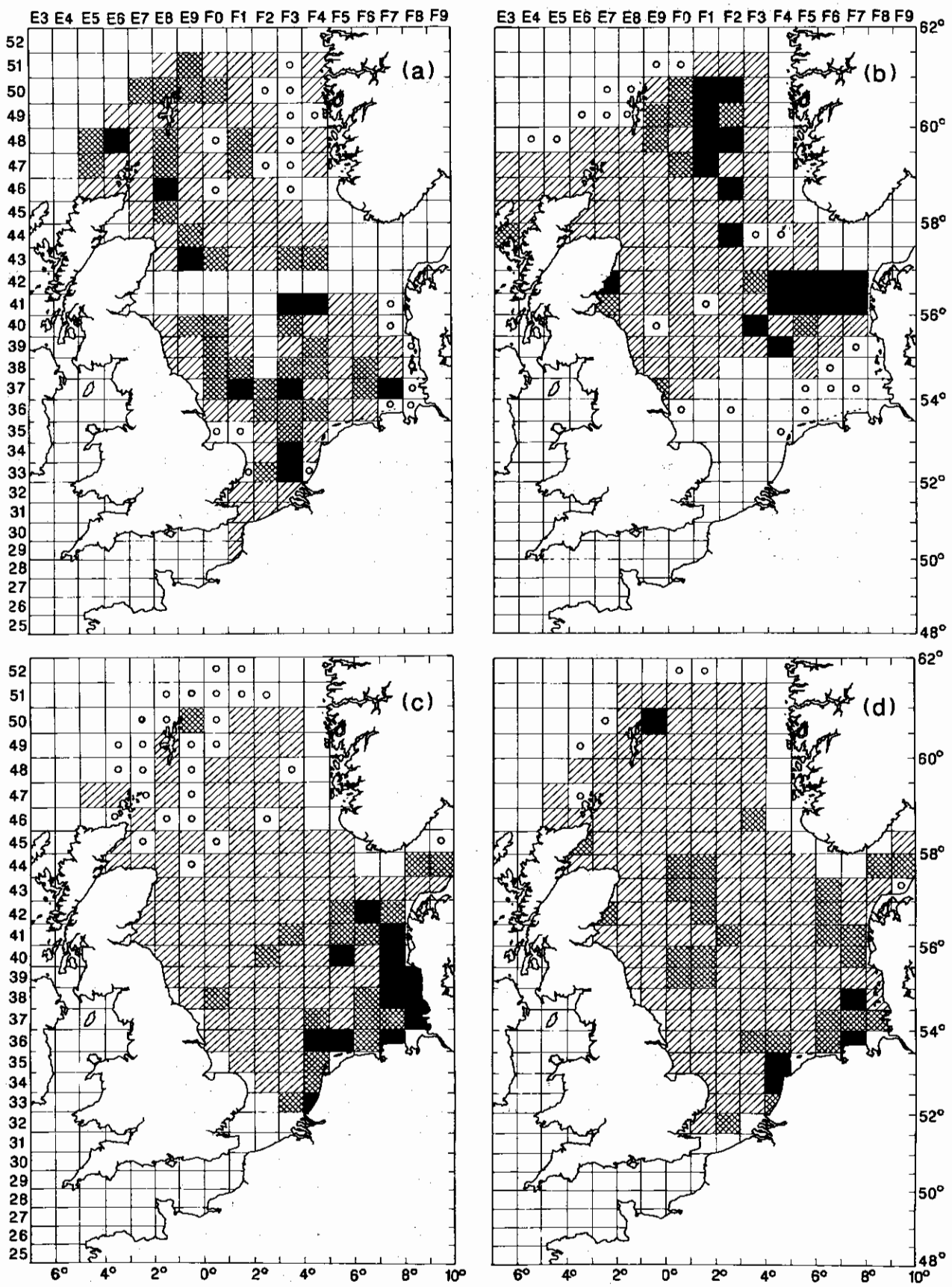

Figure 1 The distribution of cod at various stages in their life history, as shown by research vessel surveys: (a) eggs in winter/spring; (b) the young of the year in June; (c) 1-year olds in winter; (d) 2-year olds in winter; (e) older fish (3+) in winter ((a) adapted from Daan, 1978; (b-d) from Riley and Parnell, 1984; (e) adapted from Daan, 1980).

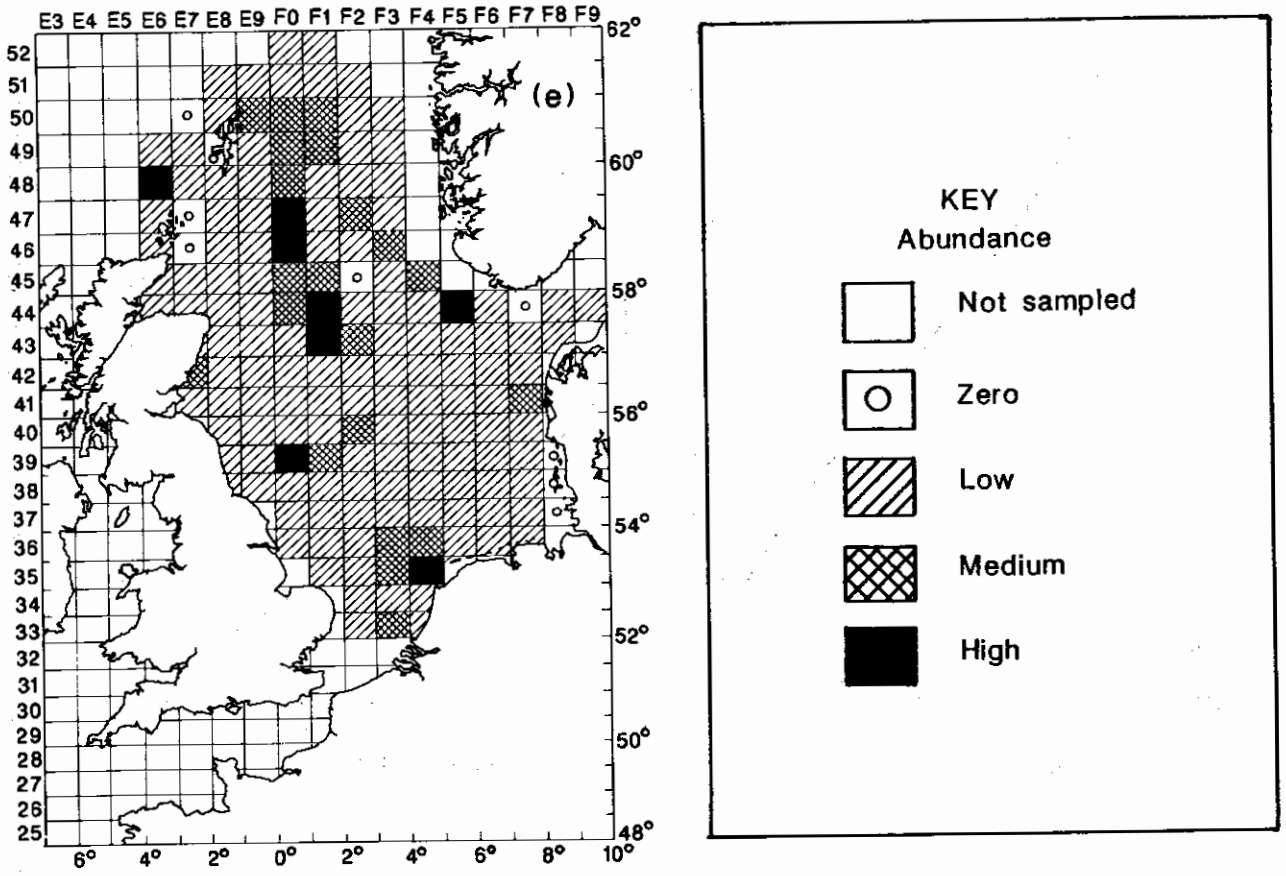

Figure 1 continued

2.2 Growth and mortality

The rate at which individual fish grow and the rate at which their numbers decline naturally in the sea are important factors in determining how best to exploit them. The total weight of fish in the sea at any one time (known as the biomass) is the product of the total number of fish and the average weight of the individuals. During the lifespan of a year class of fish, the biomass first increases and then decreases as the balance between the growth rate and the numerical abundance alters. The age at which the maximum biomass occurs is a factor to be considered in managing a fish stock.

