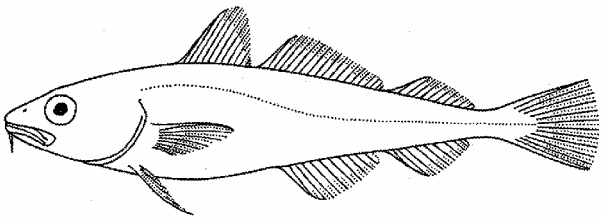
ICESCIEM

ICES-FishMap

Cod	*Gadus morhua* Family Gadidae	Max size: 150 cm Max age: 25 years



Introduction

***Taxonomy**:* Cod (*Gadus morhua* Linnaeus, 1758) belongs to the family of the Gadidae, the gadoids or cod-like fishes. The genus *Gadus* is represented by three species: Atlantic cod *Gadus morhua*, Pacific cod *Gadus macrocephalus* and Greenland cod *Gadus ogac*. Three subspecies of *Gadus morhua* are recognised: *Gadus morhua morhua* is the most common one, inhabiting both the western and eastern side of the Atlantic, *Gadus morhua callarias* is restricted to the Baltic Sea, and *Gadus morhua marisalba* occurs in the White Sea.

common names			
Danish	Torsk	*Icelandic*	Þorskur
Dutch	Kabeljauw	*Latvian*	Menca
English	Cod	*Norwegian*	Torsk
Estonian	Tursk	*Polish*	Dorsz
Faeroese	Toskur	*Portuguese*	Bacalhau
Finnish	Turska	*Russian*	Трескa
French	Morue	*Spanish*	Bacalao
German	Kabeljau, Dorsch	*Swedish*	Torsk

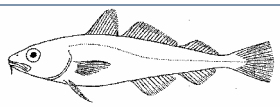
General: Since time immemorial, King Cod has been one of the most important commercial fish species of the North Atlantic, and a crucial factor for the economy and in the politics of Iceland, Norway, Spain and Newfoundland [1]. Originally fished by hook and line, cod is now mainly targeted by demersal trawl and gill nets, although it may be caught in virtually all demersal and pelagic fishing gears. Even when other species are the main target, a by-catch of cod is difficult to avoid.

The total international catch from the whole North Atlantic peaked at about 4 million tonnes in 1968. In recent years cod stocks have declined everywhere and catches have been reduced to less than 1 million tonnes. In Canadian waters a moratorium on the cod fishery was introduced in 1992, but this has not resulted in clear signs of a recovery since then. Also the North Sea stock has declined to a critically low level and a rebuilding plan has been agreed by the European Commission in 2004.

Minimum Landing Size: 35 cm in the North Sea and 30 cm in the Skagerrak/ Kattegat.

Distribution

Biogeographical information: Cod occurs throughout the boreal region of the North Atlantic: in the west from North-Carolina to Labrador, around Iceland and Greenland, and in the Northeast Atlantic from the Bay of Biscay up to Svalbard (Spitsbergen) and Novaya Zemlya. In the North Sea cod may be found from shallow coastal waters to the shelf edge (200 m depth) and even beyond. Catches have been reported from the deepest parts of the Norwegian Deeps at 500 m [2].

	Cod	*Gadus morhua* Family Gadidae	

Distribution in February: Sub-adult cod occur throughout the North Sea, Skagerrak and Kattegat (Fig. 1). Over the last 20 years the density in winter has on average been highest off the continental coast of the Netherlands and Germany, in a broad band from northeast England to southern Norway, and in Skagerrak and Kattegat.

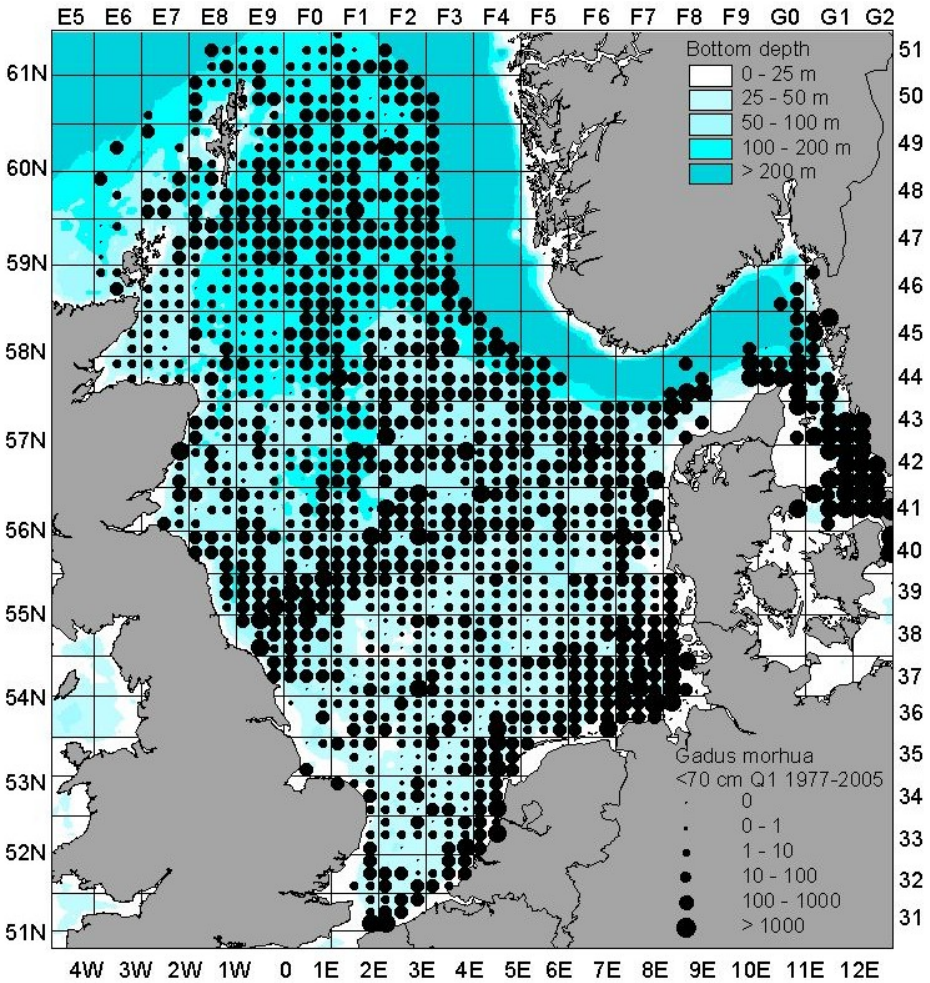
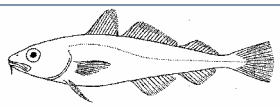


