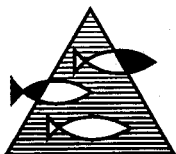# PROSJEKTRAPPORT

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Rapport:	
FISKEN OG HAVET	NR. 15 - 1996
Tittel:	Senter: Marint miljø og Marine ressurser
LING, BLUE LING AND TUSK OF THE NORTH-EAST ATLANTIC	Seksjon: Flødevigen
Forfatter(e):	Antall sider, vedlegg inkl.: 126
Odd Aksel Bergstad, Havforskningsinstituttet og Nils Roar Hareide, Møreforskning (Editors)	Dato: 27.06.1996

Sammendrag:

Linefisket etter lange og brosme har lange tradisjoner i Norge. Blålange har alltid vært tatt som bifangst i fisket på Eggakanten, men for rundt 15 år siden startet et direkte garnfiske etter denne arten på dypt vann. De sener år har disse artene gitt 5-10% av førstehåndsverdien i norske landinger. Denne rapporten gir en oversikt over fisket og bestandsbiologien til disse tre artene med spesiell vekt på ting som er relevante for framtidige bestandsberegninger basert på resultat fra norske undersøkelser fra 1993-95 og relevant litteratur.

Lange, brosme og blålange fiskes av den havgående autolineflåten i områdene vest og nord av de Britiske øyer, i Nordsjøen og ved Færøyane og Island. Dessuten av line- og garnbåter av forskjellig størrelse i hjemlige farvann langs Eggakanten.

English summary on page 4.

Emneord - norsk:	Emneord - engelsk:
1. Lange, blålange, brosme	1. Ling, blue ling, tusk
2. Biologi	2. Biology
3. Bestandsvurdering	3. Assessment

Prosjektleder

Seksjonsleder

SUMMARY

The longline fisheries for ling (*Molva molva*) and tusk (*Brosme brosme*) have long traditions in Norway. Blue ling (*Molva dipterygia*) was always a by-catch in Norwegian slope waters but about 15 years ago this species became the target of a deep-water gill-net fishery. In recent years 5-10% of the firsthand value of Norwegian landings was attributed to these species. This report provides an overview of the fisheries and population biology of the three species, with emphasis on aspects of relevance to future stock assessments, based on results from Norwegian investigations in 1993-95 and literature reviews.

The Norwegian fleets which target ling, tusk and blue ling are the high-seas autoline vessels which operate in waters to the west and north of the British Isles, in the North Sea and at the Faroes and Iceland, and longline and gill-net vessels of various sizes fishing in home waters along the Norwegian slope. Exploitation occurs in all parts of the distribution area of the species.

It is still unclear whether separate stocks occur in different sub-areas. Spawning areas are wide-spread, also the distribution of eggs and larvae. Very little is known about migrations. The age and size structure of the catches in various fishing areas show only minor variation. New studies by electrophoresis of tissue enzymes and hemoglobins indicate that tusk from all areas sampled in the northeastern Atlantic belong to the same gene pool, wheras the results for ling and blue ling are inconclusive.

Estimates of mortality show that exploitation rates are high, and catch per unit of effort (CPUE) analyses of ling and tusk based on both private and official logbooks from the longliners indicate a considerable decline in the population sizes since the 1970s. The catch per unit of effort may have declined by about 70%. Strategies and requirements for future monitoring by improved CPUE measures and age-based assessement models are discussed.

TABLE OF CONTENTS

PREFACE

In 1993, the Institute of Marine Research (IMR) initiated a 3-year collaborative project on ling (*Molva molva*), blue ling (*Molva dipterygia*) and tusk (*Brosme brosme)*. Collaborating partners were the Møre Research (Møreforsking) and the Department of Fisheries and Marine Biology (IFM) of the University of Bergen. The project was supported financially by the Norwegian Research Council through 1995 and the Nordic Council through 1996. This is the final report to the Norwegian Research Council, emphasising scientific aspects and results. The report is deliberately comprehensive, and includes, in addition to original project results, descriptions of fisheries, technology, and literature data on biology of the three species.

The different partners wrote separate or collaborative contributions to the report which were edited and assembled by Odd Aksel Bergstad and Nils-Roar Hareide:

Introduction	IMR (Bergstad, Nedreaas), Møre Research (Hareide)
The species	IMR (Bergstad)
The Fisheries	Møre Research (Hareide)
Strategy and methodology	IMR (Bergstad, Godø, Klungsøyr), Møre Research (Hareide), IFM (Nævdal)
Biology	
Eggs and larvae	IMR (Bergstad)
Ageing	IMR (Bergstad)
Growth	Møre Research (Hareide), IMR (Bergstad)
Maturation	Møre Research (Hareide)
Age and size distr.	Møre Research (Hareide), IMR (Bergstad)
Population structure	IFM (Nævdal)
Occurrence of contaminants	IMR (Klungsøyr, Bergstad)
Population changes in time	IMR (Godø), Møre Research (Hareide)
Assessment and man. strat.	IMR (Bergstad, Godø), Møre Research (Hareide)
Future research	IMR (Bergstad, Godø), Møre Research (Hareide)

The report focuses primarily on results of the Norwegian efforts, but includes also some information gained through the collaboration with the fisheries institutes in the Faroes and Iceland. The Nordic project continues in 1996, and a final Nordic Council report will be finished at the beginning of 1997.

1. INTRODUCTION

1.1 Background and goals

The rather limited documented knowledge on the biology and ecology of ling, blue ling and tusk and the recognised need for an improved basis of assessments and monitoring motivated this project. The project had the following goal:

"To provide an overview of biology, growth, maturation, spawning areas, stocks and migrations of ling, blue ling and tusk in the northeastern Atlantic, the North Sea and Skagerrak and thereby provide a basis of biological assessments of the species. An additional task was to analyse contents and geographical distribution of organic contaminants (such as PCB) based on samples of muscle and liver tissue."

The fisheries for ling and tusk have long traditions in Norway, and about 15 years ago blue ling, which was traditionally a by-catch, became the target of a deep-water gillnet fishery along the Norwegian continental slope. In recent years 5-10% of the firsthand value of Norwegian landings was attributed to these three species. Norwegian fisheries include longlining and gill-netting in home waters and high-seas autoline fisheries in waters to the west and north of the British Isles, at the Faroes and Iceland, and in the North Sea and the Barents Sea. No Total Allowable Catch (TAC) has been limiting the fisheries, and in recent years concern has been expressed by the industry, managers and scientists over the state of the stocks and the prospects for the future.

Knowledge of the population biology, stock structure and stock size changes in response to exploitation has been very limited. This was also recognised by the International Council for the Exploration of the Sea (ICES) which since 1986 has made efforts to assess the state of the stock of ling, blue ling and tusk. The results have been less than satisfactory. Iceland and the Faroes also exploit these species, and the three countries together contribute about 90% of the total annual north Atlantic landings of tusk and 50 % of the landings of ling and blue ling (ICES Bulletin Statistique).

In 1992, Iceland, the Faroes and Norway, in view of the lack of basic information, agreed to initiate a project which should provide improved knowledge of the biology of the different species, and focus specifically on population genetics and long-term changes in abundance. The Norwegian sub-project started in 1993 and the Nordic project somewhat delayed in 1994.

Some scattered earlier research formed the foundation of the project. Early data on the occurrence of eggs and larvae (Schmidt 1909) showed the widespread spawning of the species, and pioneer studies of size composition, growth and distribution by Molander (1956) and Joenoes (1961) provided the first insight into their biology and ecology in northeast

Atlantic waters. More recent studies and monitoring have supplemented these early studies (Thomas 1980; Magnusson 1978, 1979, 1980, 1981,1982, 1983; Engås 1983; Moguedet 1985, 1989; Grotnes and Hareide 1989 a,b). Some of these provided time-series of length measurements and abundance in routine surveys. Others presented new information on biology but many results were of limited value because of methodological inconsistencies (e.g. ageing methods). No countries have kept continuous records of other than landings and length data of the more or less incidental catches in trawl surveys for other species. Norway has recorded effort in the longline fisheries, but so far only limited attempts were made to analyse trends in catch per unit of effort (CPUE) based on these data (Grotnes and Hareide 1989).

1.2 Organisation

The goal of the project was ambitious and optimistic and was approached from different angles and through various forms of collaboration. Contracts were signed between the Institute of Marine Research (which held the Norwegian Research Council contract) and Møre Research (MF) and the University of Bergen, Department of Fisheries and Marine Biology (IFM). MF should undertake most of the ship-board and market sampling, analyse these samples and continue the analyses of skipper's log-book information on catch and effort. IFM should carry out enzyme electrophoretic studies of population structure based on tissue and blood samples from various parts of the species' range. Other project objectives were to be adressed by various departments of the Institute of Marine Research, including the Flødevigen Marine Research Station which should focus specifically on ageing methods and the Skagerrak.

Coordinators of the project were Kjell H. Nedreaas (until March 1994) and Odd Aksel Bergstad of the Institute of Marine Research.

1.3 Plans and progress

The project plans were discussed during the writing of the proposals to the funding agencies and upon receipt of the Norwegian Research Council grant in January 1993. A strategy meeting was held in Bergen 9-10 March 1993 at which more detailed progress plans were implemented. Tasks were then distributed among the collaborating partners. Also important was a planning meeting of the Nordic project in Reykjavik, Iceland 1-2 December 1993.

The progress plans were revised at various stages of the project, especially in 1995 when unforeseen circumstances (see project report 1995) prevented the project from carrying out rather ambitious field sampling onboard commercial vessels. In some areas, especially the Skagerrak, the data supply was limited by low fishing activity. An experimental longline

fishery planned for 1993 in collaboration with the local fisheries authorities and Danish and Swedish partners was cancelled due to lack of funding.

Also, the problem of developing ageing methods has been much more difficult to solve than expected. The Nordic project has agreed on a common interpretation of ling otoliths, and recently significant progress was made with tusk otoliths. The ageing of blue ling is still unresolved and this prevented the project from pursuing this species to the extent planned. Since consistent age readings underly many other analyses (growth, age-distributions, age at maturity, age-based assessments), the lack of good ageing methods has significantly limited the progress of many activities in the project.

Despite the above problems, many aspects were studied satisfactorily and significant new information was gained on e.g. general biology of ling and tusk, on the analyses of catch per unit of effort based on private and official log-books, on population genetics, and on the occurrence of contaminants.

2. THE SPECIES: TAXONOMY AND DISTRIBUTIONS

Ling *Molva molva* (L., 1758), blue ling *Molva dipterygia* (Pennant, 1784), and tusk *Brosme brosme* (Ascanius, 1772) belong to the family Gadidae, i.e. codfishes, but are placed in the subfamily Lotinae which comprises generally elongated slender gadids with 1-2 dorsal fins and and 1 anal fin. Another characteristic is that the pelvic fins in larvae consist of 3 rays and are greatly elongated (Svetovidov 1986). All three species are primarily distributed in the warmer parts of the northeastern Atlantic and in relatively deep waters. The juvenile ling grow up in shallow water, however (Molander 1956), but as adults all three species are most abundant along the outer shelf or upper continental slope (e.g. Joenoes 1961; Svetovidov 1986).

Ling and blue ling are members of the same genus *Molva* characterised by their two dorsal fins of which the second is elongated. Other anatomical and morphological details are given by Svetovidov (1986). The two species look similar, but the blue ling has a big eye and lower jaw which projects beyond the upper jaw. The opposite is the case for ling. The big mouth and lower jaw canine teeth are adaptations for feeding on large mobile prey, mostly fish (Andriyashev 1954; Nagabushanam 1965; Koch and Lambert 1976; Macpherson 1981; Rae and Shelton 1982; Engås 1983; Mauchline and Gordon 1984; Svetovidov 1986; Thomas 1987; Bergstad 1991). The distribution of the two species overlap, but blue ling is more southerly and occurs south of the Bay of Biscay to northern Africa and in the Mediterranean where ling is rare. Both are rare in the northwestern Atlantic, but widespread in the entire southern Norwegian sea (including Icelandic shelf waters) and northwards to the soutwestern Barents Sea (see Svetovidov 1986).

The tusk belongs to the genus *Brosme* and has only one dorsal fin (which is separate from the caudal) and a single chin barbel (Svetovidov 1986). The tusk is not as elongated as the lings and appears scale-less due to the small scales being deeply embedded in the skin. It is regarded as a benthic species which prefers rocky bottom. The diet seems to be fish and crustaceans, perhaps predominantly the latter (Langton and Bowman 1980; Rae and Shelton 1982; Svetovidov 1986; Bergstad 1991).

The tusk has a more northerly distribution than the ling and blue ling and appears to prefer cooler waters. It is also common in the northwest Atlantic. In the northeastern Atlantic, the range extends from southern Ireland to Svalbard and the Kola peninsula, and it is abundant around Iceland (Svetovidov 1986)

3. THE FISHERIES

3.1 History

3.1.1 Norwegian Fisheries

Ling and tusk rank among the most important species exploited by Norwegian fisheries. In 1994 the first-hand value of the landings was 327 mill. NOK (Anon 1995). Ling and tusk are mainly caught by longline, in addition a gillnet fishery is conducted in the period May-September on the shelf-break primarily off the district Møre and Romsdal. This started as a blue ling fishery in the early 1980s.

The deep-sea longline fishery
In 1994, 52 vessels longer than 80 feet were engaged in this fishery for approx. 6 months. The fishery takes place along the continental shelf off Norway, off the Shetlands, the Hebrides, Ireland, the Faroes, and on the Rockall bank (Fig. 3.1).

History. The Norwegian offshore fishery for ling and tusk started in the 16th century in the upper continental slope area called Storegga off Møre (Strøm 1762). At that time the fishery was mainly conducted during the summer. The fishermen sailed in open boats as far as 30-60 nautical miles offshore. The fishery was risky, and many severe accidents with loss of lives occurred. Droplines as well as longlines were used, at depths between 150 and 400 m. A trip lasted for 3-5 days and each vessel made 10-12 trips during the summer months. Total landings of ling varied between 210 and 260 tonnes ungutted fish a year. Total landings of tusk and blue ling are not known (Moltu 1932).

In 1861 Swedish fishermen started a longline fishery in the Storegga. They used smacks outfitted for offshore fishing, and they had experience from fishing in the Skagerrak. The fishery at Storegga was very successful and expanded fast. In 1862, 13 Swedish and two similar Norwegian vessels were involved in the fishery. In 1863 about 20 Norwegian smacks were fishing in the area.

Around 1900 steamboats became more common. The steamers could expand the longline fishery into more remote areas such as Tampen, the Shetlands and the Faroe Islands. It is known that the steamer "Sverre" in 1902 was longlining at the Faroe Bank. The target species on unexploited banks was often Atlantic halibut, however, the catch rates of this species often declined rapidly, and ling and tusk became the target species. The landings of ling, tusk and blue ling increased as a result of the introduction of steam vessels (Fig 3.2).