The growth rate of cod varies slightly throughout the North Sea, and cod in the southern North Sea grow faster than those in the north. As Figure 2 shows, growth is most rapid in the younger fish and it gradually declines with age. Between the ages of 1 and 2 the mean weight increases by a factor of about 4, while in the following year the weight is doubled. At the same time as the individual fish are growing, their numbers are declining and would do so even in the absence of fishing. The main cause of natural mortality is being eaten by predators; in addition, cannibalism also occurs in cod. The decline in abundance of cod, due purely to natural causes, is also illustrated in Figure 2. Starting with 1000 fish at age 1 (the age at which they would normally recruit to the fisheries), less than half survive to age 2, and by the age of 5 the number is reduced to 200. However, the early growth in weight of individual cod is so rapid that, despite the sharp decline in numbers, the biomass is at its theoretical maximum at age 6.

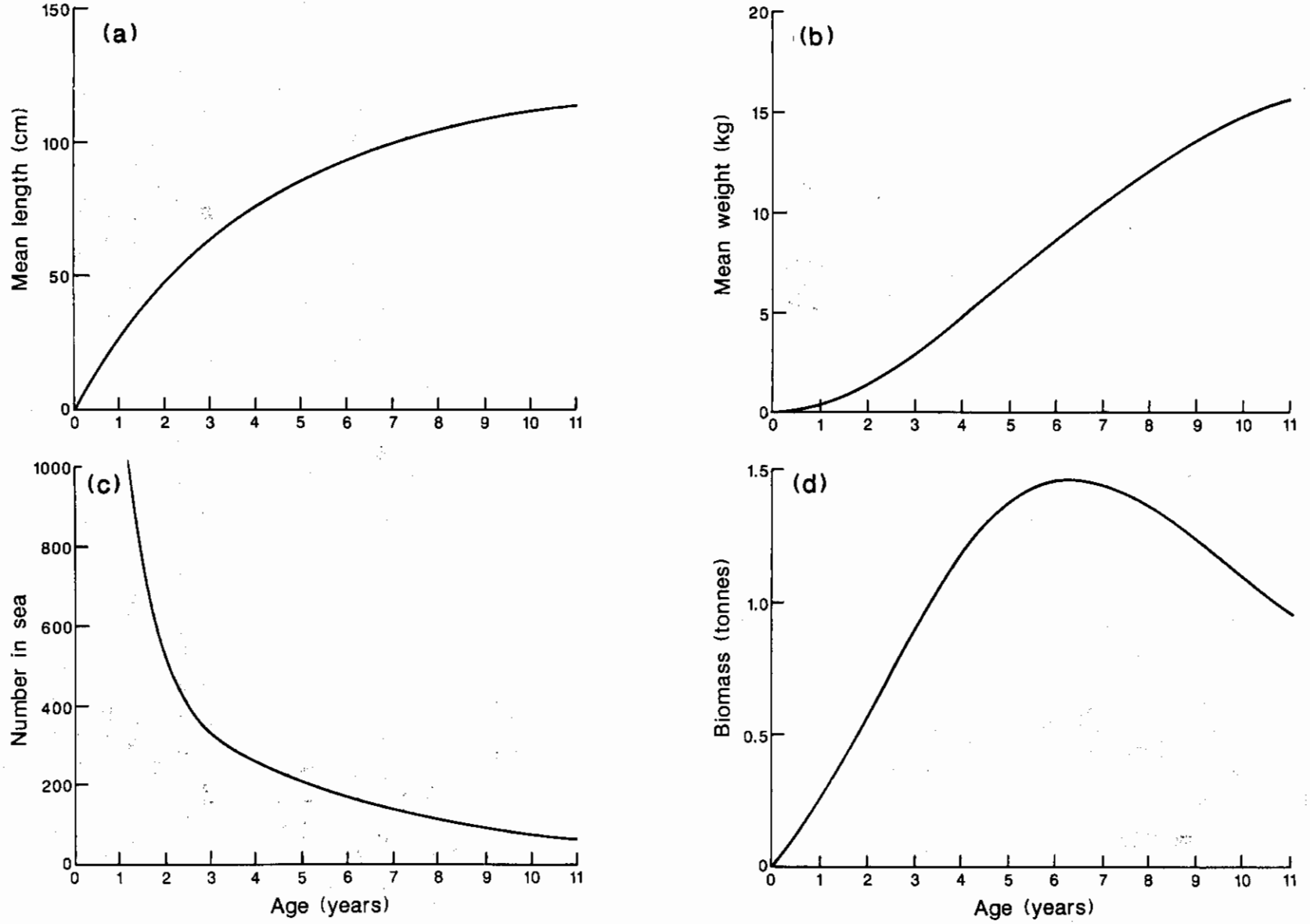

Figure 2 Growth and natural mortality of North Sea cod in relation to age: (a) growth in length; (b) growth in weight; (c) decline in number due to natural causes; (d) changes in biomass.

Table 1 shows recent estimates of the mortality on each age (percentage of stock per year) due to natural causes and due to fishing. The values represent annual rates, except for age 0, where they refer to the period July-December.

Table 1 Mortality of cod with age (%)

Age	0	1	2	3	4+
Natural mortality	80	50	20	15	10
Fishing mortality	?	10	60	60	55

The values for natural mortality are preliminary estimates resulting from an international fish stomach sampling survey (Anon., 1987). The value for the 0-group fish (those in their first year of life) refers only to the mortality of juveniles and excludes mortality of larvae, for which no estimates are available. With regard to fishing mortality on 0-group cod, it is known that many are caught incidentally in the shrimp fisheries, but the resulting mortality has not been quantified for the North Sea as a whole. The value for fishing mortality for 1-year-old cod is an underestimate, since an unknown quantity is caught and discarded at sea, mostly as dead or dying fish, both in shrimp fisheries and in finfish fisheries. The maximum age recorded for North Sea cod is 15 years but very few fish survive to this age.