Figure 1. Average annual catch rate (number per hour fishing) for cod < 70 cm in the quarter 1 IBTS survey, 1977-2004.



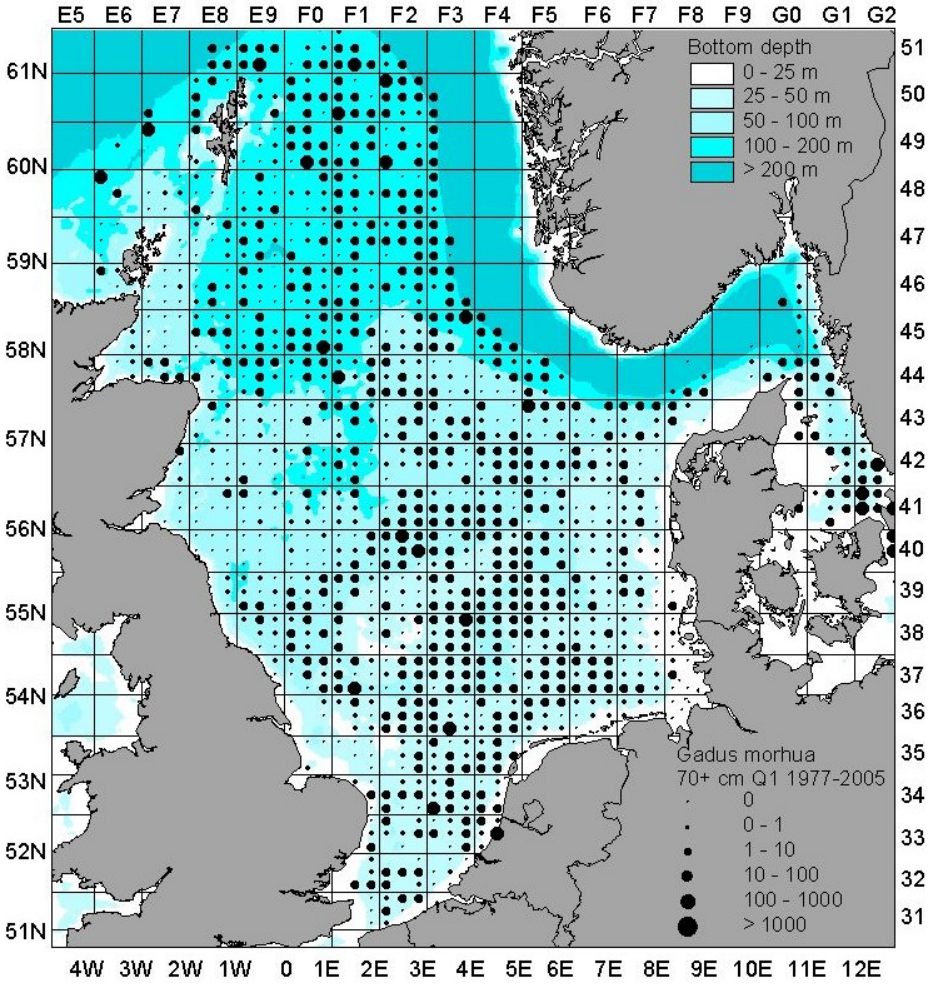


Figure 2. Average annual catch rate (number per hour fishing) for cod > 70 cm in the quarter 1 IBTS survey, 1977-2004.

Adult cod are caught in lesser quantities over large parts of the area (Fig. 2). Average densities are highest in the north, between Shetland and Norway, along the edge of the Norwegian Deep, in the Kattegat, around the Dogger Bank and in the Southern Bight.

Spawning: Spawning grounds appear to be wide-spread and not restricted to specific areas. In fact, spawning aggregations may be found offshore all over the North Sea. A comprehensive picture of the historic distribution of cod eggs over the entire North Sea does not exist, owing to difficulties in visually distinguishing between the eggs of cod and haddock. However, a recent survey in spring 2004 applying DNA-techniques for species identification [3] showed (Fig. 3) that the most important concentration was found in a limited area to the north-west of the Dogger Bank, whereas egg abundance at some locations in the southern North Sea was much lower than in earlier years [4].

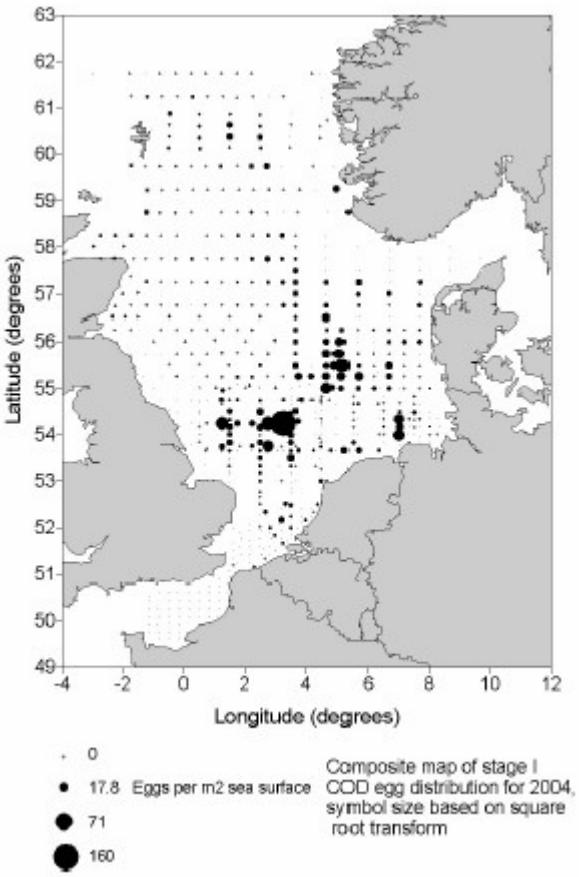


Figure 3. Distribution of stage I cod eggs in spring 2004 [3].