Figure 3.1 The ICES Fishing Areas and the most important fishing grounds of the Norwegian fisheries for ling and tusk (shaded areas).
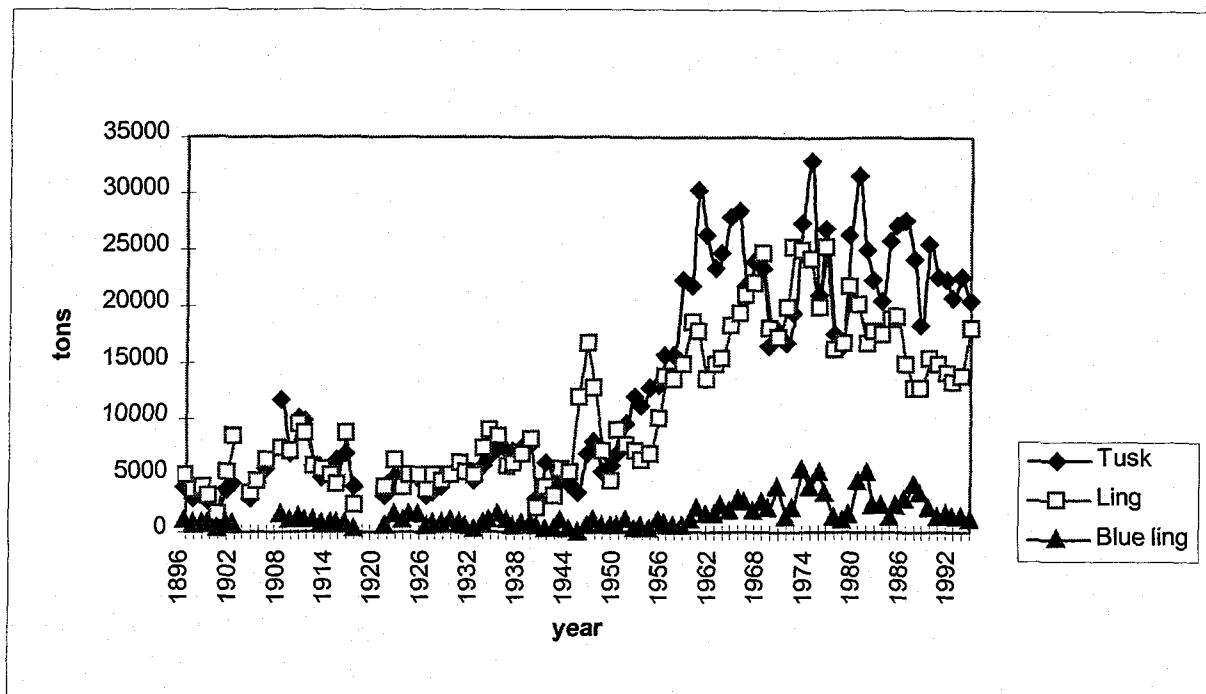
Figure 3.2. Total Norwegian catch of ling, tusk and blue ling, 1896 to 1994.

During the first years all the work was done manually on the steamboats. The longlines were set and hauled from dorries. Further expansion of the fishery to even more remote areas was inhibited by the lack of possibilities to preserve fresh bait for more than two weeks. The First World War interrupted the fishery in remote waters, but thereafter bigger vessels made it possible to land bigger catches. Still the trips did lasted no more than about two weeks because of the problems with storing the bait. The economic crisis in the first part of the1920s caused bankruptcy for several vessel owners, and the number of vessels in the fishery dropped. However, during the twenties a special group of 50-60 feet motor vessels specialised on a fishery for ling and tusk, with Atlantic halibut as an important by-catch. This fleet developed a fishery that remained almost unchanged for the next 50 years.

During World War II the fishery in remote areas and on the slope off Norway was impossible. After the war the fishery expanded again because of high fish prices and presumably accumulated stocks. The vessels built in the first years after the war were 60-90 feet, and fished on the same banks as before and also the banks west of Ireland and around Rockall.

During the 1950s a major increase in landings occurred. The total landings increased from about 10,000 tons in 1950 to about 40,000 tons in 1960. This increase was partly a result of technical improvements (described in Chapter 3.2). However one of the main reasons was the reduction in the stocks of cod during the 1950s (Fig. 3.3). A considerable effort was transferred from cod fishing to the ling, tusk and blue ling. Since that

time there has been an interplay between the two fisheries, and reduction in cod landings generally coincides with an increase in landings of ling and tusk and vice versa.

In the 1960s a few new vessels were built, mainly steelboats bigger than 100 feet. In the second part of the 1970s, however, 15 new 100-120 feet vessels were built. Some of them equipped with the autoline system. This boom ended in the first part of the 1980s. The stock of Atlantic cod was declining, and at the same time a drop in prices of ling and tusk occurred. During this decade most of the longliners installed the autoline system, primarily because of reduced catch rates in the ling and tusk fishery.

The prices of ling and tusk increased again, and reached a historical high level in 1986. At the same time the strong 1983 year class of Northeast Arctic cod led to expectations of higher cod quotas and a new boom of building new longliners occurred. Fifteen new vessels were built in the years 1984 -1986. These vessels were 115-150 feet long and could carry 150-250 metric tonnes of fish. The vessels were all equipped with the autoline system and the catch could be frozen onboard. The trip duration increased to 6 weeks. In 1989 the reduced production in the cod stock caused a reduction in the cod quotas. The longline fishery thereby became far less profitable. The fleet was in the period 1988 to 1994 reduced from 65 to 52 vessels (23 %). During the 1980s cod became a more important target species and the effort for this species was equal to or surpassed (in 1988) the ling and tusk effort (Table 3. 1).

Table 3.1 The effort of Norwegian longliners and gillnetters by gear, fishing area (ICES area in parantheses) and target species (Source: The Norwegian Directorate of Fisheries).

YEAR	1974	1976	1978	1980	1982	1984	1986	1988	1990	1992	1994	1995
Number of vessels:	103	95	93	83	74	72	72	65	60	53	52	56
Total number of weeks: (Longline+Gillnet)	4049	3812	3747	3428	3144	3185	3067	2875	2722	2448	2366	
Longline effort (thousands of hooks)	238095	235294	381356	326667	292857	445313	357143	406667	438462	424528	531915	572831
GEAR: Autoline				1 %	58 %	71 %	81 %	94 %	93 %	95 %	93 %	
Handbaited line	86 %	83 %	84 %	88 %	32 %	21 %	14 %	1 %	4 %	2 %	4 %	
Gilnet	12 %	14 %	14 %	11 %	10 %	8 %	5 %	5 %	3 %	3 %		
PERCENT EFFORT BY FISHING AREAS:												
Shetland/Orkney/Faroes/Hebrides/Rockall	61 %	64 %	53 %	62 %	61 %	48 %	56 %	47 %	55 %	39 %	40 %	
Norwegian coastal banks 62°-69° N (IIA)	18 %	24 %	22 %	13 %	5 %	6 %	7 %	?	8 %	11 %	4 %	
Skagerrak/North Sea (IIIa+IVa)	15 %	8 %	11 %	12 %	9 %	15 %	4 %	?	6 %	11 %	5 %	
Barents sea and Northern Norway (IIa)				5 %	11 %	9 %	24 %	41 %	13 %	27 %	38 %	
Greenland (XIVb)											4 %	4 %
PERCENT EFFORT BY TARGET SPECIES:												
Ling & Tusk	63 %	68 %	59 %	75 %	70 %	64 %	63 %	45 %	65 %	53 %	47 %	
Cod & Haddock	6 %		18 %	10 %	19 %	28 %	31 %	49 %	30 %	44 %	47 %	
Saithe	11 %	11 %	8 %	10 %	10 %	6 %	3 %	3 %	3 %			
Dogfish	16 %	13 %	14 %	3 %						2 %		
Greenland Halibut											3 %	

The gillnet fishery

In 1979 a deep-water gillnet fishery started off Møre and Romsdal. In the first years blue ling was the target species, but more recently ling has become the main species. In 1980 approx.

10-15 vessels were involved in this fishery. The catch rates the first two years were about 30 tonnes headed and gutted fish a week. No exact statistic are available for effort and number
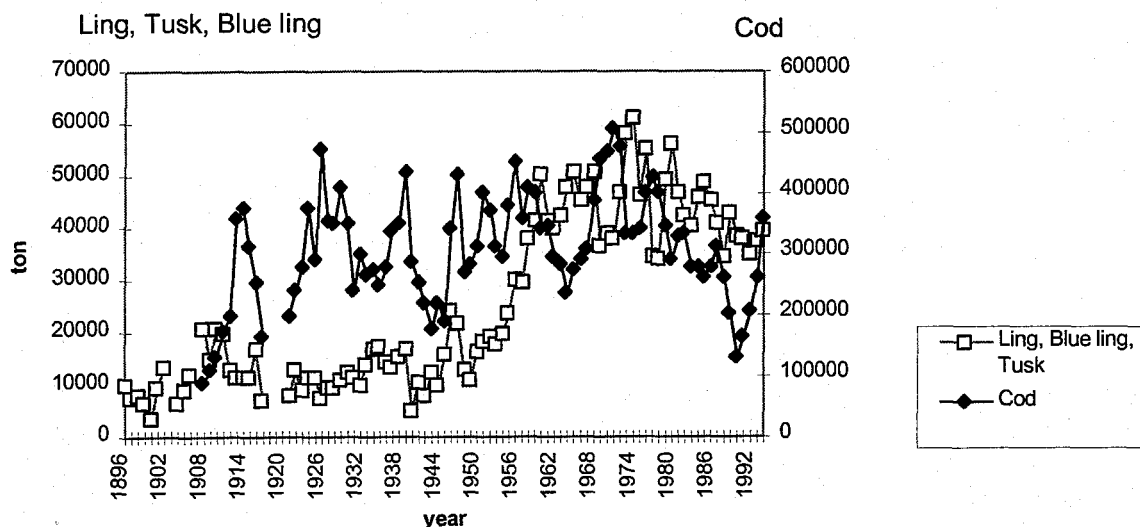

Figure 3.3 Norwegian landings of ling, tusk and blue ling combined, compared with total Norwegian landings of cod 1896 - 1994.

vessels in the fishery, but the number of vessels increased through the 1980s. Brandal (1989) found that 53 vessels were gillnetting in this area during the summer months. Most of the gillnetters came from the Møre and Romsdal District (Table 3.2). The main fishing area is the upper continental slope between 63° and 64° N. The depth fished for ling is between 150 to 400 m, whereas the blue ling is caught at greater depths (400-650 m). Because of low catch rates of blue ling the fishery is now almost entirely directed towards ling.

Table 3.2. Number of vessels, by home district, which took part in the upper slope gillnet fishery for ling and blue ling in the mid 1980s. (Brandal 1989).

District	Number of vessels
Hordaland	1
Sogn og fjordane	2
Møre og Romsdal	47
Nord Trøndelag	1
Nordland	1
Troms	1

3.1.2 Ling, blue ling and tusk fisheries in other countries

The pioneer Swedish longline fishery for ling before and after the Second World War was described by Molander (1948, 1956). This was a summer fishery, and the main grounds were the Norwegian Trench, the Shetlands and Orkneys and the Hebrides. This fishery is nowadays of minor importance.

The French have traditionally conducted a trawl fishery for saithe *Pollachius virens*, cod *Gadus morhua*, haddock *Melanogrammus aeglefinus* and ling along the the upper part of the continental slope from west of the Shetlands, and west of the British Isles. Occasionally they have extended their fisheries down the slope to exploit spawning concentrations of blue ling (Gordon and Hunter 1994). In the years after 1989 the declining catch rates of the traditional species caused a shift in target species toward deep-water species such as black scabbard *Aphanopus carbo*, roundnose grenadier *Coryphaenoides rupestris* and orange roughly *Hoplostethus atlanticus*. This has caused reduced French effort on ling and increased effort on blue ling since 1989.

Until 1989 when a targeted longline fishery for tusk was started, the Icelandic landings of ling and tusk were almost exclusively by-catches in other fisheries. The effort increased greatly and the landings rose from 3,000 tonnes in 1989 to 6,400 tonnes in 1992 (Magnusson 1994 a). The by-catches of ling taken by different fleets used to be rather stable. In 1993, however, the catch taken by longline decreased from 36 to 25% of the total catch. The catch by gillnet increased from 25% to 39% of the total catch, while the proportion taken by bottom trawl remained rather stable (27-28%) (Magnusson 1994b)

3.2 Technological developments in Norwegian longlining

3.2.1 Gear handling

Until 1903, when the first longline winch was introduced, all handling of longlines was done by hand. The winch was operated manually but made the hauling easier and safer. Soon the winches became powered by steam. In 1938 the first hydraulic winch was introduced, and this was one of the main steps in the development of present longline technology. The hydraulic winches were precise and powerful and were operated by the man who took the fish off the lines, and the lines could be hauled faster. The development of an automatic coiler was the next step which was reached by the end of the 1950s. In the early 1960s this became common on all vessels in the Norwegian fleet.

The longlines were hand-baited into troughs and set by hand until about 1930. At that time it became common to use barrels instead of troughs and the line was set by a "sjølvkastar." This made it possible to set and haul far more lines a day than earlier. Until

16

1928 the lines were baited outdoors. The introduction of a shed beside the caising for working with the baiting made it possible to work in rougher weather than previously. As floats, wooden caskets were replaced by buoys made of leather which were easier to handle. An automatic system for taking the fish off the hooks was developed in the late 1960s and became common on most vessels in the first years of the 1970s. This made it possible to haul the line continuously because there was no need to stop hauling to take off fish.

The first system for precise automatic baiting was introduced in 1971, i.e. the Mustad Autoline system. The breakthrough for this system came in 1976-1977. Already in 1980 about 2/3 of the fleet used this system. The main benefit was that fewer men was required for hauling and baiting the lines, and fishing could go on day and night. The effort per day increased substantially.

The system required a reduced distance between the hooks, so the number of hooks increased by 30-35 %. However, the baiting was not as good as for hand baiting, and about 20% of the hooks were not baited.

3.2.2 Hooks

The shape of longline hooks remained almost unchanged for several hundred years. The traditional J-shaped hook was the most common. In the middle of the 1970s the development of new types of hooks started. The first step was to twist the sharp end of the hooks. In 1987 a new type developed by O. Mustad & Son and the then Institute of Fishery Technology Research in Bergen (now incorporated in IMR as the Gear Technology Section) was introduced. This hook called the Mustad EZ gave a significant increase in catch rates. For ling and tusk this increase was 15-25 % (Bjordal 1987), and the new hook totally replaced the traditional J shaped hook during the time period 1987-1990 (Table 3.3).

Table 3.3. The marked change in percentage of J shaped hooks and EZ-hooks sold to the Norwegian longline fishery. (Based on sales statistics from O. Mustad & Son.) (Løkkeborg *et al.*, 1993).

Year	EZ	J shaped
1987	9%	91%
1988	39%	61%
1989	92%	8%
1990	98%	2%

Until the first part of the 1970s it was common to sharpen worn hooks. In later years all damaged hooks were replaced. This increased the quality of the hooks and probably the hooking frequency of fish and also increased the hauling speed because changing hooks is less time-consuming than grinding. Some vessels also started to replace all hooks after each

trip during the steaming time back to port. This resulted in improved efficiency especially in the first part of the next trip.

In 1995 the Mustad Autolin System was modified to handle circular hooks. This hook type is expected to be about 20% more efficient than the EZ hook. From 1996 on, many of the vessels are expected to start using circular hooks, and this will agin result in a marked increase in efficiency.

3.2.3 Main line

Since the first years of the 1970s 7 mm polyester lines have been the commonly used. Until then the material in longlines was hemp. The polyester lines are far stronger than hemp lines and have greater wear resistance. This makes it possible to increase the hauling speed and to haul in difficult weather.

In 1987 the "swivel line" was introduced. This line type has a swivel connection between main line and gangion. This line gave 10-20 % increase in catch rates (Bjordal 1987, 1988). The main reason for this is presumably that less fish is lost during retrieval of the gear because the swivel prevents twisting and tangling of the gangions and consequently loss of elasticity and length. Another benefit of the swivel line is that the hauling speed is increased. Bjordal (1988) found an increase of 7% compared with the traditional long lines. Swivel lines were introduced to the whole fleet during the period 1988-1990. Since 1990 all Norwegian deep sea long liners have used swivel lines.

In 1993, 9 mm polyester line was introduced because of the demand for stronger lines for fishing in deeper water. During 1994 and 1995 11.5 mm longlines for fishing even deeper were introduced (e.g. for Patagonian tooth fish off Argentina).

3.2.4 Bait

Herring was the most common bait until about 1970 when the herring stocks in the North-Atlantic declined. Mackerel then substituted herring. In the first years of the 1970s squid was introduced in the longline fishery for ling and tusk. It became common to use about 70% mackerel and 30% squid. According to most long line skippers this mix gave the best catch rates. Fig. 3.4 shows the introduction of squid as bait in the Norwegian longline fishery. In 1981 50% of total weight of bait used was squid.