2.3 Feeding

The feeding habits of North Sea cod have been extensively investigated, the most comprehensive data being collected during an international exercise in 1981 (Daan, 1983), when about 11 000 cod stomachs, as well as stomachs from other species, were collected throughout the year. Some results from that study are shown in Figure 3. In 0- and I-group cod the

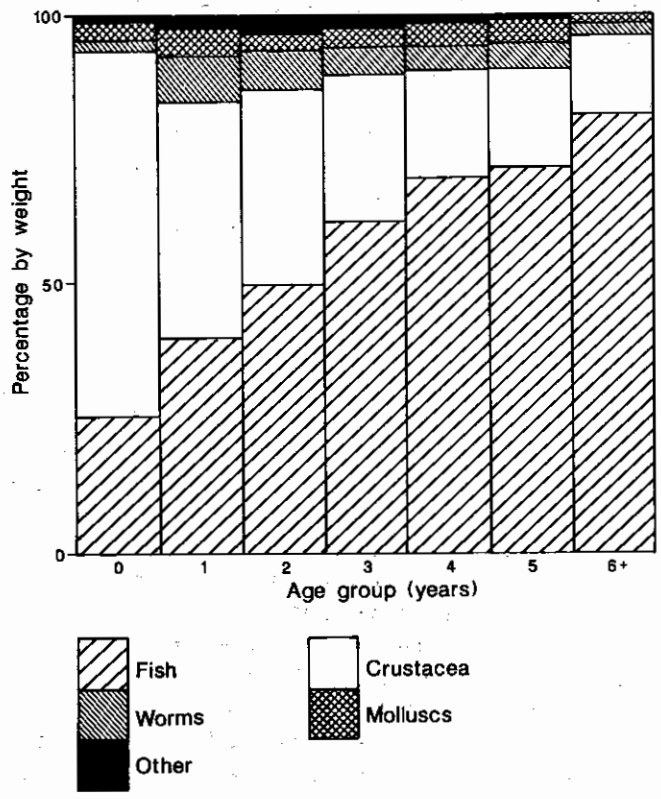

Figure 3 The food of North Sea cod (adapted from Daan, 1983).

dominant prey items are crustaceans such as shrimps but in older cod, fish comprise an increasingly important part of the diet. Most of the fish species consumed are of commercial importance and they include cod itself, with fish up to 3 years of age being vulnerable to cannibalism. Sandeels are the most important fish prey for the younger cod, whilst for older cod the predominant species are haddock and whiting. The fact that the cod is an important predator in the North Sea implies that changes in its abundance will be reflected in the mortality which it inflicts on its prey. Clearly, such species interactions should be taken into account in managing the North Sea fisheries, and this aspect is being given increasing attention by scientists.

2.4 Migrations

Many thousands of cod have been tagged and released in the North Sea, and a reasonable knowledge of the pattern of their movements has been built up over the years. Results from some of the tagging experiments are shown in Figure 4. The maximum distance travelled from the release point is of the order of 200 miles. However, the centres of density of the recaptures show much more restricted seasonal movements, alternating between the feeding areas in summer and the spawning grounds in winter, the distance between these grounds varying between 20 and 120 miles. In general, the spawning grounds lie to the south of the feeding areas. The general picture that emerges from the tagging results is of a more or less continuous distribution of cod in the North Sea, with seasonal variations in abundance in particular areas, associated with the annual migration patterns.

There is interchange between cod in the North Sea and those in neighbouring waters; its magnitude is uncertain but it is probably small in relation to the total North Sea stock. There appears to be little interchange with cod west of Scotland but there is a greater degree of exchange with cod in the Skagerrak and in the eastern English Channel. For both these areas, the tagging data suggest that there is a net movement of cod into the North Sea, i.e. that more fish enter it than leave it. A few long-distance migrations have been recorded. From a tagging experiment in the central North Sea in June 1957, two fish were recaptured from the Faroe Islands in September 1957 and one from Newfoundland in December 1961. Considerable effort was made to verify the reliability of the reported recapture positions of these fish, and they appear to be valid returns.

3. THE FISHERY

Figure 5 shows the total international landings from the North Sea cod fishery from 1906, the earliest year for which such data are available. Prior to the early 1960s, landings fluctuated between about 20 000 and 160 000 tonnes, with a marked fall in landings during the two war periods (1914-18, 1939-45). Landings peaked immediately after each war, reflecting a building-up of the stock in the virtual absence of fishing. The decline in landings in the inter-war years is consistent with the fishing down of an accumulated stock but the same pattern was not repeated after the second world war, except in the immediate post-war years. In fact, in the 1960s there was a remarkable increase in landings, which reached a peak of about 340 000 tonnes in 1972. Although there have been wide fluctuations in landings subsequently, they have remained at a high level compared to the period before 1960. One reason for the increase in landings in the past 20 years is that recruitment of juvenile fish to the fishery has been at a much higher level and this is discussed later.

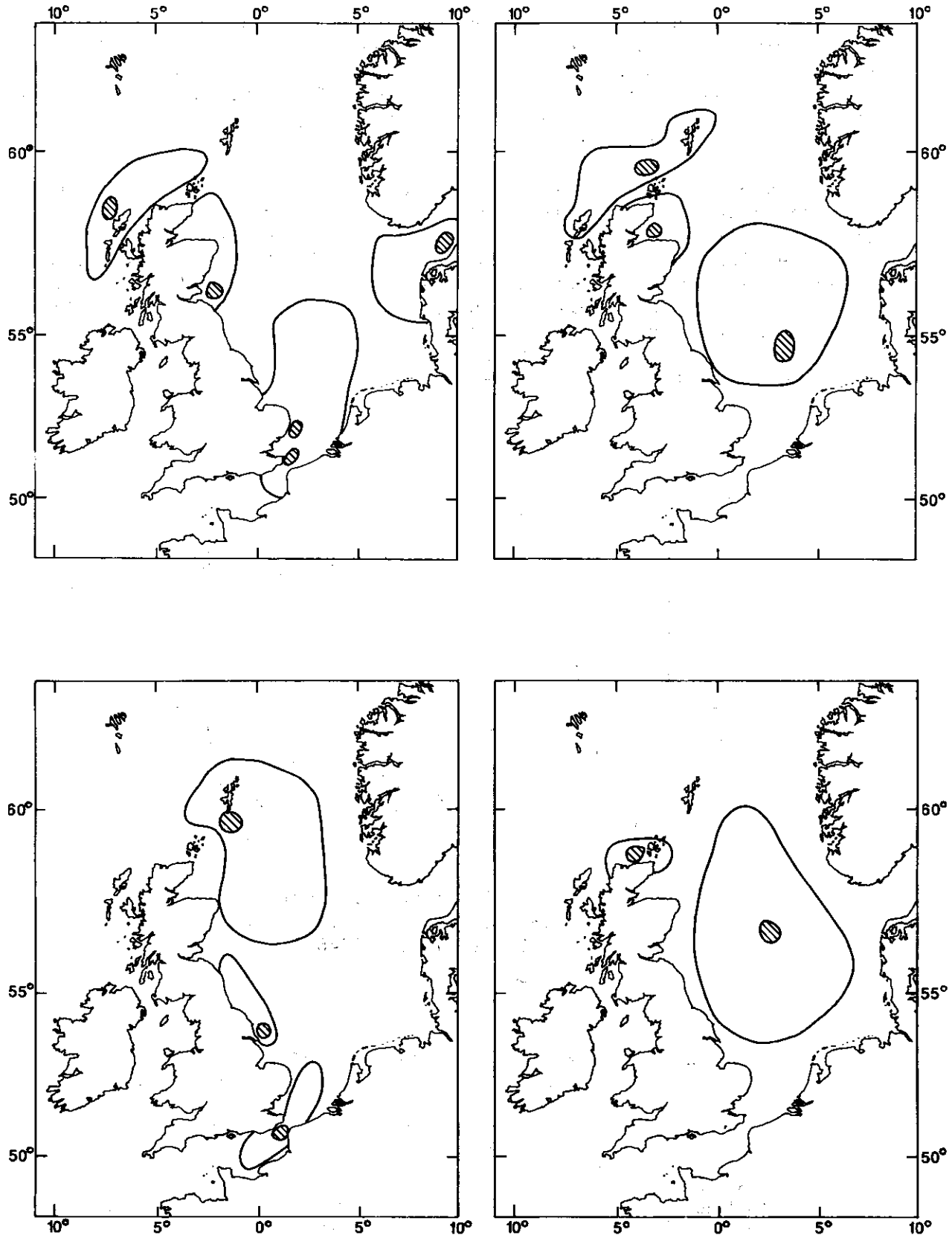

Figure 4 The approximate limits of cod recaptured from various tagging experiments. Key: ⬭ limit of recaptures; ⬭ area of release.