Spawning in the south peaks from the last week of January to mid-February, whereas in the northern part the highest concentrations of eggs may be found in April [5, 6, 7].

Distribution of 0-group: After metamorphosis, the juveniles spend a few more months away from the bottom as pelagic 0-group before adopting a demersal way of life. These 0-group are distributed over a large part of the central and northern North Sea (Fig. 4). High concentrations have been found off the coast of Jutland and in the central part of the northern North Sea during June – July [8]. However, this map may underestimate the importance of inshore waters of the continental coast, where a pelagic gear could not be operated, but where large numbers of 0-group have been reported in demersal gears [4].

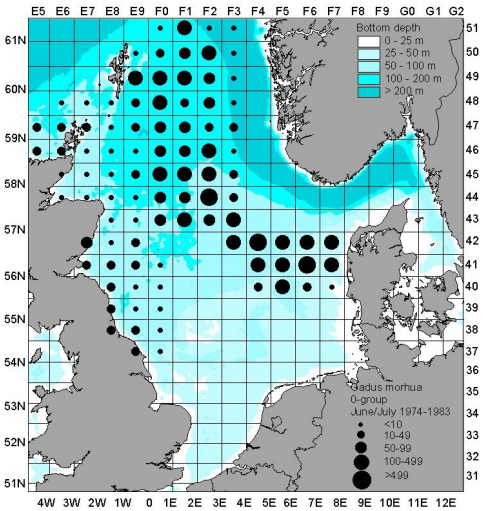


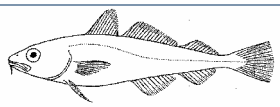
Figure 4. Pelagic O-group distribution in June-July, average number per hour, 1974-1983 [8].

Seasonal patterns: Figures 5 and 6 show the quarterly distribution for sub-adult (< 70 cm) and adult cod. Although an off-shore migration to deeper water has been described for 1- and 2-year-old cod [9] this is not obvious from these maps.

Also the distribution of adult cod does not seem to change much throughout the year (Fig. 6), although they seem to leave the warmer water of the Southern Bight during summer. The higher catches in quarter 1 may be caused by a higher catchability at this time of year, owing to changes in the behaviour of spawning cod.

Temporal changes: Over the last 20 years the distribution pattern of small cod has shown a significant change [10]. From 1985 to 1995, the highest abundance of 1-year-old cod was found along the south-eastern continental coast in the German and Southern Bights, off northeast England and in Skagerrak and Kattegat. Since then, the south-eastern North Sea has almost completely lost its importance as a nursery area (Fig. 7). In recent years, the highest abundances are found in Skagerrak and Kattegat, and north of the 50 m depth-contour between Flamborough Head and Jutland Bank.

Cod | *Gadus morhua* Family Gadidae



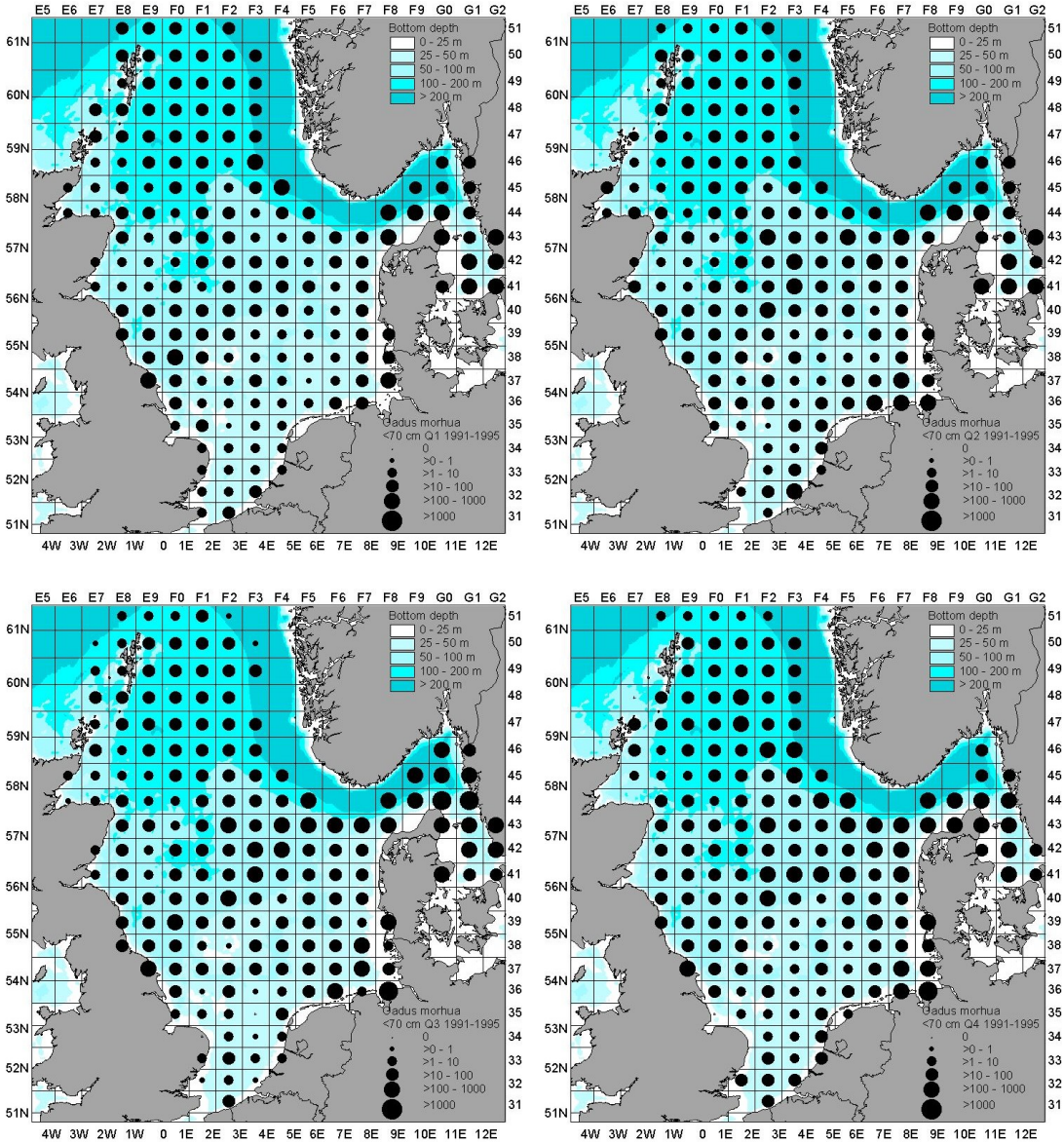
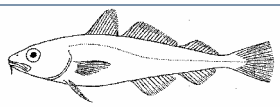