Bjordal (1983) found that squid gave significantly better catch rates than mackerel. The increase was 6% and 9% for tusk and ling respectively. This resulted in a slight change in the species selectivity of the gear, but no change in size selectivity was found. Løkkeborg et al. (1983) found that the force required to tear squid off a hook was three times higher than that for mackerel. The bait loss due to scavengers and fish attack is also probably less for squid than for mackerel.

An artificial bait is being developed and will probably be introduced on the market in 1996. The main advantage of this bait is the low price compared with traditional baits. Lower

18

bait costs will reduce the total costs of fishing operations and may lead to enhanced fishing pressure on otherwise unprofitable grounds and fish densities.
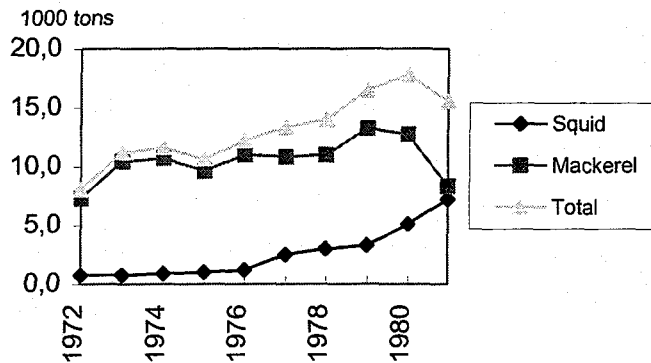

Fig. 3.4   Total weight of squid and mackerel used for bait in the Norwegian longline fisheries, 1972 - 1981 (Bjordal, not published)

3.2.5 Navigation

The first electronic navigation system was introduced in the late 1960s (Decca) and made navigation more accurate and easier. The system also made it easier to record the positions of the line settings. Around 1980 computerised navigation systems were introduced which could remember way-points and were more exact than the Decca system. The next step was the electronic plotter which gave a visual presentation of the settings. All these improvements made the fishery more effective.

3.2.6 Summary

The longline technology was modernised steadily from the 1880s to the 1930s but was almost unchanged from the 1930s to the end of the 1960s. In the two following decades some major developments in technology occurred which improved the catch rates by 1) increasing the numbers of lines hauled during a certain time period (by sheltering and increasing the size of the vessels, freezing the bait, automatic baiting, increasing the hauling speed and improving the navigation ability), and 2) by enhancing the efficiency of the gear by introducing new types of hooks, baits, and lines. The most important step was the introduction of the autoline system in the end of the 1970s.

3.3 Landings statistics

3.3.1 Ling

The total reported landings of ling in the ICES area have declined from 63,951 tonnes in 1973 to 32,245 tonnes in 1994 (50%). The mean value during this period was 43,694 tonnes. Subdivisions VIa and VII are the areas where most of the reduction occurred. One of the reasons is the lack of reporting from Spain. However the Spanish landings were mainly by-catches in the fishery for hake *Merluccius merluccius*, and the effort in this fishery has declined during the recent years. Hence the Spanish landings probably dropped considerably from the level of about 7,000 tonnes reported in 1988.
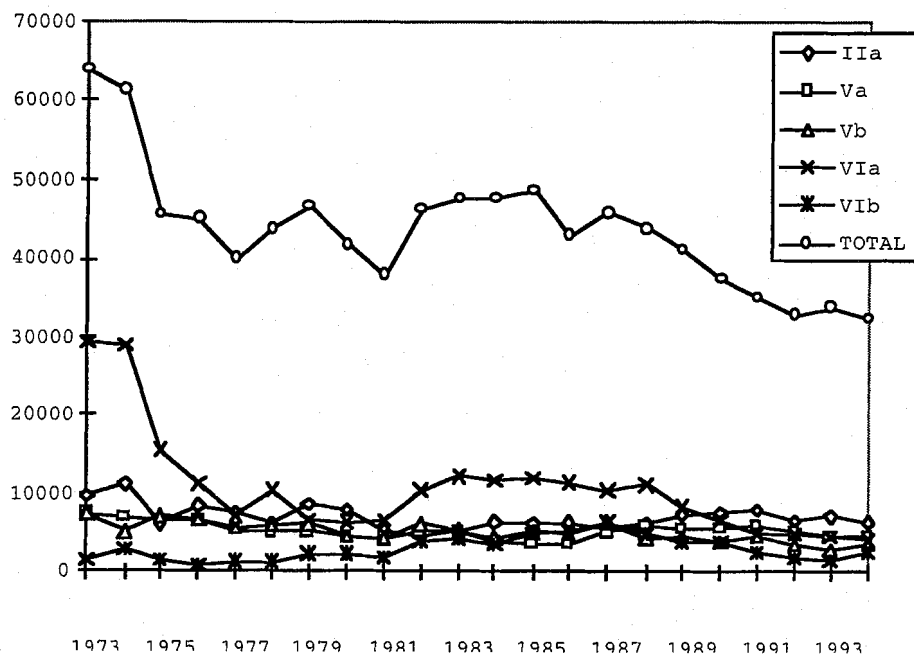
Figure 3.5 Total landings of ling as officially reported to ICES.

The Norwegian landings have gradually declined from a level of 25-30,000 tonnes during the period 1973 to 1985, to 18,000 tonnes in 1994 (Fig. 3.6).

20
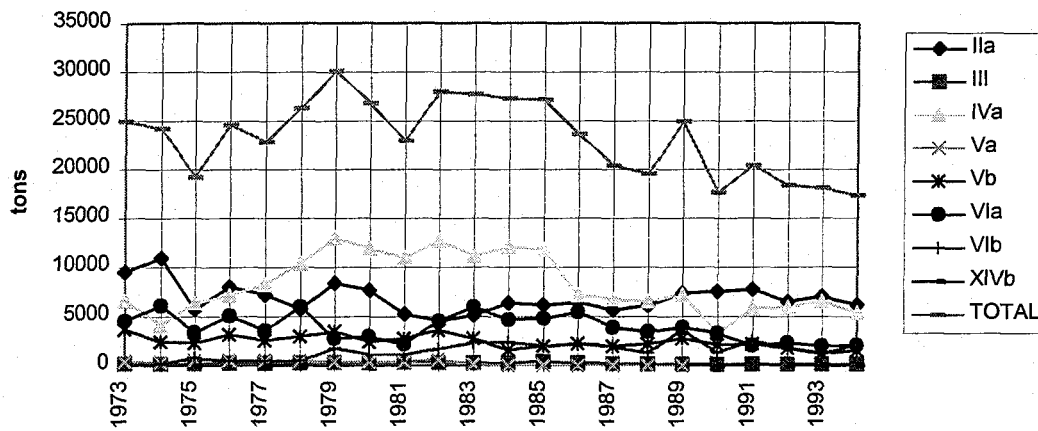
Figure 3.6 Total Norwegian landings of ling as officially reported to ICES.

3.3.2 Tusk

Total reported landings of tusk varied between 30,000 and 40,000 tonnes in the period 1973-1993 (Fig. 3.7). In 1994 the total was 28,000 tonnes. The mean value of total landings during the period was 37,841 tonnes.

Figure 3.6 Total landings of tusk as officially reported to ICES.

Norwegian landings were fairly stable at a level of about 30,000 tonnes until the first part of the 1990s when they declined to a level of about 25,000 tonnes (Fig. 3.7). In 1994 the landings dropped to 19,000 tonnes.
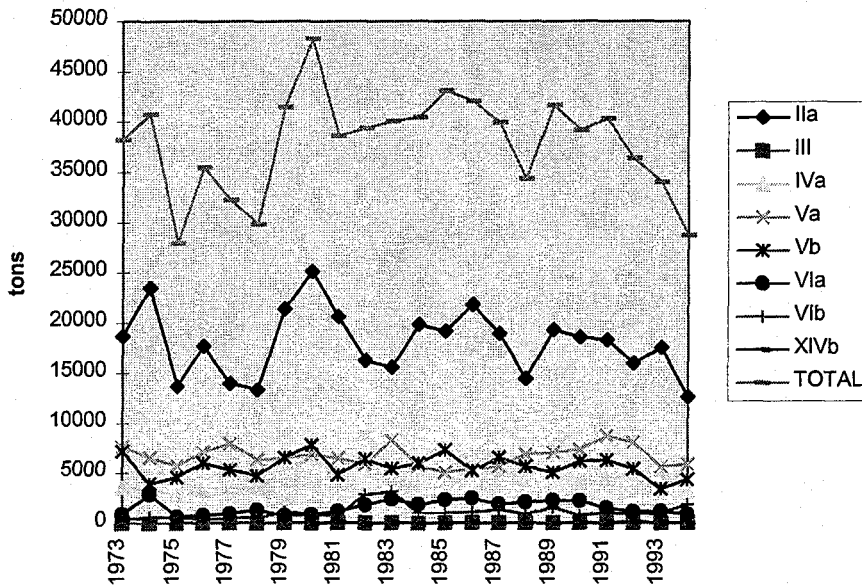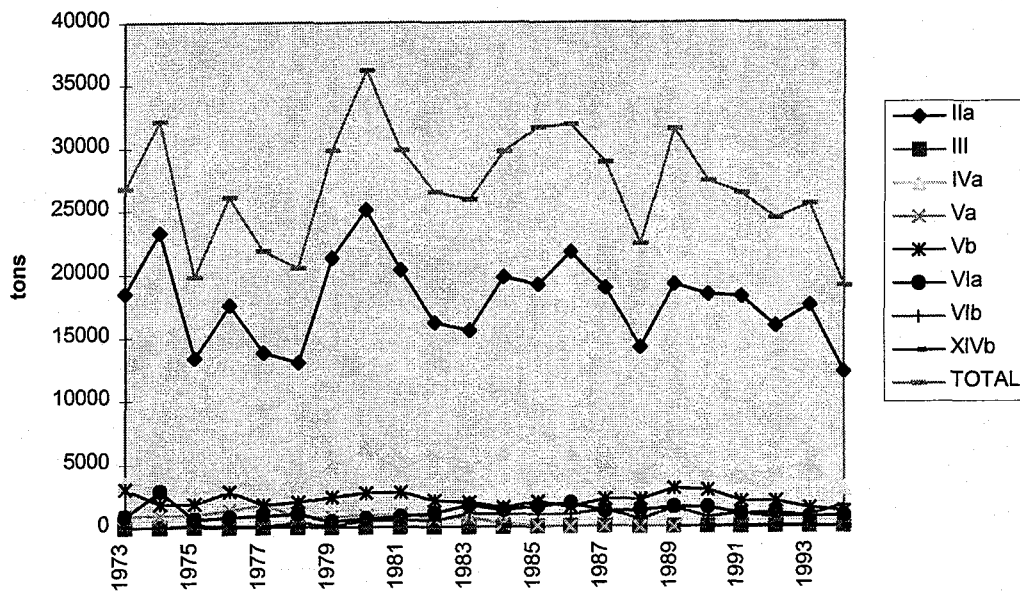
21

Figure 3.7 Total Norwegian landings of tusk as officially reported to ICES.

3.3.3 Blue ling

The landings of blue ling have been very variable during the two last decades. The fishery has typically depended to a large degree on the discovery of new spawning areas. The concentrations on these areas have decreased after a short time. The highest annual landing of 36,456 tonnes of blue ling occurred in 1980 (Fig. 3.8).

The landings of 4,629 tonnes reported to ICES in 1994 were the lowest during the last twenty years. No landings were reported from France which probably landed about 4-5,000 tons. Despite the uncertainty about the actual landings figures, available data show that there has been a severe decline in total landings of this species. Norwegian landings of blue ling have been variable. Before 1979 most of the landings came from by-catches in the longline fishery for ling and tusk in ICES Divisions Vb and IIa. In the years thereafter the gillnet fishery on spawning concentrations in Division IIa have been the most important. The landing in 1994 was however the lowest during the last twenty years (Fig. 3.9).
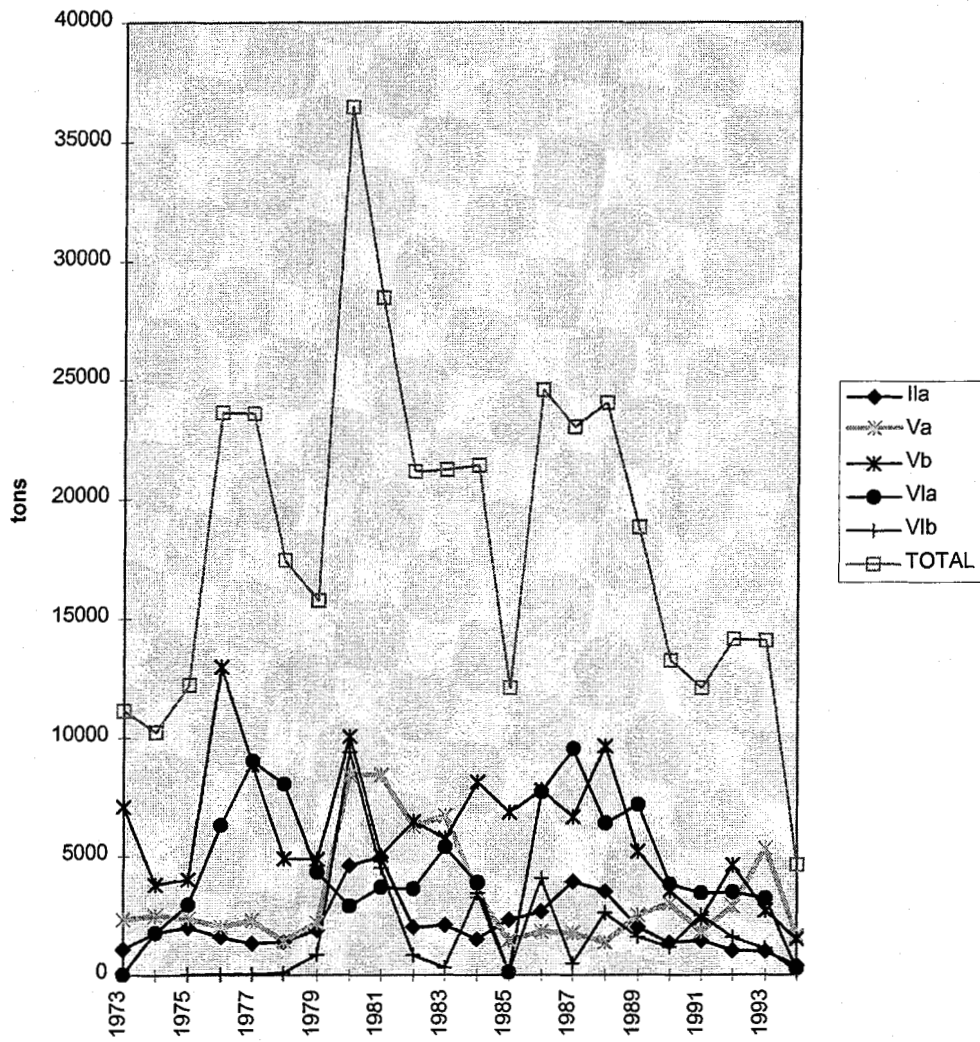
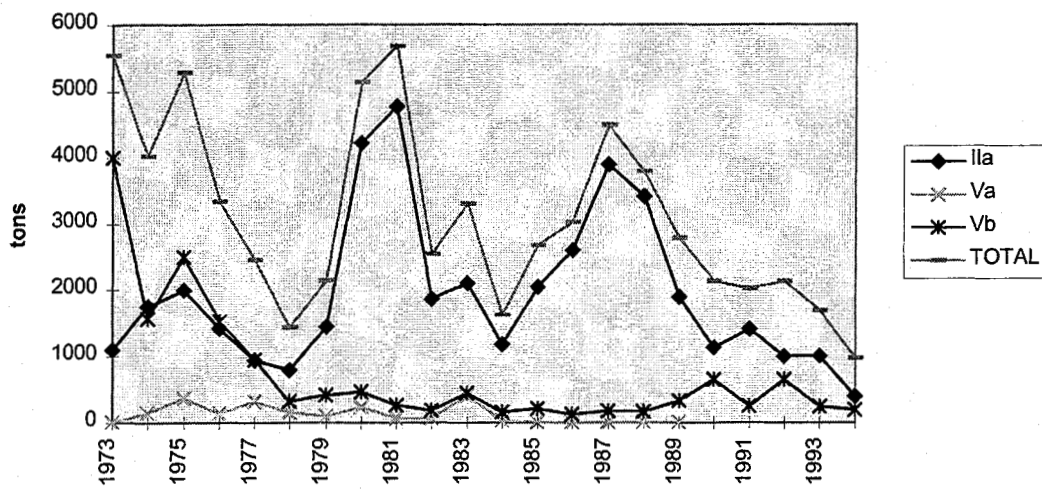Figure 3.8. Total landings of blue ling as officially reported to ICES.