Figure 5 also shows landings by England and by the UK as a whole since the last war. English landings have fluctuated between about 20 000 tonnes and 60 000 tonnes during that period; they have accounted for about half the UK total and, in recent years, for about 20% of the total international landings. A breakdown of the landings by country, averaged for the 5-year period 1981-85, is given in Table 2.

For many years, English landings of cod from the North Sea were of minor importance compared to those from other areas. As Table 3 shows, more than three quarters of English landings of cod in the post-war years up to the 1970s were traditionally taken from the distant-water grounds at Iceland, the north-east Arctic, the Norway coast and at Faroe. However, with the adoption of 200-mile fishery zones in the late 1970s, UK fishing activity in these areas has been drastically reduced or, in some areas, has ceased altogether, and this has resulted in over 80% of English cod landings being taken from the North Sea in recent years.

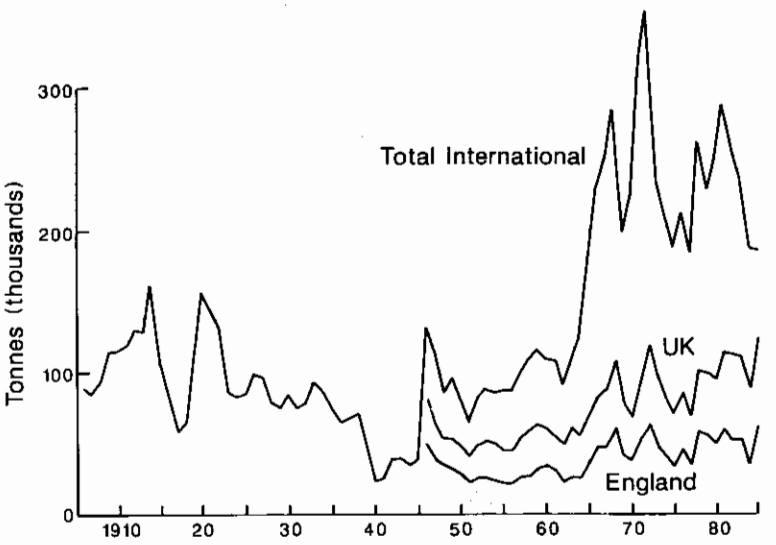

Figure 5 Total international landings of cod from the North Sea, 1906-85; UK and English landings, 1946-85.

Table 2 Landings (whole weight) of cod from the North Sea by country, as officially reported (mean 1981-85)

Country	Tonnes	%
Scotland	56 945	24
England	52 906	22
Denmark	52 748	22
Netherlands	35 637	15
Germany (Fed. Rep.)	17 946	8
France	7 978	3
Norway	7 516	3
Belgium	6 534	3
Others	641	< 1
Total	238 851	100

Table 3 English landings (whole weight) of cod in selected years, by area of capture

Area	1953		1963		1973		1983	
	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%
North Sea	23 352	6	24 843	8	47 223	18	53 383	84
West of Scotland and Rockall	7 261	2	4 245	1	2 072	1	1 230	2
Irish Sea	2 739	1	717	+	3 132	1	1 405	2
English Channel	58	+	23	+	501	+	648	1
Bristol Channel, south of Ireland	1 059	+	138	+	191	+	211	+
Skagerrak	10	+	2	+	12	+	-	-
North-east Arctic and Norway coast	132 971	34	122 529	40	76 650	29	5 840	9
Iceland	172 744	45	115 653	38	121 231	46	-	-
Faroe	12 429	3	4 318	2	5 074	2	-	-
West of Ireland	179	+	150	+	19	+	-	-
Greenland			686	+	744	+	-	-
North-west Atlantic	35 472	9	32 917	11	5 436	2	1 174	2
Total	388 274	100	306 221	100	262 285	100	63 891	100

+ indicates less than 0.5% - indicates no landings

Cod is by far the most important species landed in England from the North Sea, both in terms of weight and value (Table 4). In the period 1981-85 cod accounted for 40% by weight and 45% by value of all fish and shellfish landed by UK vessels in England from the North Sea. Table 5 shows the quantities landed at major ports in selected years. Grimsby is the most important port in terms of quantity landed, supplying around 40% of the total landings from the North Sea in 1983. In earlier years the north-east district was second in importance, but landings at the Yorkshire ports have increased over the years until they supplied about 30% of the total quantity in 1983. At Lowestoft, landings have declined sharply in recent years, and many vessels have been converted for duties in the oil and gas industries.

There has been a marked change over the years in the proportion of the English catch of North Sea cod taken by various gears (Table 6). In 1953 over 80% of the landings were taken by otter trawl, but this proportion fell in the 1960s as increasing quantities were taken by seiners. In recent years there has been an increase in landings by bottom pair-trawlers, which contributed around 30% of the total in 1983.

The geographical distribution of English catches of cod in the North Sea by trawlers and seiners in selected years is shown in Figures 6 and 7. Catches by trawlers (Figure 6) are mainly taken in the western-central North Sea but in recent years grounds west of the Shetland Islands have become more important. With seine-caught cod (Figure 7), a shift in distribution from the English north-east coast towards the north and east can be detected, with the greatest quantities coming from the central North Sea in 1983.

Table 4 Ranked order of species for English landings from the North Sea (average 1981-85)

Species	Weight (tonnes, whole)	Species	Value (£'000s)
Cod	45 801	Cod	24 396
Haddock	14 171	Plaice	8 497
Plaice	14 066	Haddock	5 445
Sprat	7 181	Nephrops	2 142
Cockles	5 247	Lemon sole	1 967
Whiting	4 970	Dover sole	1 232
Mussels	3 675	Whiting	1 225
Spurdogs	3 087	Spurdogs	1 099
Saithe	3 036	Lobsters	906
Lemon sole	2 265	Saithe	761

Table 5 English landings (whole weight) of cod from the North Sea in selected years by port of landing and MAFF districts

	1953		1963		1973		1983	
	tonnes	%	tonnes	%	tonnes	%	tonnes	%
North Shields	6 599	28	3 605	15	6 642	14	7 466	14
Other ports	1 147	5	1 596	6	2001	4	3 332	6
Total NE District	7 746	33	5 201	21	8 643	18	10 798	20
Hull	101	+	1 081	4	1 907	4	1 912	4
Whitby	205	1	643	2	1 900	4	2 875	5
Scarborough	839	4	1 078	4	2 994	6	4 677	9
Bridlington	738	3	660	3	2 970	6	6 042	11
Other ports	–	–	403	2	821	2	715	1
Total Yorkshire District	1 883	8	3 865	15	10 592	22	16 221	30
Grimsby	10 667	46	10 105	41	20 357	43	21 275	40
Other ports	–	–	–	–	–	–	5	–
Total Grimsby District	10 667	46	10 105	41	20 357	43	21 280	40
Lowestoft	2 672	11	4 966	20	6 187	13	3 985	7
Other ports	–	–	16	+	652	2	659	1
Total Eastern District	2 672	11	4 982	20	6 839	15	4 644	8
Total SE District	3	+	19	+	213	1	421	1
Total NW District	374	2	665	3	579	1	21	+
Other districts	8	+	7	+	–	–	–	–
Total	23 353	100	24 844	100	47 223	100	53 385	100