Figure 5. Quarterly IBTS 1991-1995 cod < 70cm

Cod

Gadus morhua
Family Gadidae



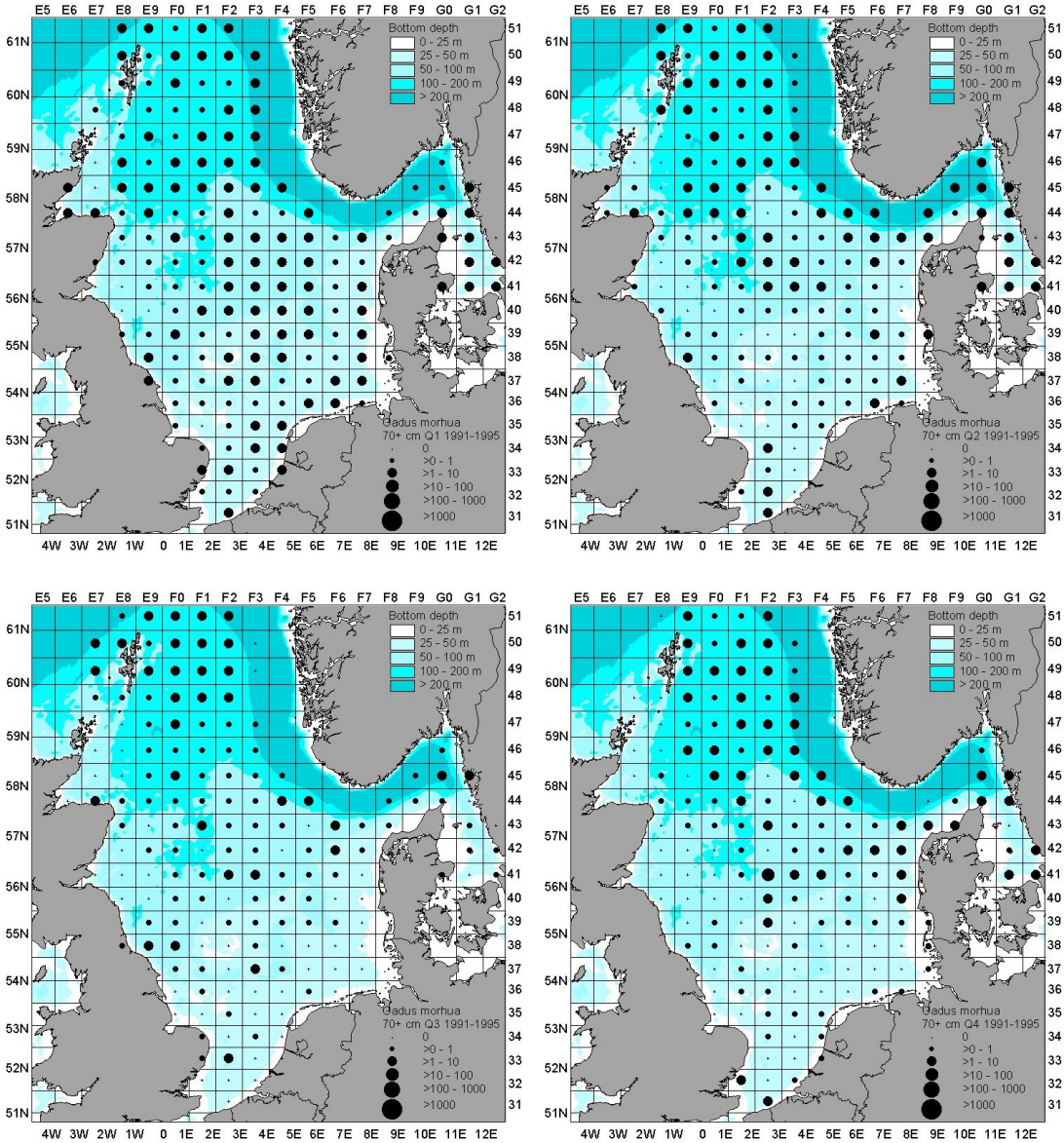
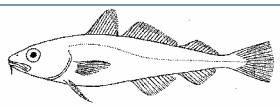


Figure 6. Quarterly IBTS 1991-1995 Cod >70cm.