Figure 3.9. Total Norwegian landings of blue ling as officially reported to ICES

4. STRATEGY AND METHODOLOGY

In this chapter, strategies and methods applied in the different project activities are described.

4.1 Literature survey

Since a comprehensive bibliography was lacking, it was decided at the beginning of the project to assemble literature on the fishery, biology and ecology of ling, blue ling and tusk. Standard literature searches were run (Biosis, Oceanic, ASFA, Bibsys), but in addition the "grey literature" was explored for more scattered accounts. The results of the literature survey is a bibliography (see reference list at the end of the report), and a table of references with short records of the contents of the reports (Table 4.1).

4.2 Catch per unit of effort (CPUE) analyses

4.2.1 Private logbooks

Most of the longline skippers record data on gear and catch by each set in personal logbooks. Usually the logbooks contain information on positions, depths at start and end of each set, time of setting and retrieving, and weight of the catch. The logbooks are personal catch record database and are used to optimise the vessels economic outcome by time of year and area.

Logbooks from three longliners were used in this study. The vessels are equipped as standard Norwegian offshore longliners (ref. Ch. 2.1 and 2.2). The time series of logbook data start in the seventies and cover most of the years up to 1994. Normally the chosen vessels target cod in northern Norwegian waters in the period October - March, and during the rest of the year catch ling and tusk in Faroese waters, along the shelf north and west of the British Isles, at Rockall and along the Norwegian continental slope. The three vessels were chosen because they cover typical fishing strategies of the fleet. Vessel 1 concentrated the effort in Faroese waters but fished occasionally in the other areas. Vessel 2 was mainly fishing off the Hebrides and on the Rockall bank. Vessel 3 was mainly fishing off Shetland and occasionally in other areas.

Reference	Species	Publ.Unpubl	Year	Vessel (Res./Com.)	CPUE	Gear	Main/By-catch	ICES areas	Length distr.	Age distr.	Length-Weight	Length at age	Age/length Keys	Age-Weight	Y/R	Reproduction	Distribution-biology	Other
ANON 1983	T	P	1983	C	x	L. line	B	IIa									Depth distr.	
ANON 1990	B,L,T	P	1980-89	C												x		Total landings
BAKKEN & AL 1975	B,T	P	1974	R/C	x	Trawl/L. line		IIa									Depth, geogr.	
BENJAMINSEN 1981	B,L,T	P	1981	C	x	Gillnet	B	IIa									Depth distr.	
BERGSTAD 1988	B,L,T	P	1984-87	R		Trawl	B	IVa, III	x	x	x	x					Depth distr.	Species comp.
BERGSTAD 1991	B,L,T	U	1984-87	R		Trawl	B	IVa, III	x	x	x			x			Depth distr.	
BERTIGNAC & MOGUEDET 198	L	P	1985	C	x	Trawl	M	VIa		x								
BJORDAL 1987	L,T	P	1986	C	x	L. line	M											Gear technology, hook
BJORDAL 1983	L,T	P	1983	C		L. line	M	IIa	x									Gear technology, bait
BJORDAL & FUREVIK 1988	T	P	1988	C		Trap	M	IIa	x									Fish trap trials
BREIBY & ELIASSEN 1984	T		1984	C	x	L. line, Gillnet	B	IIa									Depth	
DAHL & AL 1987	B,L,T	P	1987	R	x	Trawl	B	IIa, IVa										
EHRICH & CORNUS 1979	B	P	1980-83	R/C		Trawl	M	Va,Vb,VIa,VIb,VII	x	x	x		x					Gear tech.
EHRICH 1982	B	P	1979-198	R		Trawl	B	IVa,Vb									Depth distr.	
EHRICH 1983	B	P	1974-80	C		Trawl	B	VIb							x			
EHRICH 1984	B	P	1974-75	R		Trawl		IVa,Vb										
ERICH & REINSCH 1985	B	P	1980-198	R	x	Trawl	M	VI, Vb	x		x	x		x				
ELIASSEN & BREIBY 1983	T		1993	C	x	L. line, Gillnet	B	IIa	x								Depth	
ENGÅS 1982	B	U	1982	C	x	Gillnet/L.line	B	IVa									Depth	
ENGÅS 1983	B,L	P	1981	C	x	Gillnet	M	IIa	x		x			x				Selectivity, discards,feeding, fisheries
FRANCO et al. 1987	T		1986	C	x	L. line	M	IIa	x									Gear technology, bait
GARCIA DE LEON et al. 1993	L	P	1986-199	C	x	Trawl	M	VIIe	x									
GORDON & DUNCAN 1985	B,L,T	P		R		Trawl	B										Depth distr.	
GROTNES & HAREIDE 1989	L,T	P	1971-87	C	x	L. line	M	Vb	x		x							Fishing eff. Total landings
GROTNES & HAREIDE 1990	L,T	P	1971-88	C	x	L. line	M	Vb						Recr				Fishing eff. Total landings
GUNDERSEN et al. 1995	B,T	P	1994	C	x	L.line		XIVb	x	x								
HAREIDE & GROTNES 1988	L,T	P	1987	C	x	L. line	M	Vb,VIab,IVa	x	x	x		x					
HAREIDE & GROTNES 1989	L,T	P	1989	C	x	L. line	M	Vb,VIab,IVa	x	x	x		x					
HAREIDE 1989	L,T	P	1971-87	C	x	L. line	M	Vb	x	x	x			x			Geogr. distr.	
IVERSEN 1936	B,T	P	1931-193	R/C	x	L. line	B	XIVa,b									Depth, geogr.	
JOHANSEN & NÆVDAL 1991	T	P	1991	C		L. line	M	IIa,VIb1,VIa+b		x								Genetic. stud.
KOCH & LAMBERT 1974	B	P	1973	R		Trawl												
KOCH 1983	B	P	1983	R	x	Trawl	B	VIb	x					x				
LØKKEBORG & BJORDAL 1992	L,T	P				L. line	M											Gear technology, hook, bait
LØKKEBORG 1987	L,T		1986	C	x	L. line	M	IIa	x									Gear technology, bait
MADSEN & OLSEN 1983	L	P	1983	C	x	L. line	M	VIIh									Depth distr.	
MAGNUSSON 1975	B	P	1975	R		Trawl	B	Va, XIV	x									
MAGNUSSON 1976	B	P	1976	R		Trawl	B	Va, XIV	x									
MAGNUSSON 1977	B	P	1977	R		Trawl	B	Va, XIV	x									
MAGNUSSON 1978	T	P	1978	R		Trawl	B	Va, XIV	x									
MAGNUSSON 1978	B	P	1978	R		Trawl	B	Va, XIV	x									
MAGNUSSON 1979	B,L	P	1979	R/C		Trawl	B	Va	x									
MAGNUSSON 1979	T	P	1979	R/C		Trawl	B	Va	x									
MAGNUSSON 1980 a	T	P	1980	R		Trawl	B	Va	x									
MAGNUSSON 1980 b	B,L	P	1980	R		Trawl	B	Va	x									
MAGNUSSON 1981	B,L	P	1981	R/C		Trawl	B	Va	x									
MAGNUSSON 1981	T	P	1981	R/C		Trawl	B	Va	x									
MAGNUSSON 1982	B,L	P	1982	R/C		Trawl	B	Va		xl						x		
MAGNUSSON 1983	T	P	1983	R/C		Trawl	B	Va		xl						x		
MAGNUSSON 1983	B,L	P	1983	R/C		Trawl	B	Va		xl								
MAGNUSSON 1983	T	P	1983	R/C		Trawl	B	Va		x								
MAGNUSSON 1984	B,L	P	1988	R/C		Trawl	B	Va	x	xl		xl				x	Depth distr.	Total landings
MOGUEDET 1985	B	P	1985		Trawl	M	IVa	x		x							Both sexes, L-W rel., maturity
MOGUEDET 1989	B	P	1984-85	C		Trawl	M	VIa	x		x		x					
MOLANDER 1956	L	P	1939-195	R/C	x	L. line	M	III,IVa,Vb,Va	x	x	x	x	x	x		x		Ageing
MYKLEBUST 1976	B,L,T	P	1976	R	x	L. line	M	IVa, IVa, Ivb										Weights
MØLLER & NÆVDAL 1969	B,L,T	P																Genetics
OTTERLEI & HAREIDE 1987	L,T	P				L. line	M											Socioeconomics, Fisherie
RAHARDJO JOENOES	B,L,T	P	1955-195	R	x	Trawl	B	IIa,IVa,III,Va,b		x	x	x	x			x	Depth, geogr.	Ageing
REINSCH 1984	B	P	1983	C		Trawl	M	IIa,Vb,XIV	x		x							
REINSCH 1987	B	P	1986	C		Trawl	M	Vb,xIVa	x		x							
REINSCH 1987	B	P	1986-87	C		Trawl	M	Vb,xIV		x			x					
REINSCH 1982	B	P	1981	R		Trawl	B	VIa,b,Vb,XIVb	x		x							
REINSCH 1983	B	P	1981-198	R		Trawl	B	VIa,b,Vb,XIVb	x			x						

Table 4.1 References to reports on the biology and fishery of ling, blue ling and tusk

	Species	Publ./Unpubl	Year	Vessel (Res./Com.)	CPUE	Gear	Main/By-catch	ICES areas	Length distr.	Age distr.	Length-Weight	Length at age	Age/length Keys	Age-Weight	Y/R	Reproduction	Distribution-biology	Other
SCHÖNE 1983	B	P	1983	R	x	Trawl	M	VIb	x									Exploratory
SHIBANOV et al. 1988	B	P	1986-87	R		Trawl	B	Vb									Depth distr.	
SCHMIDT 1907	B,L,T	P	1903-190	R				IVa,VI,Va,Vb,VII								x	Geogr. distr.	
TAMBS-LYCHE 1987	T	P		R		Trawl/L. line	B	IVa									Depth distr.	
TEMPLEMAN & FLEMING 1954	L	P	1954	C		L. line												Distribution
TEMPLEMAN 1969	B	P															Geogr. distr.	Morphometrics
THOMAS 1980	B	P	1977-79	R/C		Trawl	M	IVa,Vb	x	x	x	x	x	x		x	Depth distr.	Parasites, temperature, market
THOMAS 1987	B,L,T	/	1976	C	x	L. line	M	VIa +b, Vb, IVa	x	x	x	x	x	x	x			
VETRHUS 1988	T	N	1988	C	x	Trap	M	IIa, IVa										
VILHELMSDOTTIR 1980	B	P	1977-79	C/R		L. line	B	Va	x	x								
VILHELMSDOTTIR 1982	B	P	1975-81	R		Trawl	B	Va	x	x	x	x		x				
WAGNER & STEHMANN 1975	B,L	P	1974	R	x	Trawl	B	VIa, VIb, VII, Vb									Depth distr.	Temperature
YATSU & JØRGENSEN 1988	B,T	P	1987	R		Trawl	B	XIVb										Swept area, biomass estimate

1) Only Blue ling

Table 4.1. Continued

Catch data: The catch information has been allocated to three different strata systems to improve the understanding of the geographic distribution of effort:

1. ICES areas and sub-areas.
2. Norwegian Fishery Statistics areas.
3. Fishermen's common names of the fishing grounds.

In most cases the logbooks contain records of total catch per set without specification of species composition. Data on species composition was obtained by either of three methods:

1. Directly from log books. Vessel 3 recorded species composition per set in the period 1980 to 1985, and this information has been used when available.
2. Vessel 2 logged information of species composition per day, in the period 1979-1994. Day catches by species were used to split total catch by set.
3. Each vessel has allowed the project to use trip landings by species in the analysis. To obtain a rough catch by species by set, the total set catches have been split by the species composition of the trip landings. This method was used whenever Methods 1 and 2 were inapplicable.

The catch data were recorded as headed and gutted weight and prior to the analyses these were converted by the official factor 1.4 to total weight. Although we believe that as much information as possible has been extracted from the available data, it is quite clear that the catches by species have to be treated with caution.

Effort data: Effort data are based on the number of lines per set (see Table 3.1). Number of hooks were obtained by multiplying the number of lines by the number of hooks per line. The gear and the baiting method have changed substantially during the

period studied. The most important factor is the introduction of the autoline system. This system baits about 85% of the hooks, and the effort has been adjusted accordingly. The density of hooks has increased from 100 to 130-140 hooks per 185 m standard line length, and exact information on the number of lines by trip is available from the three vessels. The introduction of the EZ hook in the late 1980s is known to improve catches by 15%. Simultaneously, the introduction of swivels mounted on the snoods have proved to rise CPUE by about 15%. Introduction rates are available for the three vessels, and effort has been adjusted accordingly. The effort adjustments by vessel and period are given in Table 4.2. To correct for the hook effects, the number of hooks are multiplied by the documented efficiency factors, i.e. the unit of effort is given in "thousands of baited 1973 hooks".

Catch per unit of effort: CPUE was calculated for each longline setting. The mean CPUE per trip is an average of the set catches, and the annual average is the average trip catch weighted by number of trip sets. Splitting the CPUE data into ICES areas gave misleading results on species compositions among the various banks and at different depths within the same area due to rough area stratification. Therefore, in the analysis presented below, the Norwegian Fishery Statistics strata system has been used.

4.2.2 Official log books

Presently, the ocean operating longliners have to keep logbooks supplied by the Directorate of Fisheries when operating outside the Norwegian EEZ. In case of control the book has to be presented to the inspection officer. Submission of logbooks for official use is presently not required by law. The collection of data for scientific analysis is therefore currently dependent on fishermen who voluntarily submit their logbooks. The logbooks contain information on catch position, catch date and hour at start of line retrieval. Further, total catch weight (live weight) by species, and effort in number of hooks is given. Catch and effort information is given by set and is expected to be comparable with the data from the private logbooks.

4.2.3 Official total catch and effort statistics

Every second year a representative sample of the Norwegian fishing fleet is reviewed through an official effort study by means of a questionnaire system. The investigation gives an overview of the distribution of effort of the longliners on ling, tusk, blue ling versus other fish stocks like cod and haddock (Table 3.1). Effort is given in weeks. Due to the efficiency increase described above, number of weeks is a very imprecise measure. Combining the observed changes in efficiency from the private log books (i.e. number of hooks per day (HPD)) with changes in officially recorded effort (weeks*vessel spent in the fishery), serve as another control or alternative for arriving

at a CPUE measure. We used the detailed information on changes in effort (HPD) from the private log books combined with changes in efficiency due to technological advances (see Table 4.1). Accordingly, the official effort statistics in weeks could be converted to hooks. Total number of hooks (HOOKS) used in the western areas (Shetland, Faroe Islands, Hebrides, Rockall) was estimated by:

$$HOOKS = weeks*pctwest*7*HPD \qquad Eq. 1$$

where weeks is the total number of weeks times number of vessels in the longline fleet and "pctwest" is the percentage of total effort of the fleet spent in the western areas (Table 3.1). HPD is the average number of hooks per day used in the western areas by *the three vessels studied. HOOKS will be biased when calculated according to Eq. 1* because "weeks" include all time spent, i.e. time for transportation, fuel refill, days of bad weather without fishing etc. We have considered the working routines of the fleet and found that about four days are lost due to these factors for each trip in recent years. In the first years of the time-series on average as much as 12 days were lost. This includes the substantial increase in efficiency due a gradually expansion of trip duration along with the renewal of the fleet. HPD was been adjusted accordingly in three steps (1974-1978, 1980-1984, 1986-1994).