Table 6 English landings of cod (whole weight) from the North Sea in selected years by method of capture

Gear	1953		1963		1973		1983	
	tonnes	%	tonnes	%	tonnes	%	tonnes	%
Beam trawl	–	–	–	–	22	–	14	–
Otter trawl	19 416	83	12 059	48	24 940	53	21 029	39
Pair trawl	–	–	–	–	3 384	7	15 885	30
Seine	2 422	10	10 576	43	16 066	34	11 777	22
Drift, gill, trammel, tangle	–	–	–	–	–	–	876	2
Danish gill net	–	–	–	–	–	–	1 595	3
Long lines	1 513	7	2 208	9	2 432	5	2 124	4
Other	–	–	–	–	379	1	83	–
Total	23 351	100	24 843	100	47 223	100	53 383	100

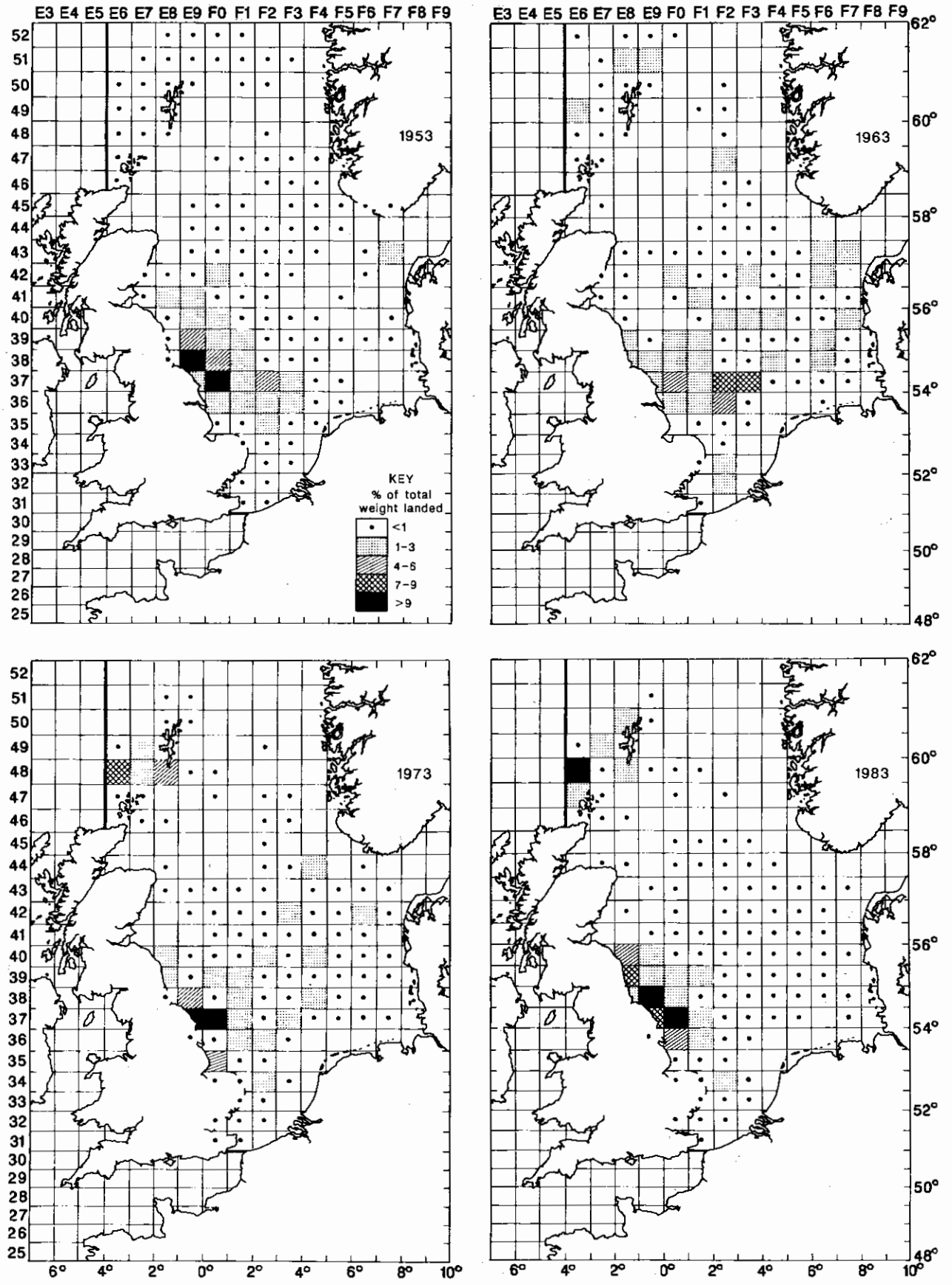

Figure 6 The distribution of cod landings by English trawlers in selected years.