Cod

Gadus morhua
Family Gadidae



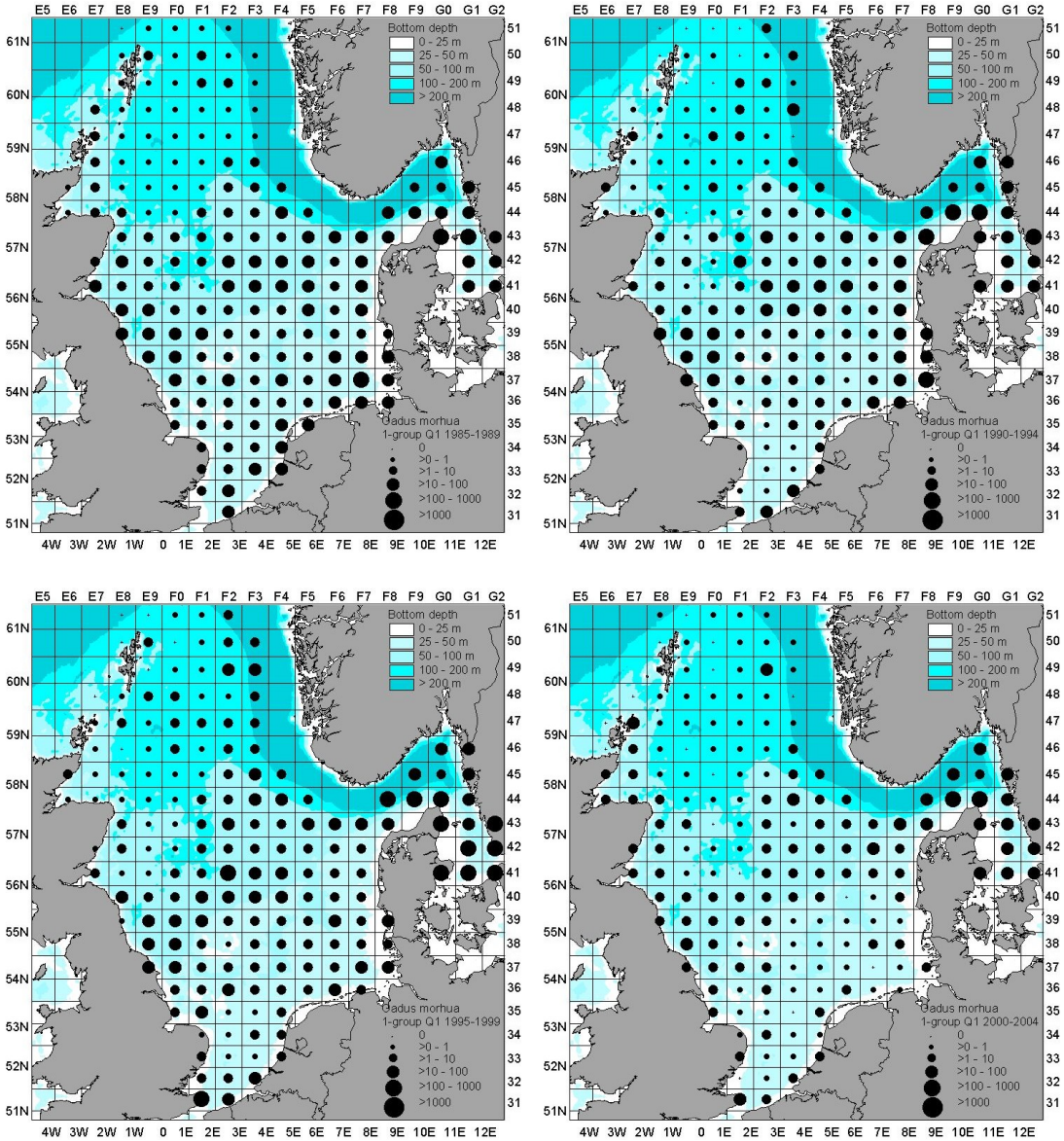
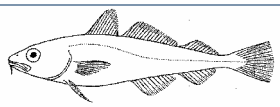


Figure 7. Temporal changes in distribution of 1-year-old cod. Q1 IBTS: 1985-1989, 1990-1994, 1995-1999 and 2000-2004. Data from the IBTS [2].

Life history

Habitat characteristics: After spending the first half-year of their life pelagically, first as eggs and larvae and then as metamorphosed juveniles, the 0-group adopt a demersal way of life in July/August at a size of approximately 7 cm. Demersal cod is found in a wide variety of habitats. Juveniles are often found in more shallow waters than the adults and therefore more exposed to variations in temperature. They are found at the highest water temperatures in summer and autumn and at the lowest temperatures in winter [11].



Age, growth rates: Growth rates differ by area. For example, average length of 2-year-old cod caught during IBTS surveys in the years 1970-1980 varied between 32 cm and 44 cm [12]. Cod in the southern North Sea initially grow somewhat faster than those in the north but they reach a smaller maximum length [13]. A recent growth curve is shown in Figure 8. During the adult phase, growth of males is somewhat retarded compared to females and the really big cod are often females.

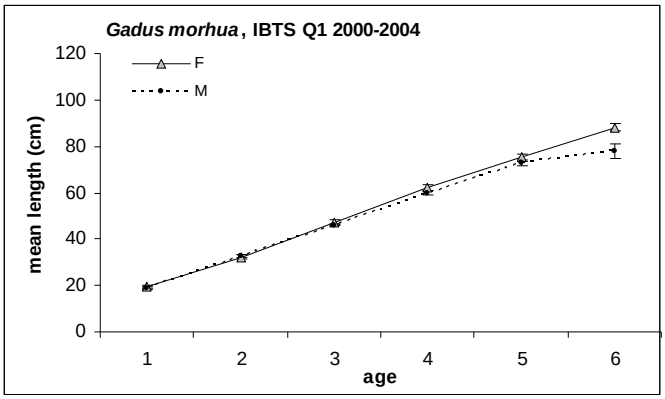


Figure 8. Mean length (cm) per age group. Data from the quarter 1 IBTS, 2000 – 2004.