Table 4.2. Gear specification and adjustment of effort for Vessel 1-3.

Vessel 1

Time period:	1974-1978
Vessel:	110 ft without shelter deck
Gear:	100 fm lines,1 fm betw. hooks.
Hooks:	Traditional J shaped, Mustad nr 7.
Baiting:	Manual
Bait:	Mackerel (100%)
Corrections:	No correction

hooks =Lines*100 hooks

Time period:	1978-September 1981
Vessel:	32.4 m sheltered vessel (built in 1978)
Gear	100 fm lines, 1 fm betw. hooks.
Hooks:	Traditional J shaped, Mustad nr 7.
Baiting:	Manual
Bait:	Mackerel (75%) and squid (25%)
Corrections:	No correction

hooks =Lines*100 hooks

Time period:	October 1981-1989
Vessel:	35.7 m sheltered vessel
Gear	100 fm lines 140 cm betw. hooks.
Hooks:	Traditional J shaped, Mustad nr 7.
Baiting:	Mustad autoline. 85% baiting
Bait:	Mackerel (75%) and squid (25%)
Corrections:	Autoline

hooks =Lines*100fm*1.85m*0.85/1.40m

Time period:	1989-1994
Vessel:	39.9 m vessel
Gear	100 fms swivel lines
Hooks:	Mustad EZ 12/0
Baiting:	Mustad autoline. 85% baiting
Bait:	Mackerel (75%) and squid (25%)
Corrections:	Autoline,EZ hooks, swivel line

hooks=Lines*100fm*1.85m*0.85*1.15*1.15/1.30m

Vessel 2

Time period:	1974-1977
Vessel:	26,6 m steel hulled vessel
Gear	150 fm lines 1 fm betw. hooks.
Hooks:	Traditional J shaped, Mustad nr 7.
Baiting:	Manual
Corrections:	No correction

hooks = Lines*150 hooks

Time period:	1978-1981
Vessel:	39.9 m vessel (built in 1978)
Gear	150 fms lines 130 cm betw hooks.
Hooks:	Traditional J shaped, Mustad nr 7.
Baiting:	Mustad autoline 85% baiting
Bait:	Mackerel (75%) and squid (25%)
Corrections:	Autoline

hooks =Lines*150fm*1.85m*0.85/1.40m

Time period:	1981-1989
Vessel:	39.9 m vessel
Gear:	100 fm lines, from1986-1987
	140cm between the hooks.
Hooks:	Traditional J shaped, Mustad nr 7.
Baiting:	Mustad autoline. 85% baiting
Bait:	Mackerel (75%) and squid (25%)
Corrections:	Autoline

hooks=Lines*100fm*1.85m*0.85/1.40m

Time period:	1987-1994
Vessel:	38.1 m vessel
Gear	100 fms lines
Hooks:	Mustad EZ 12/0. Introduced
	1987-1989 (25,50,100%)
Baiting:	Mustad autoline. 85% baiting
Bait:	Mackerel (75%) and squid (25%)
Corrections:	Autoline,EZ hooks, swivel line

hooks= Lines*100fm*1.85m*0.85*1.15*1.15/1.30m

Vessel 3.

Time period:	1979-1985
Vessel:	27.0 m shelter decked vessel
Gear	100 fms lines
Hooks:	Traditional J shaped, Mustad nr 7.
Baiting:	Hand baiting
Bait:	Mackerel (75%) and squid (25%)
Corrections:	No correction

hooks =Lines*100 hooks

Time period:	1985-1988
Vessel:	27.0 m shelter decked vessel
Gear	100 fms swivel lines
Hooks:	Traditional J shaped, Mustad nr 7.
Baiting:	Mustad autoline. 85% baiting
Bait:	Mackerel (75%) and squid (25%)
Corrections:	Autoline

hooks = Lines*100fm*1.85m*0.85/1.40m

Time period:	1988-1994
Vessel:	34 m shelter decked (built 1988)
Gear:	100 fms lines
Hooks:	Mustad EZ 12/0
Baiting:	Mustad autoline. 85% baiting
Bait:	Mackerel (75%) and squid (25%)
Corrections:	Autoline

hooks=Lines*100fm*1.85m*0.85*1.15*1.15/1.30m

4.3 Sampling of biological data

Samples for analyses of biological variables were collected from commercial longline and gillnet vessels. The intention was to sample all ICES Sub-areas and Divisions where Norway has a fishery, i.e. IIa, IIIa, IVa, Vb1 and Vb2, VIa, VIb, and VII (ref. Fig 3.1). Because of low fishing activity in IIIa and VII, rather few samples were obtained from these areas. The original goal was to sample each area in every quarter of the year, but this proved too ambitious.

The fishing trips of the longliners normally last for six weeks and several ICES areas may be visited during a single trip. The catch is usually landed headed and gutted, and market sampling of e.g. otoliths and gonads is thus impossible. Onboard sampling was necessary, and this was achieved by either sending project personnel onboard, or by hiring fishermen to collect samples. In the latter case, only heads were sampled and stored until the vessel returned to port. This is a cheap strategy, but information on weight, sex and stage of maturity is missing. In 1993, most of the samples were obtained in this manner, whereas in 1994 and 1995 project personnel went to sea to sample the catches. In addition, some samples of ungutted fish were bought from the vessels and some head samples collected.

The total material of the three species available to the project at the end of 1995 is presented in Tables 4.3-4.5. In addition to material sampled by the project, some data from 1976 collected by IMR were available. Also included are length and catch data collected by the Norwegian Coast Guard when inspecting fishing vessels, and length data obtained from selected longliners with which IMR has special agreements (the "Ressurslink"). Some unpublished data from 1988-90 sampled by the Norwegian College of Fisheries in Tromsø were also included in the analyses (Hareide and Otterlei, unpubl.).

For each species and sub-area linear regressions were estimated relating head length and headed length to total length (measured to the nearest cm below). There were no significant difference between sub-areas, and the following equations were used overall:

Ling   Total length = Head length * 4.4 + 0.4 $(r^2=.98, n=426)$
              Total length = Headed length * 1.21 + 1.65 $(r^2=.99, n=426)$

Blue ling   Total length = Head length * 4.3 + 1.79 $(r^2=.95, n=35)$
              Total length = Headed length *1.27 - 3.65 $(r^2=.98, n=31)$

Tusk   Total length = Head length * 4.4 + 1.9 $(r^2=.95, n=1111)$
              Total length = Headed length *1.23 +1.0 $(r^2=.98, n=1028)$

Stage of maturity was determined macroscopically by visual inspection of the gonads. A scale ranging from 1 to 7 as used by Molander (1956) for ling was applied. Stages 1 and 2

are immature fish, Stage 3 and 4 are recovering and/or ripening, 5 and 6 ripe and running and Stage 7 is spent.

Age was determined from otoliths according to the procedures described in Ch. 4.4.

Table 4.3 Samples of *ling* used for analyses of biological variables (number of individuals).

Year	Data			ICES	area				
		IIa	IIIa	IVa	Vb1	Vb2	VIa	VIb	Total
1976	Age								
	Total length			1133		253	492	57	2385
	Head length								
	Headed length								
	Sex								
1988	Age			439					439
	Total length			989					989
	Head length								
	Headed length								
	Sex			439					439
1989	Age			225		394	48	198	1297
	Total length			473	45	614	916	518	2566
	Head length								
	Headed length			46			31		77
	Sex			432	41	528	915	395	2311
1990	Age								
	Total length	236		4					240
	Head length	99							99
	Headed length	249		694		318		261	1522
	Sex	171							171
1991	Age								
	Total length	63							63
	Head length								
	Headed length								
	Sex								
1993	Age	108	30	588	106		195	4	1067
	Total length	1	30	157	1				189
	Head length	122		461	106		218	47	954
	Headed length			27			254		281
	Sex			156					156
1994	Age	296	189	187	1		27	193	893
	Total length	19	189	103	1		27	45	384
	Head length	304		133	1		25	194	657
	Headed length	16		694	1		616	252	1579
	Sex	19		103	1		27	45	195
1995	Age	171	17	469			581	46	1284
	Total length	382	17	2016			282	48	2745
	Head length			127			411	47	585
	Headed length			320			111	48	479
	Sex	174		2010			282	48	2514
Total age		575		1908	107	394	1283	477	4744
Total length		701		4875	47	867	1717	1118	9325
Total head length		525		721	107		654	288	2295
Total headed length		265		1781	1	318	1012	561	3938
Total sex		364		3140	42	528	1224	488	5786

Table 4.4. Samples of *tusk* used for analyses of biological variables (number of individuals are listed).

Year		IIa	IIIa	IVa	Vb1	Vb2	VIa	VIb	XII	Total
				ICES	area					
1976	Age									
	Total length			377	289	142	150	853	337	2148
	Head length									
	Headed length									
	Sex									
1988	Age	14		200						214
	Total length	14		976						990
	Head length									
	Headed length									
	Sex	14		306						320
1989	Age			13			93			106
	Total length	250		1036	107	470	402	954		3219
	Head length									
	Headed length						22			22
	Sex			206	89	231	402	685		1613
1990	Age									
	Total length	822		26						
	Head length	87								
	Headed length	548		610		852	973			2983
	Sex	294								294
1991	Age									
	Total length	865			139					1004
	Head length									
	Headed length									
	Sex									
1993	Age	871	194	336	486		174	292		2332
	Total length	76	194	50	16			1		337
	Head length	1371		336	464		190	341		2702
	Headed length	56		31	14					101
	Sex			33						33
1994	Age	1185	154	111	192		205	601		2448
	Total length	467	154	83	201		205	448		1558
	Head length	1625		83	60		106	552		2426
	Headed length	204		1315	61		109	665		2354
	Sex	460		82	201		205	448		1396
1995	Age	355	25	354			72			806
	Total length	377	25	1194			35			1631
	Head length	135		87			70			292
	Headed length	135		1052			34			271
	Sex	377		1174			32			1583
Tot. age		2425		1014	657		544	893		5533
Tot. length		2871		3742	752	612	792	2256	337	11362
Tot.head l.		3228		506	524		366	893		5517
.Tot. headed l.		943		2058	75	852	1138	665		5731
Tot. sex		1145		1801	290	231	639	1133		5239

33

Table 4.5 Samples of *blue ling* used for analyses of biological variables (number of individuals)

Year	Data	IIa	III	IVa	Vb1	Vb2	VIa	VIb	XII	Total
1976	Age									
	Head length									
	Total length							153	92	245
	Headed length									
	Sex									
1989	Age									
	Head length									
	Total length			2	1	3	5	1		12
	Headed length									
	Sex				1	3	5	1		1
1993	Age									
	Head length				160		1			161
	Total length				2					2
	Headed length									
	Sex									
1994	Age						1			1
	Head length				33		3	5		41
	Total length				33		3			36
	Headed length				32		3			35
	Sex				33		3			36
1995	Age									
	Head length									
	Total length	6		2						8
	Headed length									
	Sex	2		2						4
Tot. age							1			1
Tot. length					193		4	5		202
Tot. head l.		6		4	36	3	8	154	92	303
Tot.headed l.					32		3			35
Tot. sex		2		2	34	3	8	1		50

4.4 Development of ageing methods

For all the three species there was a need for reconsidering the ageing methods applied in earlier studies, and on that basis, perform further technical development and inter-calibration of age readings. This task was given high priority in the project, both on national and Nordic level. The aim has been to develop agreed ageing practices which provide precise age estimates when used routinely. The only structure useful for ageing ling, blue ling and tusk are the sagittal otoliths. The work has not included validation of the otolith ages. This is a major important task which was considered beyond the scope of this project.

The work on ageing has involved the following main steps:

1) Review of the international literature and the methods previously used in Norway

(including repeated reading of some old samples)

2) Further development of pre-processing techniques.

(storage, illumination, orientation of otoliths during reading, sectioning etc.)

3) National inter-calibrations (ling and tusk 1993-1994, see Table K for details)

4) Nordic inter-calibrations (1994, 1995, see Table K for details)

5) Nordic workshops to conduct and discuss inter-calibrations

(Fevik, Norway 31 Aug.-2 Sept. 1994, Arendal 18-20 Sept.1995)

Table 4.6. Age reading inter-calibrations carried out in the project period 1993-1995. Fa - The Faroes, Ice - Iceland, MF - Møre Research, IFREMER - Lorient Laboratory, France, IMR - Institute of Marine Research

Time	Species	Sample (Nos.)	Parties involved	Report*
Apr 1993	Ling	50	IMR Bergen and Flødev., MF	Nedreaas (1994)
Apr 1993	Tusk	49	"	Nedreaas (1994)
June 1993	B.ling	52	IMR, MF, Fa, Ice, IFREMER	Reinert (1994a)
Apr 1994	Tusk	20	IMR Bergen and Flødev., MF	unrep.
Spring 1994	B.ling	103	IMR Flødev., MF, Fa, Ice	Reinert (1994b)
Spring 1994	Tusk	49	IMR Flødev, MF,Fa, Ice	Workshop rep. 94
Spring 1994	Ling	50	IMR Flødev, MF, Fa, Ice	"
Autumn 1994	Tusk	60	IMR Flødev,MF,Fa,Ice	Bergstad (1994)
Spring 1995	Tusk	15 photos	IMR Flødev.,MF,Fa,Ice	Bergstad (1995a)
Aug 1995	Tusk	88	IMR Flødev, MF,Fa,Ice	Bergstad (1995b)
Sept 1995	B.ling	60	IMR Flødev,MF,Fa,Ice	Workshop rep. 95
Sept 1995	B.ling	30	"	"
Autumn 1995	Tusk	92	"	In progress

* the reports are internal unpublished working documents or minutes from workshops

For ling, Molander (1956) described methods for reading whole otoliths, and his or very similar methods and interpretations were used in later studies of this species (Bergstad 1991) and in this project. At the Nordic workshop in 1994, agreement was reached on a best interpretation of the otolith growth zones (annuli) and a reading technique for whole otoliths. The otoliths were submerged in water or glycerol and viewed sulcus-side down by bright transmitted light. Otoliths from ling of total length (TL) greater than around 90 cm become very robust and cannot be read whole. Sectioning has been attempted (transverse sections through the nucleus), but with limited success. Breaking and viewing of the broken surface does not seem to be a better alternative.

For tusk, reading of whole submerged otoliths (sulcus-side up) seemed the most promising method, at least for fish of TL<70 cm. This technique was also used previously by Norwegian, Icelandic and Faroese readers. The interpretation problems were however graver than for ling, and several inter-calibrations were made which showed that unacceptable disagreement existed between readers. The situation has improved, however, and in Norway tusk otoliths were read routinely from the Autumn 1994 onwards. A final Nordic inter-calibration of tusk otoliths is now in progress.

Blue ling otoliths are very robust, also those from small fish, and most previous workers produced sections to expose annuli (Engås 1983; Ehrich and Reinsch 1985; Thomas 1987; Bergstad 1991, also recently French workers). An exception was Magnusson (1982) who read annuli from broken surfaces. No generally accepted ageing method has been developed for blue ling and consequently Norwegian samples were not aged. The Nordic project is making some progress and will focus further on this species in 1996.

4.5 Population genetics

The aim was to reveal genetically controlled variation by standard electrophoresis and related methods, and to utilise these variation for comparative studies on fish from different fishing grounds or areas of distributions. In accordance with comparable results from other fish species, it was not anticipated to find specific genes or genotypes in any sub-area of distribution, but it was presumed that different genotype distributions, reflecting different gene pools, should be informative with respect to sub-structuring of the species.

The studies started in 1989, but the main parts have been carried out in the period 1993-1995. Part of the sub-project has been carried out by graduate students at Department of Fisheries and Marine Biology, and the description of genetic variation in tusk is based on the thesis of Torild Johansen (Johansen 1994). Correspondingly, the description of ling analyses is based on parts of the thesis of Otto Igland (Igland 1994).