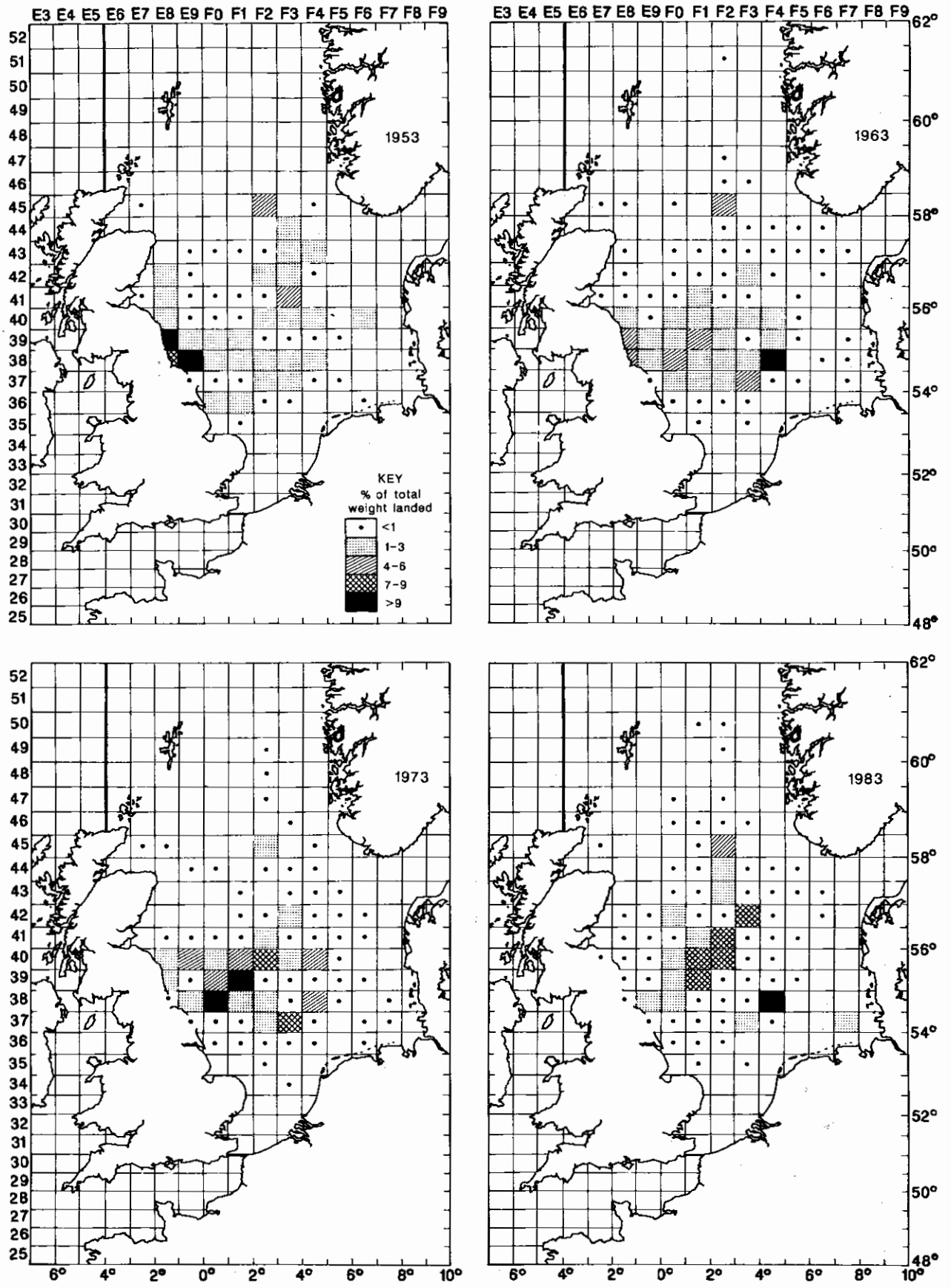

Figure 7 The distribution of cod landings by English seiners in selected years.

The age compositions of cod landed by the seiner fleets at Grimsby and North Shields, which have traditionally taken a high proportion of the English catch, are shown in Figure 8. Two-year-old fish predominate in the landings, markedly so in the case of North Shields seiners, although in the most recent period the percentage of 2-year olds has increased in landings by Grimsby seiners, to reach similar levels to those landed by North Shields seiners. The increase in recruitment in the 1960s is reflected in the age compositions of the landings of both fleets, in the increased abundance of 2-year olds after the period 1958-62.

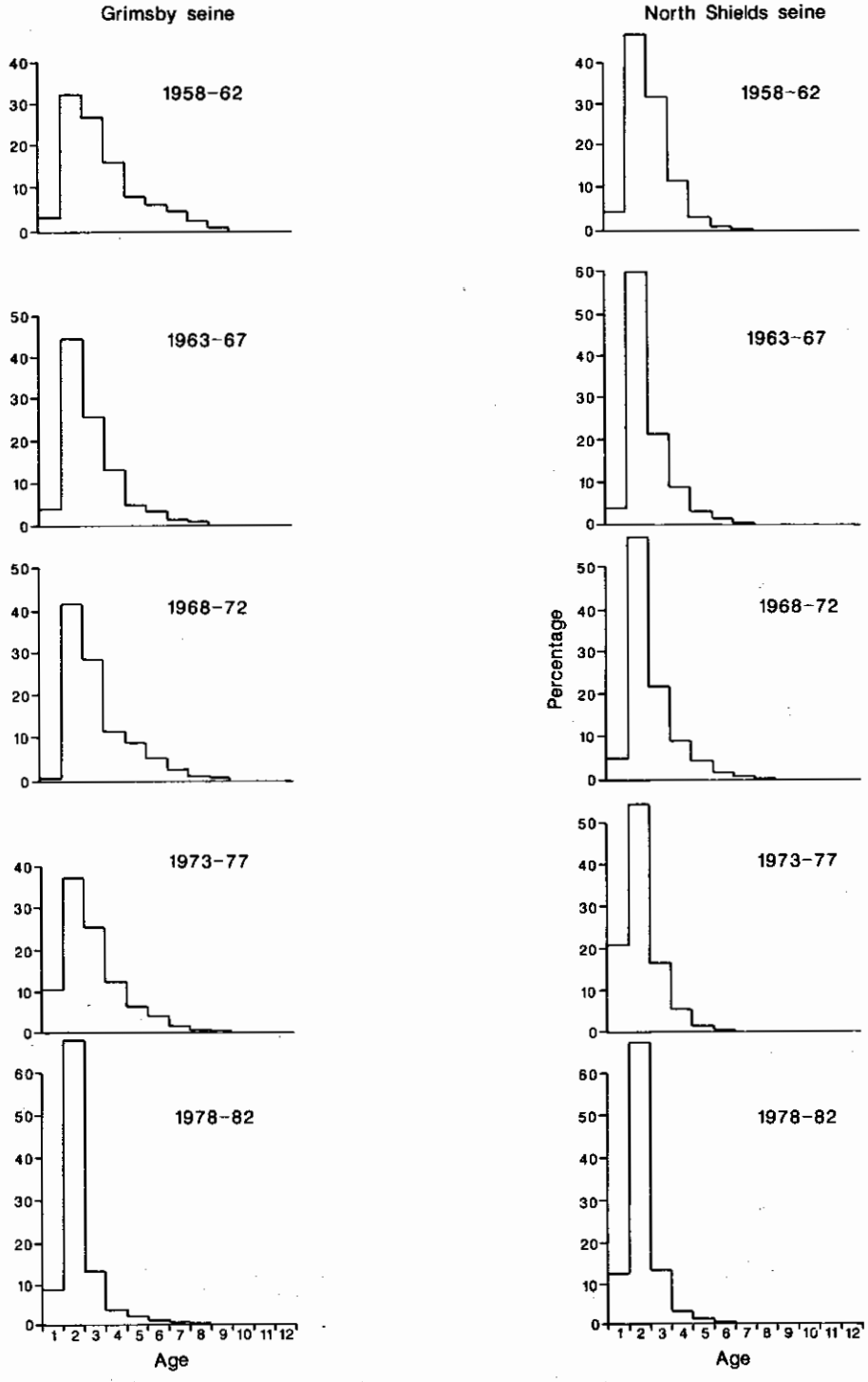

Figure 8 Age compositions of North Sea cod (averaged over 5-year periods) landed by two English fleets.