Reproduction: Some cod mature in their second year of life, but it is not before they are six years old that they are all mature. Length at first maturity varies spatially and temporally. Males mature slightly earlier than females, and there is a tendency for cod in the southern North Sea to mature at a younger age than in the northern North Sea [14,15].

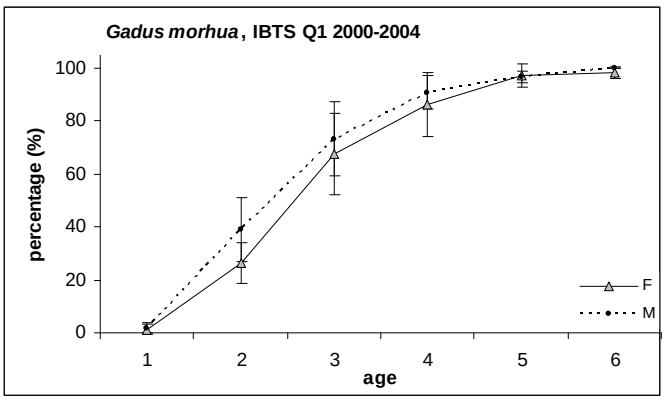
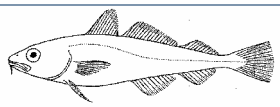


Figure 9. Percentage maturity per age group. Data from the quarter 1 IBTS, 2000 – 2004.



An average mature female carries around five hundred ripe eggs per gram body weight, which equals five million eggs for a 10 kg (100 cm) fish. Fecundity varies with time and place [14]. Egg size increases with age of the female and the chances of an egg to survive are greater for bigger eggs [16,17]. The high concentration of first-spawners to the spawning stock may have a negative effect on the survival rate of the eggs [17].

Spawning takes place anywhere in the water column [18]. Captive females shed the pelagic eggs in up to nineteen batches at intervals of about one to twelve days [19]. The eggs take ten to thirty days to hatch depending on temperature [20].

Migrations: Older cod do not disperse at random throughout the North Sea. Based on tagging studies, the average annual feeding and spawning movements are usually limited to distances between 20 and 120 nm, depending on tagging location [21,22]. Especially south of the Dogger Bank, cod migrate southwards for spawning during autumn and north again to their feeding grounds during spring.

When cod were still abundant in the south-eastern North Sea, a clear seasonal migration was observed in 1- and 2-group cod. The juveniles aggregated in the shallow coastal areas during the winter period and dispersed in a north-westerly direction over deeper parts of the central North Sea in summer [9]. In the Norwegian Deep seasonal migrations (up and down the slope) are likely to occur as well [2].

Food habits: Larvae of 2 – 8 mm in length, caught pelagically during February and March, feed principally on the nauplii and copepodite stages of copepods [23].

The 0-group continue to feed pelagically after metamorphosis but their diet changes as they grow larger. Specimens of 5 cm, collected in the northern North Sea during July, had already changed from a diet that consisted mainly of copepods and euphausiids to a diet that was dominated by fish [24].

From a length of 7 cm onwards, the juveniles become demersal, which is mirrored in their diet that is dominated by crustacean prey (e.g. *Crangon crangon*, crabs). Larger specimens feed predominantly on fish (Fig. 10), most of which are of commercial importance and include gadoids, sandeel, flatfish, and clupeids [25]. The size preference increases with predator length: cod seem to prefer fish prey that is approximately 20% of its own size in length or 2% in weight, even though incidentally fish of up to 70% of its own length have been found in stomachs.

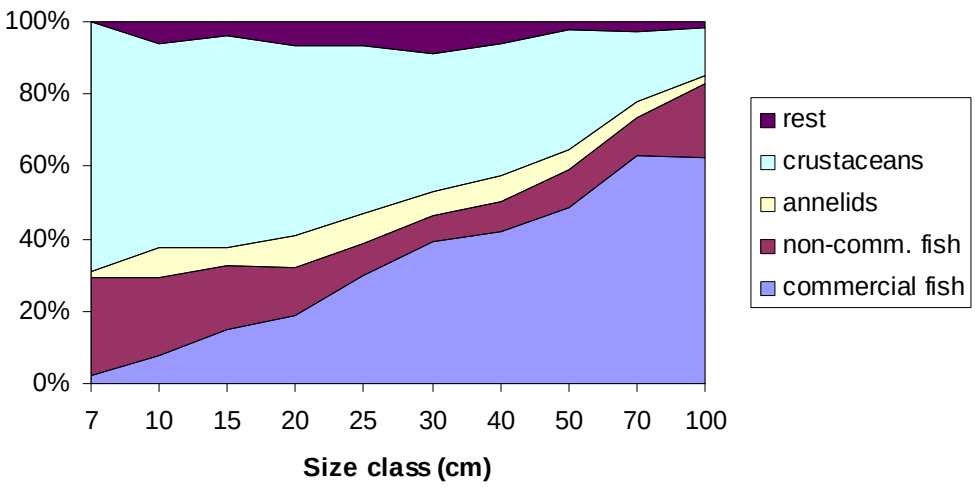
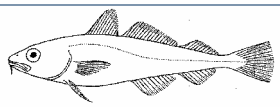


Figure 10. Average stomach contents as percentage weight by size class. Data from the Stomach Sampling Project in 1981 [25].