An overview of the collected material of tusk and ling is presented in Table 4.7. The greater part of the material analysed concerns tusk (11 samples), while five samples of ling have been analysed. Concerning blue ling only one sample from Iceland and two smaller samples from East Greenland waters have been collected.

Sampling was conducted onboard commercial longline vessels or on vessels hired to carry out scientific sampling or observations. The samples were either taken directly from the fish onboard the vessels, and the tissue and blood samples were stored in microtest plates, or fish heads, usually with a bit of liver in their mouth, were collected by fishermen and sent to the laboratory in frozen state. All sampling for population genetics were combined with sampling of biological data, and the data on length, age, sex and stage of maturity were in this respect used to characterise the samples. Head lengths were converted to total length based on

36

regression estimated on fish in samples of which both body lengths and head lengths (from tip of snout to the posterior end of the operculum) were recorded (see section 4.3).

Table 4.7. Material collected for population genetic studies of tusk and ling. TL = total length, HL= head length (from tip of the snout to end of operculum).

| Sample no | Locality | Date | Position | | No. of specimens | | | | | | |
| | | | N. long | W.lat. | Genetic data | | | Biological data | | | |
					muscle	liver	Hb	Otolitt	sex	TL	HL
	TUSK										
1	St. Kilda	Aug. 90	58°14'N	09°12'W	294	294	152	110	200	294	
2	Storegga	June 90	62°48'N	04°41'E	270	270	226	250	154	269	96
3	Faroe Island	Sept. 90	60°43'N	07°02'W	96	-	-	96	-	-	96
4	Rockall	Sept. 90	68°00'N	19°00'W	56	56	-	56	-	-	56
5	*Davis Strait*	Aug. 92	65°43'N	55°00'W	80	80	-	-	-	-	-
6	East Greenland	Sept. 93	63°52'N	35°59'W	102	102	97		89	157	
7	Kragerø	Oct. 94	58°30'N	09°00'E	59	-	59	59	-	59	
8	Øygarden	Jan. 95	60°24'N	04°58'E	44	44	68		68	68	
9	Shetland	May/June 95	61°20'N	03°00'W	281	337	337	337	337	337	
10	Vesterålen	Jun./July 95	60°24'N	14°00'E	405	405	250	405	405	405	
11	Iceland	Oct. 95	62°00'N	16°00'W	296	296	225	274	274	274	
	LING										
1	Bremanger, Norway	May 92.	61°48'N	04°30'E	96	-	-	-	-	96	-
2	Shetland	Aug.92	60°15'N	00°30'W	102	102	-	-	-	-	102
3	Shetland	May/June 95	61°20'N	03°00'W	183	183	-	183	183	183	
4	Vesterålen	Jun./July 95	67°30'N	14°00'E	54	54	-	54	54	54	
5	Iceland	Oct. 95	62°00'N	16°00'W	134	134		261	261	261	

The length distributions of the samples showed significant differences. Both the length distributions and the age determination indicated that most of the specimens had reached sexual maturity although this could not be determined by visual inspection of the gonads. An exception was tusk sample no 8 from coastal areas in West-Norway, which represented younger year classes. Thus fish of all ages are represented among the material, although the greater part are collected from adult stages.

Tissue samples (muscle and liver) were stored in a frozen state from sampling until analysed. Before analyses the cells were disrupted by use of ultrasound after adding equal volumes of distilled water.

Hemoglobins were analysed fresh onboard the vessels or in the laboratory providing that the samples could be brought ashore within a few days. Agar gel electrophoresis, originally described by Sick (1961) and modified by Jørstad (1986), was applied for hemoglobin analyses. For the earliest samples Tris-HCl-buffer, pH 8.0, was used, but the results were considerably improved by changing to Smithies buffer, pH 8.6 (Smithies 1959). Because of the need to be analysed fresh, and sometime because of non-optimal results with the Tris-HCl-buffer, only part of the material has been analysed for hemoglobin variation.

Tissue samples were analysed by starch gel electrophoresis after the method described by Jørstad (1986). A number of buffers were tried, but most emphasis was laid on the histidine-citrate buffer, pH 7.0 (Harris and Hopkinson 1976), hereafter called histidine buffer, and the citricacid/morpholine buffer, pH 6.1 described by Allendorf et al. (1977),hereafter called AM-buffer. Individual variation which could be interpreted to have a simple genetic background, are based upon the buffer system which gave the best technical results. In case where genetic variation was indicated, although not clear enough for proper classification of the individuals, isoelectric focusing was tried (Anon 1990).

Enzymes were stained by standard histochemical staining methods (Harris and Hopkinson 1976) utilising the enzyme activity. Hemoglobins were stained by the so-called Quick Stain method (Mc Farland 1977).

Distributions of phenotypes were compared to expected Hardy-Weinberg distributions to test the interpretations based on banding patterns in the gels. Likewise comparisons of samples were performed using a contingency test with Levene's corrections. All calculations of genetic parameters, including tests of sample heterogeneity, were carried out using the computer program BIOSYS.

4.6 Contaminant analyses

Samples of liver from ling and tusk were collected from three areas, the Shetlands and Faroes and the Skagerrak. From each of the two first areas 5 samples were available, each containing 5 specimens, in total 25 specimens. From the Skagerrak 25 specimens of each species was available.

The concentration of PCB (Congeners 28, 31, 52, 101, 105, 118, 128, 138, 149, 153, 156, 170, and 180) was determined for all samples. An internal standard was added to the samples prior to extraction by hexan:aceton by Ultraturrax and treatment with sulfuric acid and fractionating by a florisil column. The PCB analyses were made by capillary gas chromatography and ECD detector.

5. BIOLOGY

5.1 Ling

5.1.1 Distribution of eggs and larvae

Field investigations of eggs and larvae were not included in the project, but available data from published and unpublished reports were compiled. The aim was to obtain an updated impression of the distribution of eggs, larvae and pelagic juveniles. The distribution of eggs and early larvae is one of the sources of information on spawning areas and times.

The eggs and larvae of ling were first described by M'Intosh and co-workers (M'Intosh and Prince, 1890; M'Intosh,1892; M'Intosh and Masterman,1897) and Heincke and Ehrenbaum (1900) and Ehrenbaum (1905-09). Most of the early data on distributions of eggs and larvae stem from the exploratory surveys conducted in 1903-1906 by the Danish research ship "Thor" and were published by Johs. Schmidt (1905, 1906, 1909). He also published descriptions of post-larvae and juveniles.

Ehrenbaum (1905) found ling eggs scattered in the North Sea, e.g. the deeper parts of the German Bight and at about 100 m depth north of Greater Fisher, in March-May. Schmidt (1909) found ling eggs over wide areas of the north-eastern Atlantic. Dannevig (1945) recorded ling eggs in the inner Oslofjord in April. In more recent surveys, ling eggs were either not reported or occurred in very low numbers.

Schmidt (1909) caught larvae and pelagic juveniles over most of the range of the species. Areas of apparent concentration were the waters southwest of Iceland and the Hebrides and Rockall. Catches were also made in the northern North Sea and the inner Skagerrak. Damas (1909) also reported catches from the northern North Sea but only few from the Norwegian shelf northwards to Lofoten. Bjørke (1981) reported no catches of ling larvae in the April surveys, and in recent Norwegian pelagic 0-group fish surveys along the entire shelf from Rogaland to Finnmark in April-May no ling occurred (Nedreaas and Smedstad 1987, Mehl et al. 1988, Nedreaas et al. 1989, Senneset et al. 1990). The same was the case in summer surveys covering the shelf north of approx. 62° N (Bjørke et al. 1989, 1991).

Ling larvae were recorded from larval surveys on the Norwegian Skagerrak coast in the period May-July (Myrberget 1965) and also in the open Skagerrak (Lindquist 1968). Bergstad and Gordon (1994) caught 7 ling larvae of total length 7-9 mm at 150 m depth in the Skagerrak in June, but in a seasonal sampling of the upper layers (0-60 m) in the same area, no ling larvae were recorded (Johannessen and Moksness 1991, E. Moksness, unpubl. data).

Based mostly on Schmidt's, Ehrenbaum's and Damas' data it appears that ling larvae occur in Atlantic water masses of temperatures 6-7° C and that the spawning area may be extensive, with apparent centres at Iceland, the Faroes and the Hebrides. The lack of records from recent surveys may reflect the depth distribution and/or timing of the sampling effort.

Schmidt (1909) caught most of his larvae in the depth zone 30-100 m, and few recent surveys sampled depths greater than 50-60 m. Most egg and larvae surveys were conducted in the spring, probably early compared with the spawning season. A particularly interesting observation is the widespread occurrence of tusk eggs (Ch. 5.3), but no ling and blue ling eggs along the Norwegian shelf. This may indicate that spawning of the ling in this area is at most sporadic. It may also reflect insufficient sampling.

5.1.2 Ageing

An exchange of 50 ling otoliths were carried out in 1994 between the nordic partners and the results were summarised at the workshop in 1994. Table 5.1 shows the results of pairwise comparisons among the different readers. This analysis indicated that there were systematic differences between the Icelandic and Bergen readers, and all the others. Plots of the deviations showed that Iceland and Bergen tended to estimate higher ages than others. However, when discussing the interpretations and considering Molander's (1956) results, it was easy to reach agreement on a common most probable age estimate. This was confirmed when new independent readings of 20 ling otoliths were made at the workshop (Table 5.2).

Table 5.1 Results of pairwise comparisons of age readings of 50 ling conducted in 1994. Probabilities from a series of Wilcoxon Signed Ranks tests. MF= Møre Research, IMRF= IMR Flødevigen, IMRB=IMR Bergen.

Readers	Iceland	MF	IMRF	IMRB
MF	0.0001			
IMRF	<0.0001	0.1		
IMRB	<0.0001	0.0001	<0.0001	
Faroes	0.0013	0.3	0.1	0.001

The conclusion was therefore that the Nordic project agreed on a common reading technique and interpretation for ling otoliths. The precision of the age estimates was considered acceptable and the technique simple. Otoliths should preferably be kept in ethanol or water after collection. If kept dry, soaking in water overnight may be necessary to re-expose the annuli. The otoliths should be read by transmitted light when submerged sulcus-side down in glycerol.

Otoliths from ling of TL>90-100 cm cannot be viewed in this way. Various attempts have been made to read annuli from broken surfaces or thin sections, but none have been overly successful. In commercial catches, rather few ling are this large, and most otoliths are readable. However, future work should aim at developing an acceptable method for big fish.

Table 5.2 Results from independent reading of 20 ling otoliths at the Nordic workshop in 1994. Reader codes as in Table 5.1.

FISH No.	AGE by READER				
	Icel.	MF1	MF2	IMRF	Faroes
1	4	4	4	4	5
2	5	5	5	5	5
3	6	6	6	6	5
4	4	4	4	4	4
5	5	5	5	6	5
6	4	4	5	4	5
7	4	4	4	4	4
8	4	4	4	4	4
9	6	6	6	6	7
10	4	4	4	4	4
11	5	5	5	5	5
12	4	3	3	3	4
13	4	3	3	3	4
14	4	5	3	3	4
15	6	5	6	5	6
16	6	5	5	5	6
17	3	2	2	2	3
18	7	6	6	6	7
19	6	5	7	5	6
20	7	6	7	6	7

5.1.3 Size distribution of catches

Division IIa

In Division IIa (Norwegian coast north of 62 N) the mean length of ling in the catches has varied between 77 cm and 91 cm during the period 1989 -1994 (Table 5.3). Figure 5.1 shows the length distributions. North of 64 ° N most of the landings are by-catches, while direct gillnet and longline fisheries for ling are conducted south of the 64° N. This means that combined length distributions from the whole area may be biased.

During the time-period 1990 - 1994 the proportion of relatively large fish, e.g. TL>100 cm, has declined. This was partly caused by an apparent variable recruitment of fish of TL<70 cm, e.g. in 1991 when there was almost no sign of recruiting length groups. In 1993 and 1994 new length groups were coming into the fishery, and caused a decline in mean length in 1993 and 1994.

Division IVa

In the Northern North Sea and north of Shetland most of the Norwegian landings of ling stem from directed longline fisheries. The length distributions indicate a reduction in mean length since the 1970s (Fig. 5.2) and a declining proportion of big fish in the landings.

Table 5.3 Mean length of ling by year and ICES area, from Norwegian longline catches
N - numbers measured.

ICES Area		1976	1988	1989	1990	1991	1993	1994	1995
IIa	Mean			81.7	89.4	91.1	79.5	77.1	
	Std. dev			15.2	13.5	13.5	13.7	12.3	8.3
	N			61	384	63	122	304	382
IVa	Mean	87.0	81.1	76.8	81.1		74.6	77.0	81.1
	Std. dev	13.8	14.4	12.5	12.3		14.5	10.8	13.0
	N	1133	989	487	698		589	830	2207
Vb1	Mean			80.0			76.7		
	Std. dev			13.7			12.1		
	N			45			107		
Vb2	Mean	90.3		82.7	85.0				
	Std. dev	13.8		12.0	13.7				
	N	253		614	318				
VIa	Mean	80.0		79.1			71.9	72.0	73.7
	Std. dev	11.5		13.5			10.6	10.5	10.0
	N	492		969			472	616	583
VIb	Mean	89.7		72.5	77.7		79.8	92.0	88.3
	Std. dev	9.8		16.7	13.6		12.4	16.2	12.2
	N	507		518	261		47	401	48
All areas	Mean	86.5	81.1	78.4	83.3	91.2	74.5	78.4	81.1
	Std. dev	13.0	14.4	14.2	13.7	13.6	13.1	13.9	13.0
	N	2385	989	2694	1661	63	1337	2152	3220

This is a combined effect of a depletion of the stock of large fish and variable recruitment. Especially in 1993 the proportion of fish of TL<70 cm was high, about 45 % by numbers in the catches. In 1994 and 1995 this length category contributed 23% and 18%. This indicates relatively high recruitment in 1993.