4. THE STATE OF EXPLOITATION

Data for the number of fish of each age landed in the total international fishery are available from 1963. From these data estimates of fishing mortality (the fish capture rate) and stock size can be made using a technique known as virtual population (or cohort) analysis (VPA) (this is explained in Pope, 1982). Figure 9 shows such estimates, and it can be seen that fishing mortality has been steadily increasing, while spawning stock biomass increased up to 1970 but has subsequently declined to the

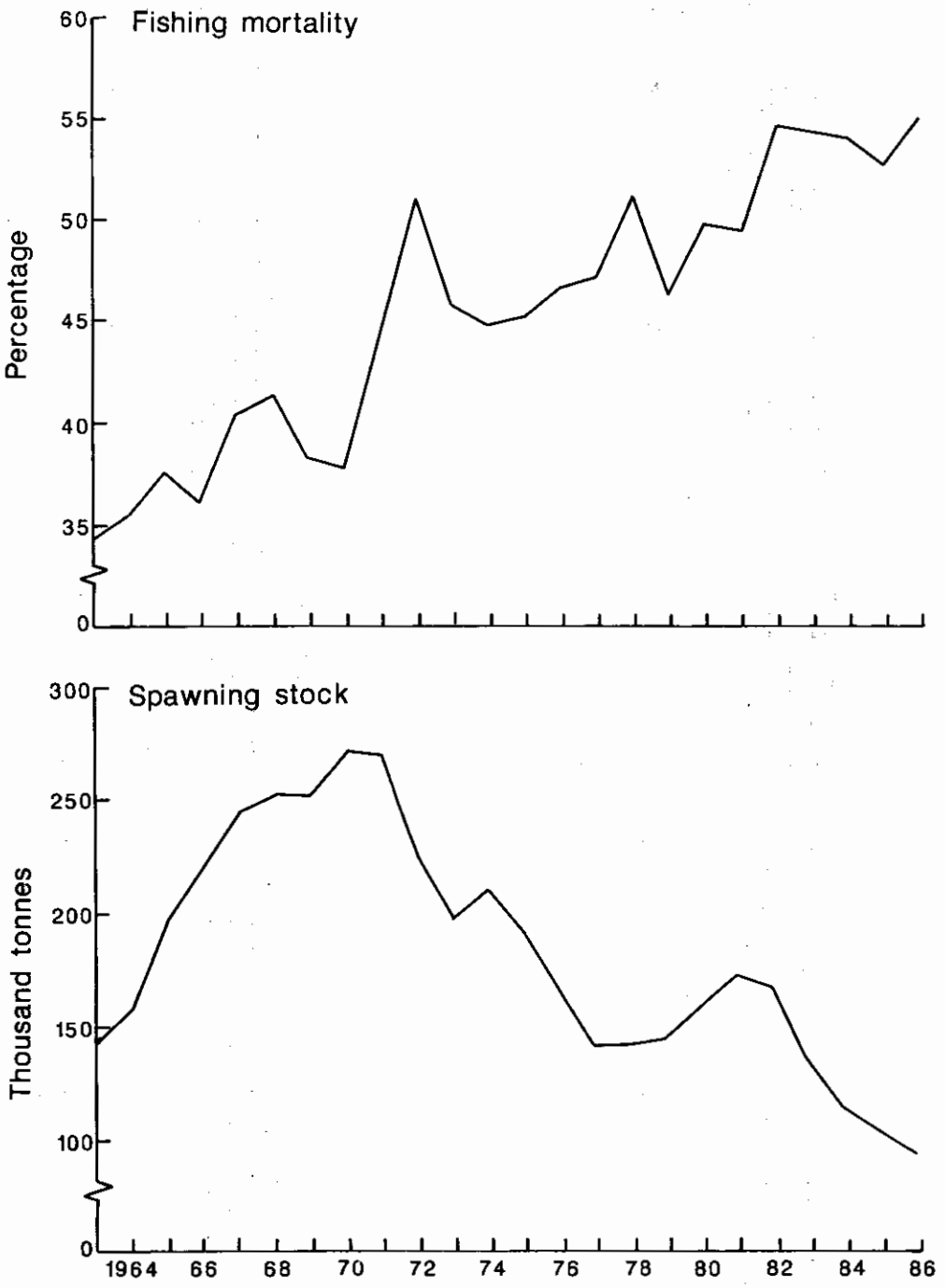

Figure 9 Trends in fishing mortality (averaged over ages 2 to 8) and spawning stock biomass for North Sea cod.

lowest levels recorded in the period. Figure 10 shows the fishing mortality for each age (exploitation pattern) averaged over successive 5-year periods. This again illustrates the increase in fishing mortality with time, and it also shows that there has been a shift in exploitation in recent years towards the younger ages.

Trends in recruitment are shown in Figure 11, using VPA data and catch-rates for the two English seiner fleets. All three data sets show the marked annual fluctuations in recruitment that typify most fish stocks. These fluctuations are thought to result from variations in mortality rates during the larval phase, but the mechanisms which cause them are not well understood. In addition to annual fluctuations, on theoretical grounds there must be an underlying relationship between the size of the spawning stock and the number of recruits that it produces. The precise form of this relationship in North Sea cod is not known but, from experience with other cod and haddock stocks, we know that recruitment can be seriously reduced at low levels of spawning biomass. It is not known whether the current low level of spawning biomass will result in reduced recruitment but clearly there is an increasing risk as spawning biomass declines.

The English fleet data in Figure 11 also illustrate the increase in recruitment which occurred in the 1960s, starting with the fish spawned in 1963. The factors responsible for this enhanced recruitment are not known but one theory is that it is associated with the decline in the abundance of herring and mackerel. This could have resulted in more planktonic food becoming available for the larvae of cod, and in a decrease in predation by herring and mackerel on cod larvae. If true, it implies that the recent increase in the herring stocks could adversely affect cod recruitment.

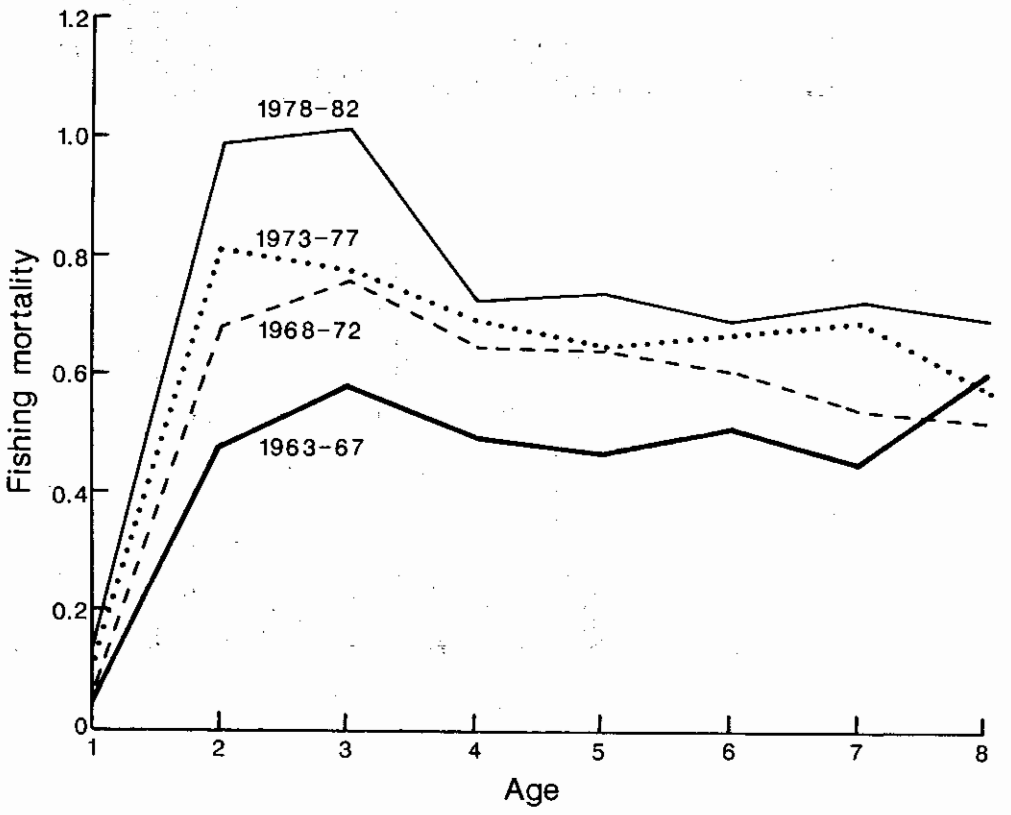

Figure 10 Exploitation patterns averaged over successive 5-year periods.