Predation: Due to its large maximum length of about 150 cm the cod is almost at the top of the food chain and therefore plays a crucial role in the ecosystem. Its food consists for a large part of other commercial fish species, including its own kind. Depending on its life stage, predators of cod, apart from man, will be other fish-eating species (from grey gurnard *Eutrigla gurnardus* to cod itself) and marine mammals such as grey seal *Halichoerus grypus*. Figure 11 shows the main predators for 0-group (during the second half of the year) and 1-group cod. The data result from a large-scale stomach sampling programme in 1991 [26]. There is a striking difference between the predation in both life-stages. During their first year the main predator is the grey gurnard, whereas the main cause of mortality during the 1-group stage is the fishery.

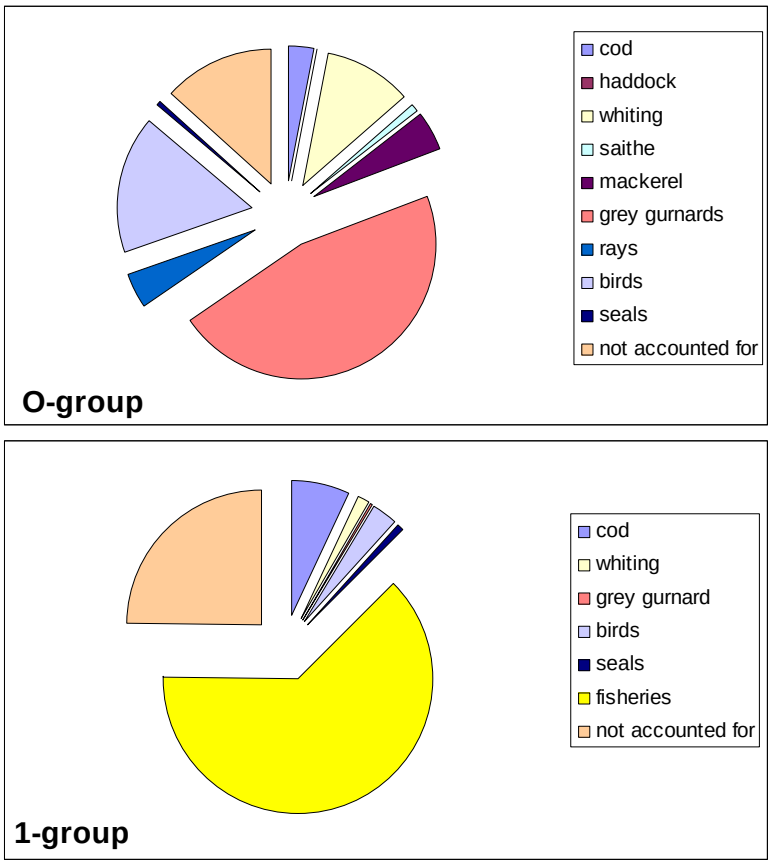
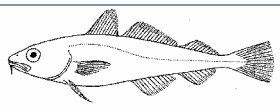


Figure 11. Main causes of mortality during the O-group and 1-group phase of cod in 1991. Data based on the 1991 Stomach Sampling Project [27]

Population structure

Age and length composition: The population in the North Sea is dominated by the 1- (10-25 cm) and 2-year-olds (20-40 cm). In Skagerrak/Kattegat, 1-group fish is most abundant. These days catches of cod older than 10 years have become rare, whereas such old specimens were regularly caught 25 to 30 years ago.

Length composition: Catches in the North Sea and in Skagerrak/Kattegat during winter consist mainly of the two youngest age classes (Fig. 12). In Skagerrak/Kattegat 1-group fish is most abundant.

	Cod	*Gadus morhua* Family Gadidae	

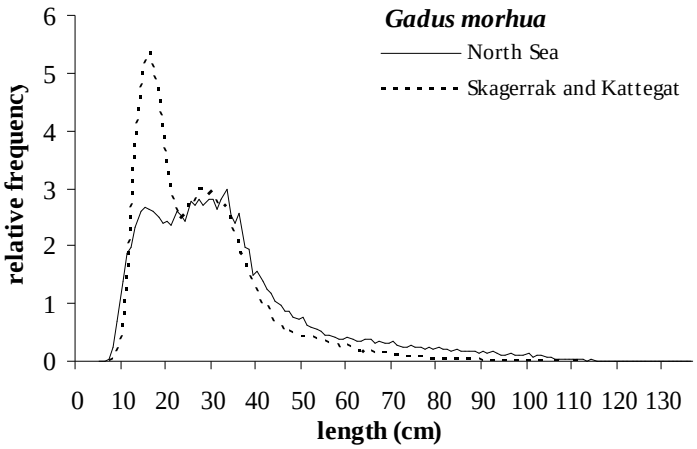


Figure 12. Length frequency distribution of cod in the North Sea and in Skagerrak/Kattegat. Data from the quarter 1 IBTS, 1985–2005.

Sex ratio: Males and females are caught in equal numbers. The biggest specimens are usually females.

Changes in abundance: From the late 1960s until the late 1980s several extremely strong year classes recruited to the stock. This succession of strong year classes caused a rapid increase in both biomass and landings in the 1960s. Similar patterns were observed in haddock, whiting and saithe and this event has therefore been called the *gadoid outburst*. The causes of this phenomenon are still obscure [28]. Some favour environmentally induced changes through changes in plankton stocks, while others link the gadoid outburst to the exploitation of the pelagic fish stocks

Stock structure: Microsatellite analysis, a sensitive genetic technique, has suggested that four genetically distinct populations may exist in the North Sea proper [29]: near Bergen Bank, in the Moray Firth, near Flamborough Head and in the Southern Bight. However, the continuous distribution maps suggest that these populations are not totally reproductively isolated.

Exploitation

Main metiers targeting the stock: The main fleets fishing for cod are those of the United Kingdom and Denmark. The main fishing gears used are otter-trawls and gill-nets, but cod is a by-catch species in almost all gears used in demersal and pelagic fisheries throughout the area. Because of changes in distribution of the cod stock and the decreased abundance, specialised fleets in some countries (e.g. the Netherlands and Germany) have severely declined over the past 10 years.