Division Vb

Length distributions from Faroese waters are shown for each of the Subdivisions Vb$_1$ and Vb$_2$ (Fig.5.3 and 5.4). In Vb$_2$ there was a much higher proportion of large fish in 1976 than in 1989 and 1990, probably indicating a change caused by the increasing exploitation in the 1970s. Faroese data (Anon 1994) show a trend towards smaller mean length in the ling landings.
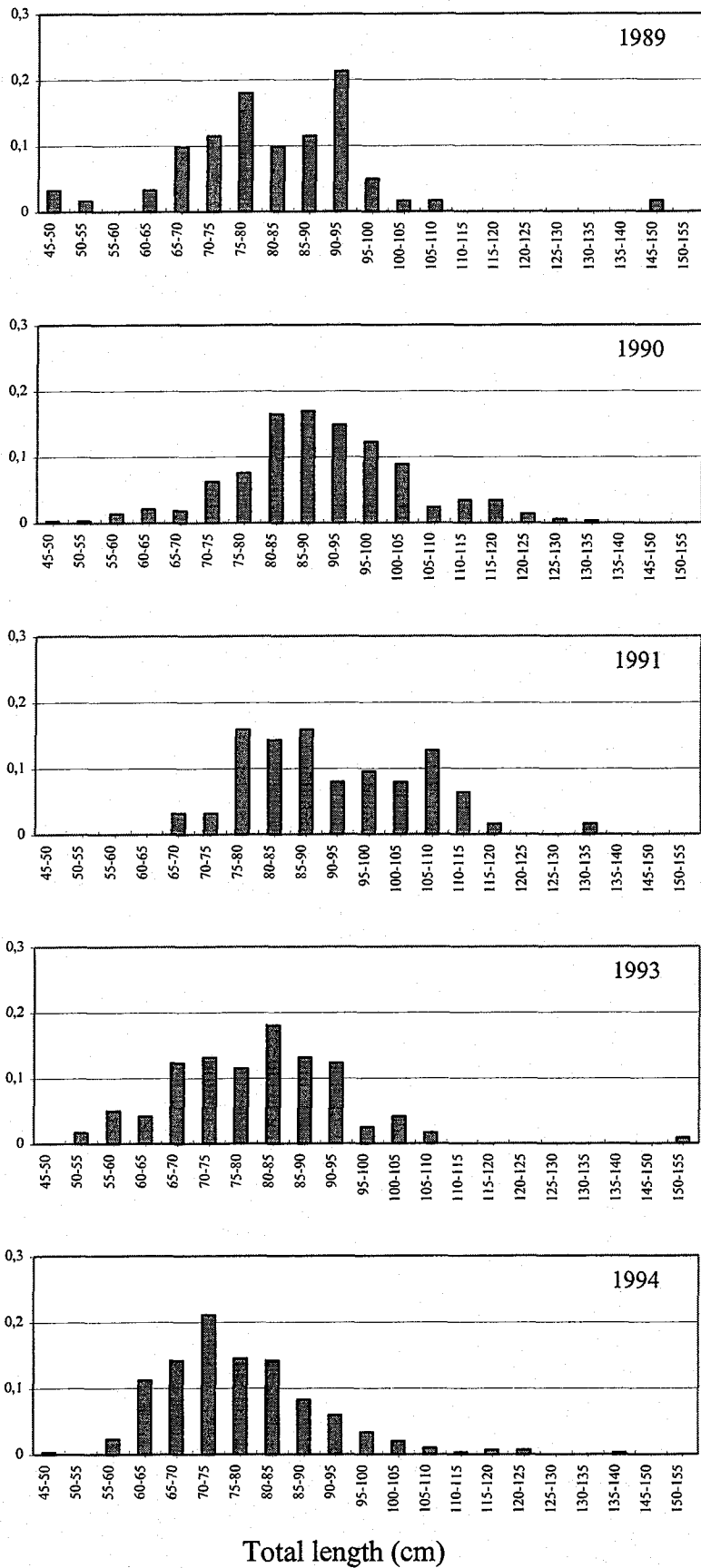
Figure 5.1 Length distribution of *ling* in ICES Division IIa by year.
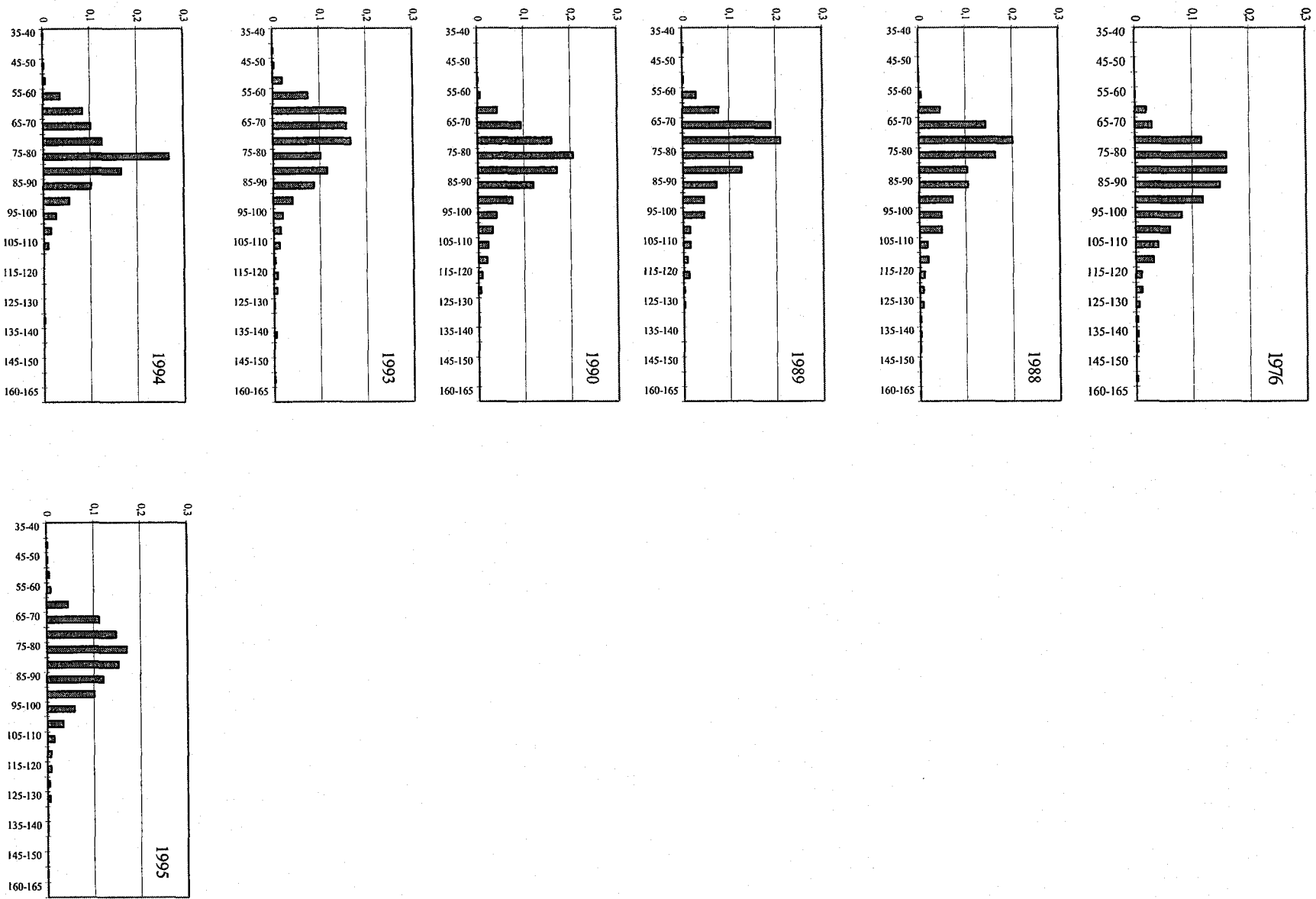
Figure 5.2   Length distributions of *ling* in ICES Division IVa by year.

45
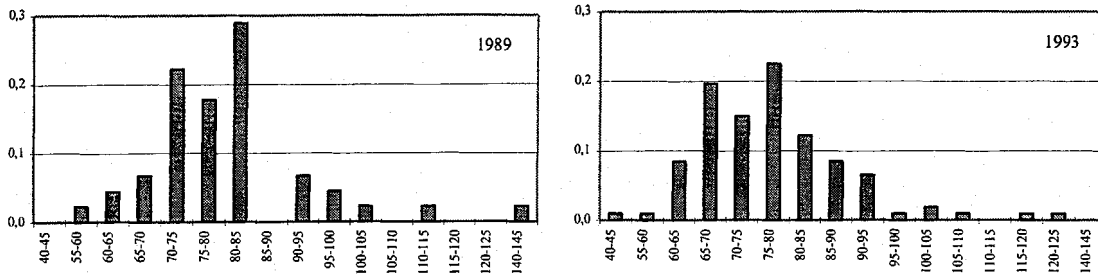
Figure 5.3 Length distribution of *ling* in ICES Subdivision Vb1 1989 and 1993
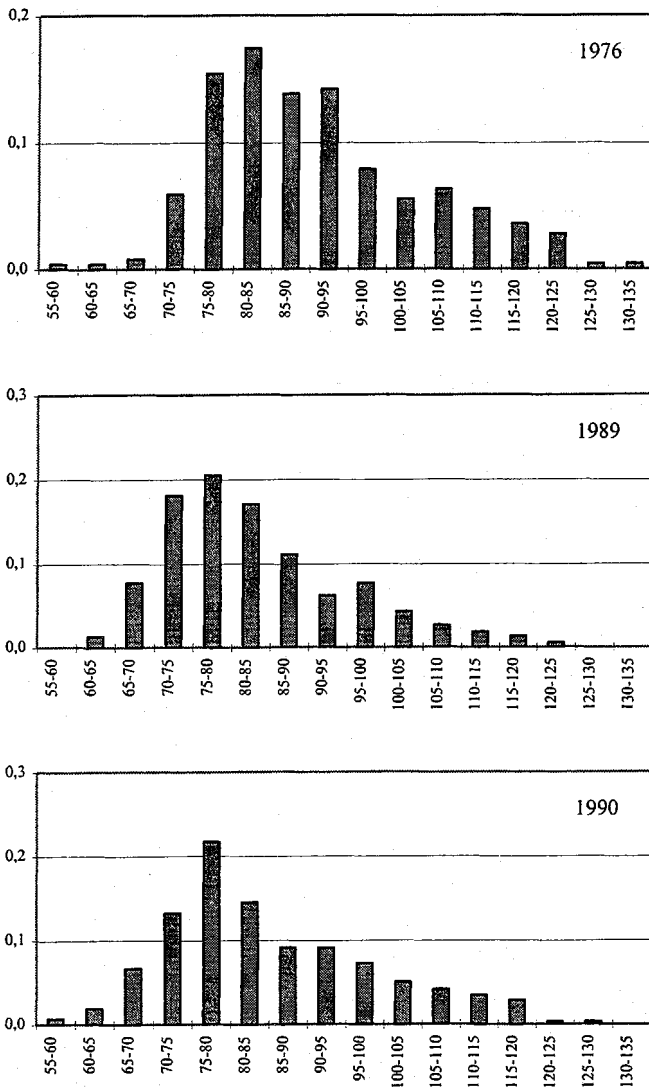
Figure 5.4 Length distributions *ling* in ICES Subdivision Vb2 1976, 1989 and 1990.

Division VIa

In the west of Hebrides waters most of the Norwegian landings of ling are caught in directed longline fisheries. The length distributions indicate a reduction in mean length since the 1970s (Fig. 5.5). The reduction in mean lengths in the period 1993-1995 (Table 5.3)

46

seems to be caused by relatively strong recruitment in 1993 and 1994. In 1993 and 1994 the proportion of fish smaller than 70 cm was 45 % and 47%, while in 1995 it was only 37%.
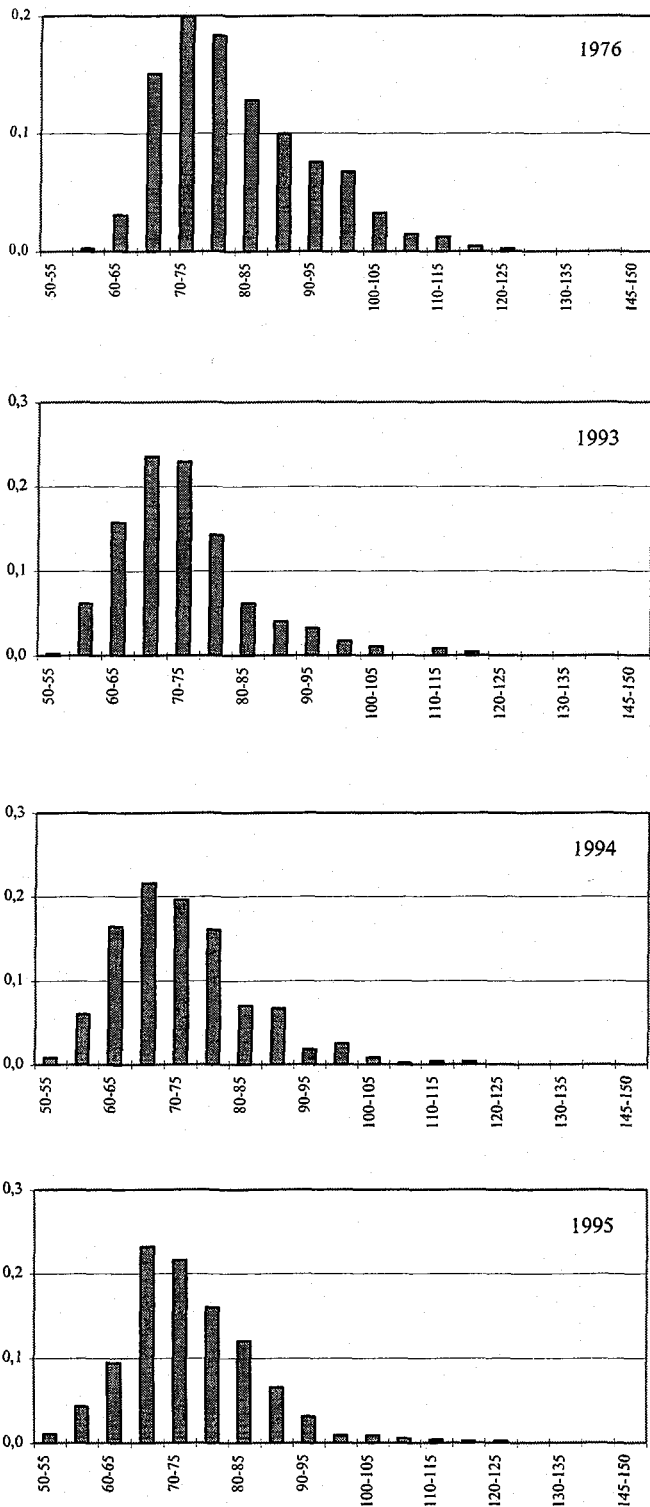
Figure 5.5 Length distributions of *ling* in ICES Division VIa by year.

Division VIb

All Norwegian landings at Rockall are caught by longlines. Ling is the main catch on the Rockall Plateau, however at some smaller banks to the north-west of Rockall, tusk is the main catch. In this area, the interannual variation in the length frequency distributions seems higher than at other grounds, probably due to greater variation in recruitment. Relatively strong recruitment occurred in 1989 and 1993. In 1993 the proportion of fish smaller than 70 cm amounted 26 % of the numbers in the catches. In 1994 and 1995 the proportions were 11% and 2% respectively.
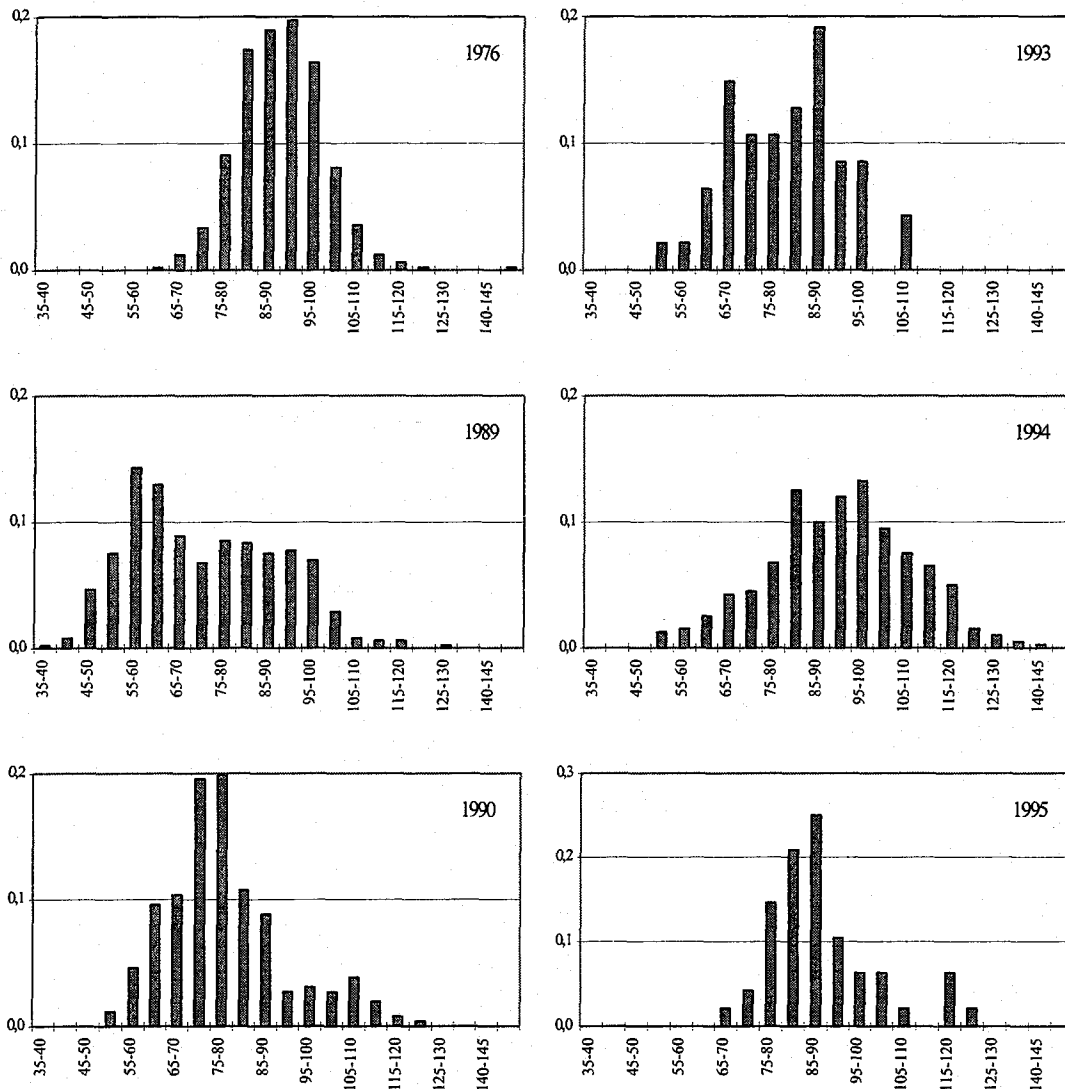
Figure 5.6 Length distributions of *ling* in ICES Division VIb by year.