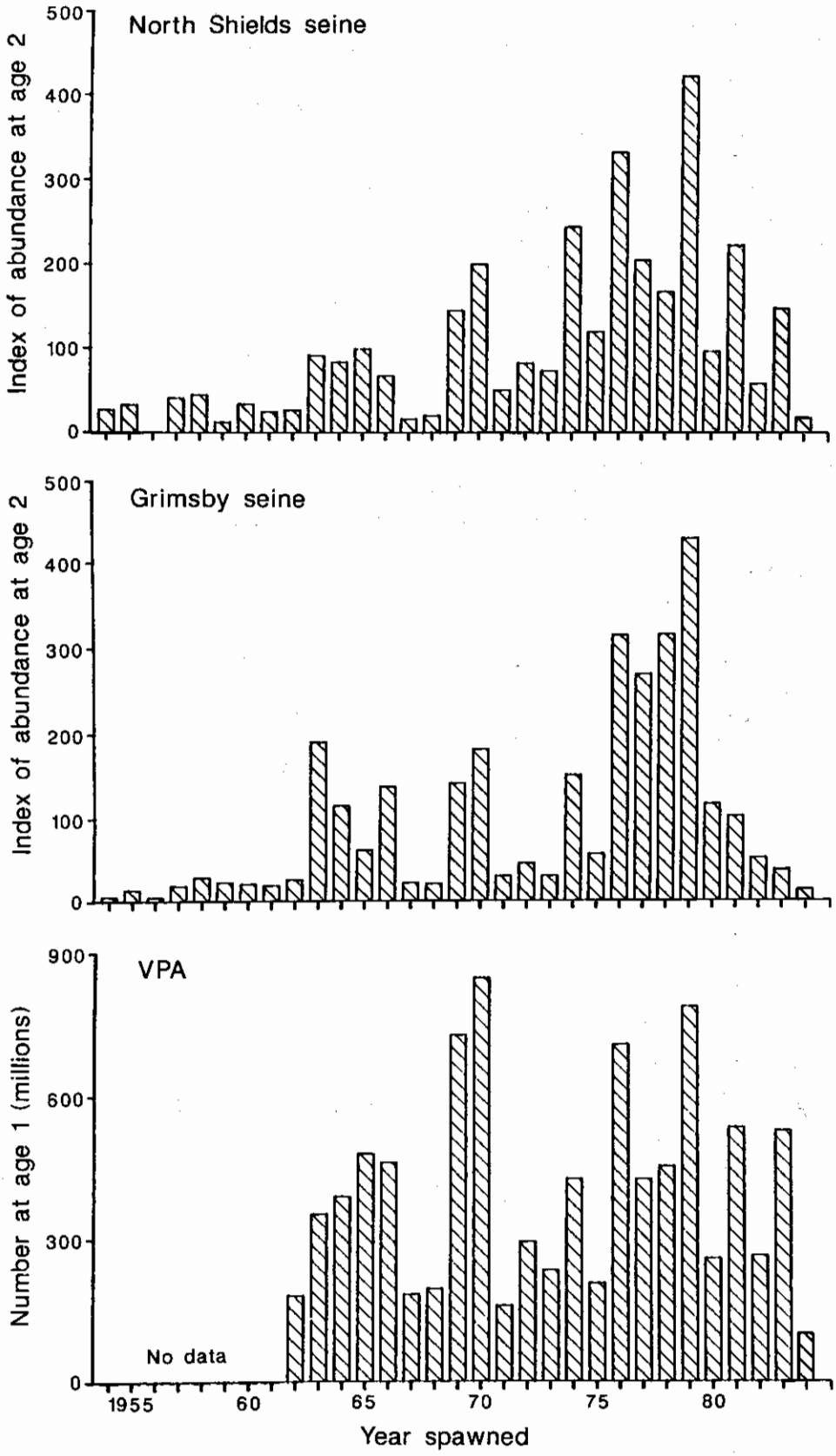

Figure 11 Recruitment data for North Sea cod as indicated from virtual population analysis (lower) and from English catch-per-unit-effort data (upper and centre).

5. MANAGEMENT OF NORTH SEA COD FISHERIES

The current (1988) management measures for North Sea cod are minimum mesh size, minimum fish size (30 cm) and annual catch quotas (since 1975). The minimum mesh sizes are 85 mm in the EC zone (except in an area in the south-eastern North Sea where it is 100 mm), and 100 mm in the Norwegian zone. If North Sea cod were to be managed in isolation, a mesh size of 150 mm or more would be appropriate for optimizing the pattern of capture with age. However, such a mesh size would severely reduce yields of the other species such as haddock and whiting, which are taken together with cod in some areas of the North Sea. A mesh size of 90-100 mm is probably the maximum which could be used in the North Sea mixed demersal fisheries, and an increase to 90 mm is proposed in the EC zone. However, larger mesh sizes would be appropriate for areas which could be identified as supporting directed fisheries for cod with relatively small by-catches of other species, or for nursery grounds. One such area is the German Bight nursery ground, where a minimum mesh of 100 mm was introduced in 1987, although the scientific recommendation was for a mesh size of 120 mm. Another possibility would be a closed area regulation, which could be targeted either on areas supporting mainly juvenile cod or mainly adult cod. However, cod spawning areas are rather diffuse and are distributed over large areas of the North Sea. Closure of these areas during the spawning season would therefore cause a major disruption to the fisheries for several demersal species. Furthermore, because the spawning stock of cod is now so small, a closure of the spawning grounds is likely to be much less effective than measures which are designed to increase the survival of the immature fish, so that a greater proportion can recruit to the spawning stock.

Another consideration in managing the North Sea cod stock is the ecological interaction with other species. Cod is one of the most important predators in the North Sea and changes in its biomass will have consequences on the levels of natural mortality suffered by its prey, which includes several other commercially-important fish species as well as cod itself. A large biomass of cod is therefore probably undesirable and work currently being done should lead to a better understanding of the ecological consequences of management actions.

The primary concern in managing the cod stock at the present time must be to halt the upward trend in fishing mortality and to improve the exploitation pattern, so as to stop the decline in spawning biomass. If this is not done there is an increasing risk that recruitment will be reduced to a level which cannot support an economically viable fishery on the stock.

Another effect of the upward trend in fishing mortality is an increase in the proportion of the younger age groups in the catch. The increasing dependence on the recruiting fish, with their marked year-to-year variations in abundance, is reflected by annual fluctuations in catch rates and in total catches. A reduction in fishing mortality would result in a more stable fishery, with a greater spread of ages in the catch. However, the effect on the overall level of yield is less certain. With the current exploitation pattern, an average-sized year class of approximately 400 million cod at age 1 will yield about 200 000 tonnes during its lifetime as it passes through the fishery. Some population models that fishery biologists have worked with have suggested that reductions in fishing mortality would result in substantial increases in yield. However, these models have not included predation effects and recent preliminary work with models which do so, together with better data, suggest that changes in yield might be rather small, and that there might even be reduced yields.

Hence our current state of knowledge indicates that the benefits of a reduction in fishing mortality are greater stability in yields from year to year, and increased biomass which will be reflected by greater catch rates.

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