Landings: Yearly landings of North Sea cod[1] have fluctuated between 50 000 and 100 000 t during the first sixty years of the last century. After this period, landings increased to a maximum of 354 000 t in 1972. In 1981 still 336 000 t was landed, but landings have steadily decreased since then to 28 200 t in 2004. These were the lowest landings since the collection of the international catch statistics started in 1903, with the exception of the period 1939-1945 [30]. Recently, also the amount of discards in the fisheries has been estimated. Total catches (landings + discards) peaked in 1980 with 590 000 t. Fluctuations in the amount of discards are mainly caused by fluctuations in the size of the recruiting year classes.

1 The assessments of North Sea cod by ICES consider an area that slightly differs from the area in the distribution maps: the eastern Channel is included in the assessments, the Kattegat is excluded.

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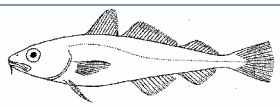
Cod	*Gadus morhua* Family Gadidae	

Spawning stock biomass and fishing mortality: The spawning stock biomass shows a similar trend as the landings: a steady increase from 1963 until 1970 followed by a decline to around 35 500 t at the beginning of 2001, well below the limit reference point for the biomass (B_{lim}) of 70 000 t. The EU and Norway have agreed that immediate action should be taken once the amount of mature cod is below B_{lim}.

For almost 30 years 50 to more than 60% of all 2 to 4-year-old cod have been caught annually. This is above the limit reference point for fishing mortality (F_{lim}) of 53% per year.

The decline of the spawning stock biomass since 1981 is directly linked to the increase in fishing mortality (Fig. 13).

Recruitment: In the period 1963 to 2005 recruitment of cod at age 1 fluctuated between 1 and 25 million per year (Fig. 13). Recent year classes have all been weak. The decline in recruitment over the past ten years may not only be caused by the decline of the spawning stock but also by higher mean sea temperatures during the first half of the year [31].

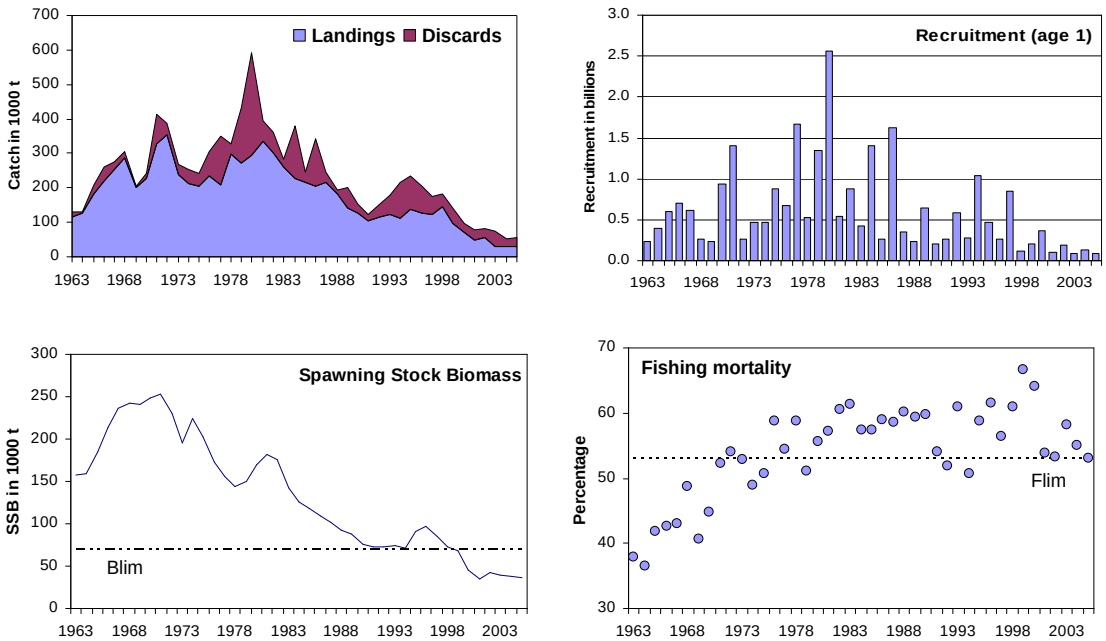
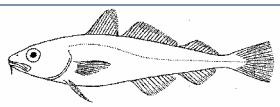


Figure 13. Time series of landings, discards and spawning stock biomass (in 1000 t), recruitment (in billions of 1-year-old fish) and fishing mortality (percentage per year of ages 2-4) [30].

Stock status: The North Sea cod stock is considered to have a reduced reproductive capacity and exploitation is unsustainable.

Protection and management: The cod fishery has been managed by TAC's and quota since 1975, but this type of management has not been effective in maintaining or creating a sustainable level of exploitation. Some years ago the EU and Norway have agreed to restrict fishing in order to bring the spawning stock size back to above 150 000 t. Because of the poor state of the spawning stock, a large part of the North Sea was temporarily closed for most demersal fisheries during part of the spawning season in 2001. This closure, however, has had no measurable positive effect on the size of the spawning stock. Since 2003 ICES recommends that the fisheries for cod be closed until an initial recovery of the cod SSB has been proven.

	Cod	*Gadus morhua* Family Gadidae	

From 2005 onwards, a recovery plan is in operation, which aims to restore the spawning stock size of at least 150 000 t. The plan consists of a number of technical measures. The minimum mesh size for vessels fishing for cod has been increased to 120 mm, and the gear must be equipped with so-called escape panels for small fish. At the same time, the number of days that vessels are allowed to fish will be limited for each segment of the fleet. Only TAC's will be agreed that are likely to result in a gradual increase of the spawning stock size, although only relatively small changes in TAC in successive years will be accepted. It is doubtful whether these goals can be reached with the agreed set of measures, because a large part of the total catch is taken as a by-catch of fisheries targeting other species that are allowed to continue fishing with smaller meshes and without effort restrictions.

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