5.1.4 Age distributions

Age distributions derived from age-length keys from the different ICES Divisions are shown in Figs 5.7-5.11. The ling recruit to the fisheries in the age range 4-7 years, with the majority as 5 and 6 year-olds. Up to 11 age-groups occur in the catches. Following recruitment, a year-class contributes significantly to the catches for 4-5 years. There were no consistent differences between fishing areas.

In some cases, relatively strong year-classes can be followed from year to year, e.g. the 5-year old 1989 year-class in Sub-division IIa in 1993 (Fig. 5.7). This year-class was prominent in the age-distributions in all the years 1993, -94 and -95.

5.1.5 Recruitment

As seen from the length and age frequency distributions, the ling is recruited to the longline fishery at a length of 50-70 cm and age of 4-7 years in all areas. Some indications of variation in recruitment were described in the preceding sections.

An alternative source of information on the variation in recruitment was however also explored. The market price of small ling, i.e of TL<72 cm is lower than that for bigger ling, hence many vessels keep records of the catches sorted according to size categories. Such information was available for 55 fishing trips for most years from 1974 to 1995. Catch per unit of effort of ling of TL<72 cm in terms of weight was calculated from these data (Fig. 5.12). Data from all fishing areas were combined, hence area-specific patterns would be masked. However, the analysis indicates that considerable recruitment variation has occurred. The rather high value for 1993 corresponds well with the indications of strong recruitment in that year seen from the length frequency distributions above.
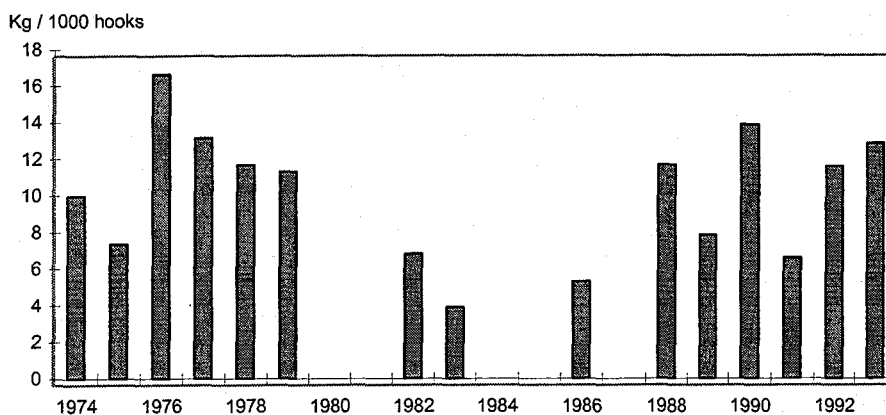
Fig. 5.12. Catch per unit of effort of ling of TL<72 cm from Norwegian longliners. Data were not available for the years 1980, -81, -84, -85 and -87.
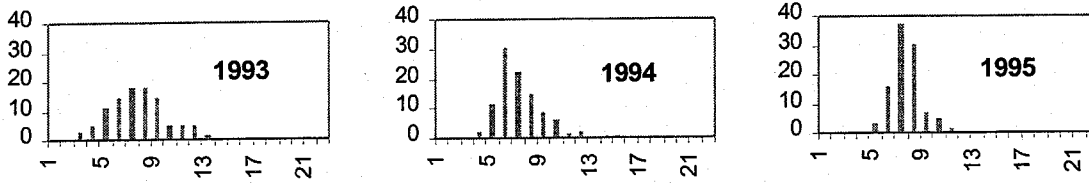
Figure 5.7. Age distributions of ling from Sub-division IIa.
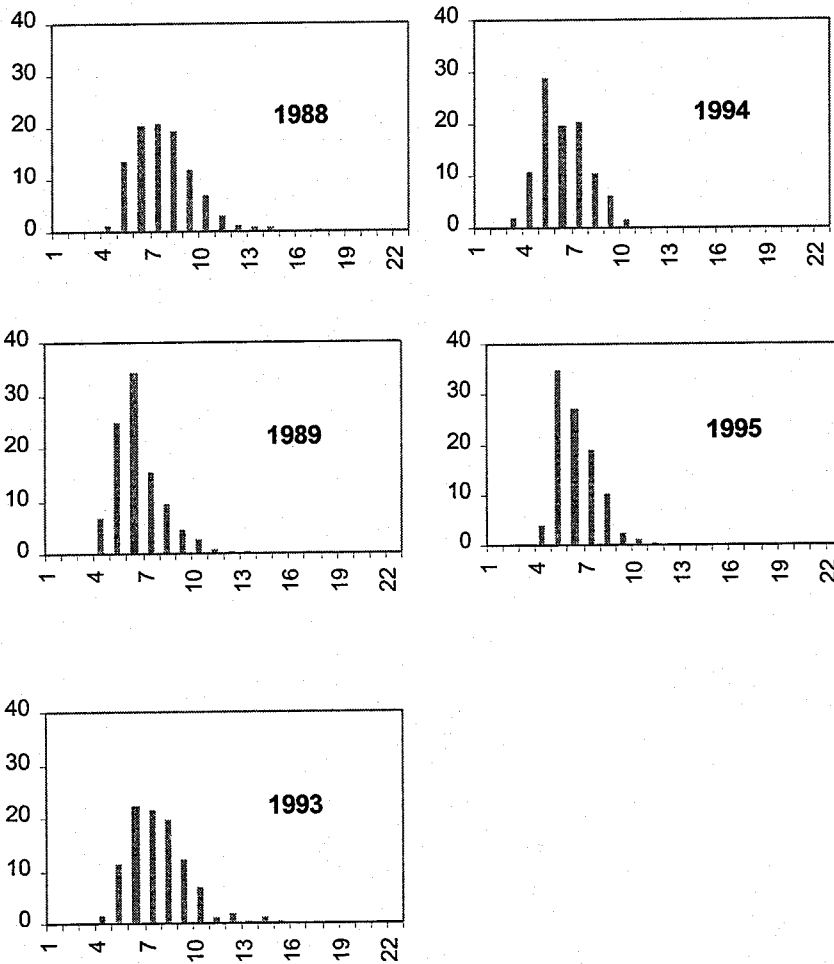
Figure 5.8. Age distributions of *ling* from ICES Sub-division IVa, 1988-95
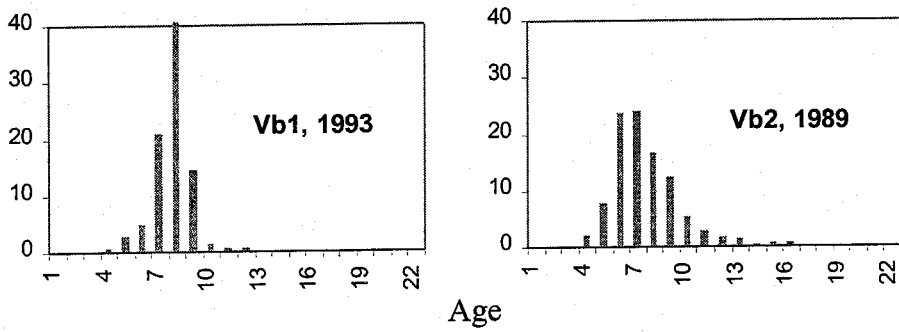
Fig. 5. 9. Percentage age distributions of *ling* from ICES Sub-divisions Vb1 and Vb2.
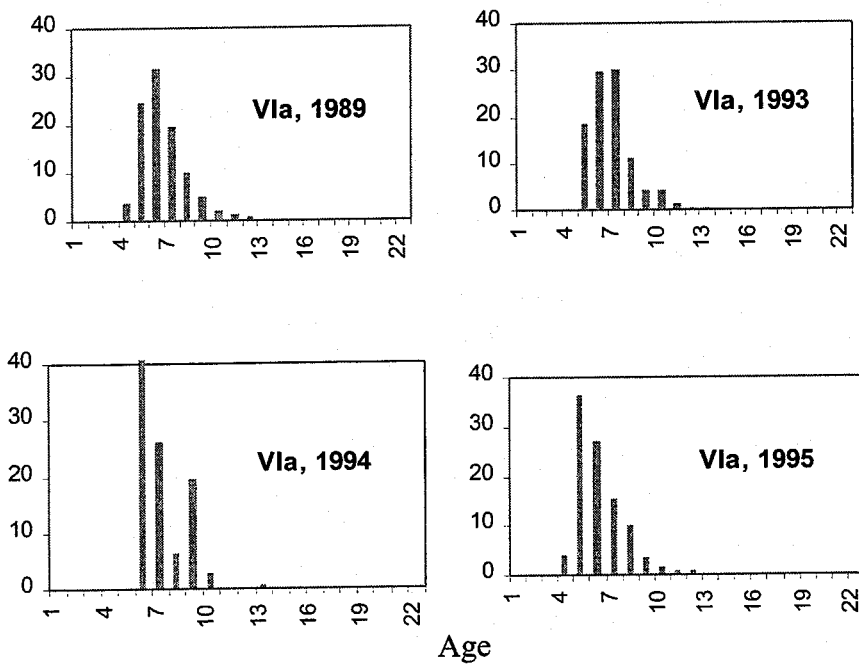
Figure 5. 10. Age distributions of *ling* from Sub-division VIa, 1989-1995.
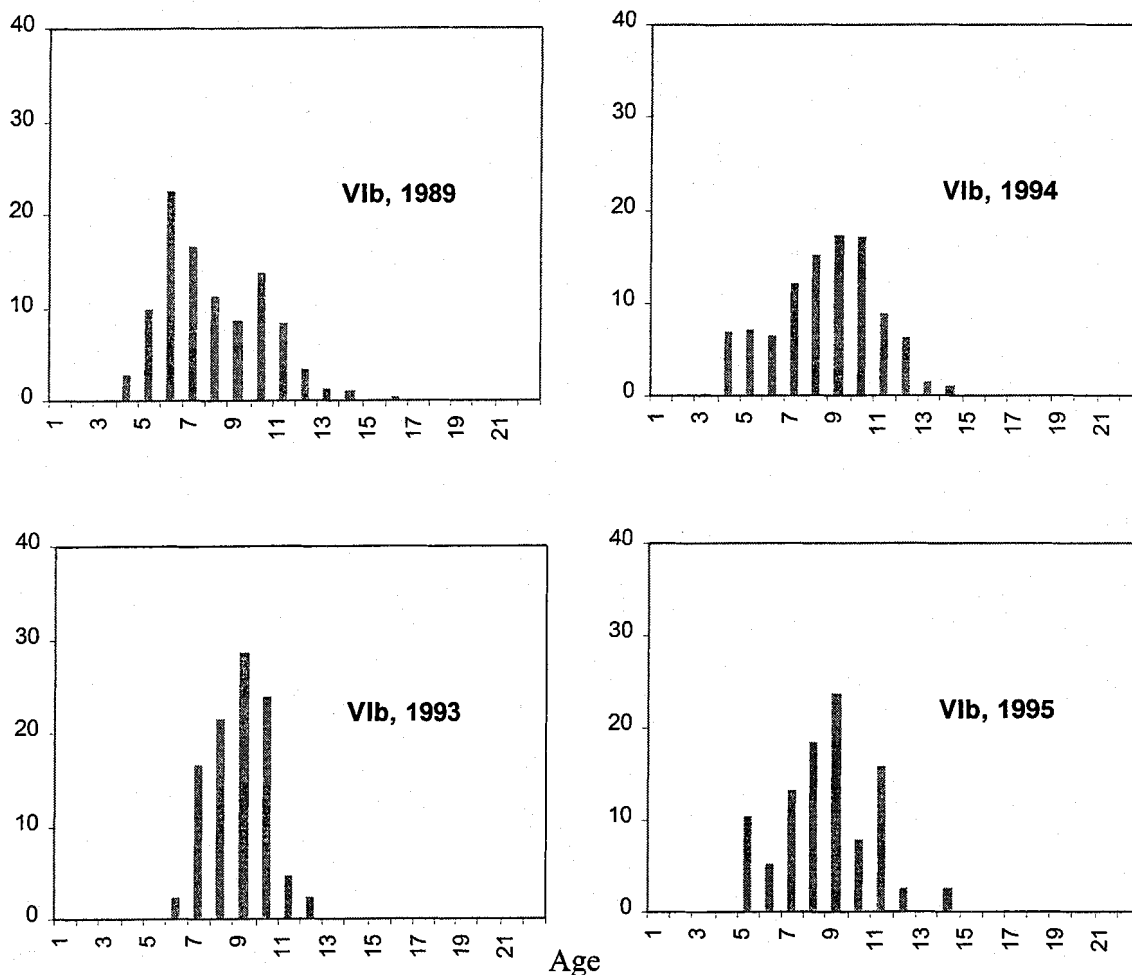
Fig. 5. 11 Age distributions of *ling* from ICES Division VIb, 1989-1995.

5.1.6 Mortality

Estimates of the coefficient of mortality, Z, can be derived from analyses of the age-distributions for single years by so-called catch curve analyses. The underlying assumptions are that recruitment is constant and that emigration and immigration is insignificant. Examples of catch-curves are shown in Fig. 5.13. Z is estimated as the linear regression of the logarithmic abundance of all fully recruited age-groups on age.

Estimates were calculated for Sub-divisions IIa, IVa, and Vb based on longline data. Z ranged from 0.4 to 1.0, with a mean value of 0.6 (S.D.=0.2, n=6). Assuming a coefficient of natural mortality M=0.1, the analysis indicate that fishing mortality is at a high level.
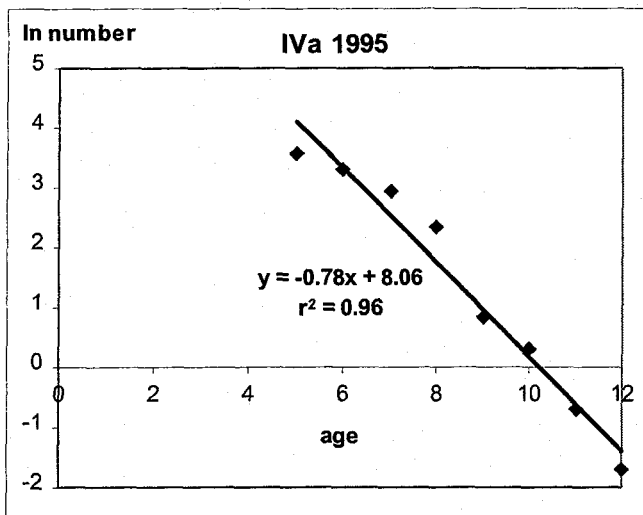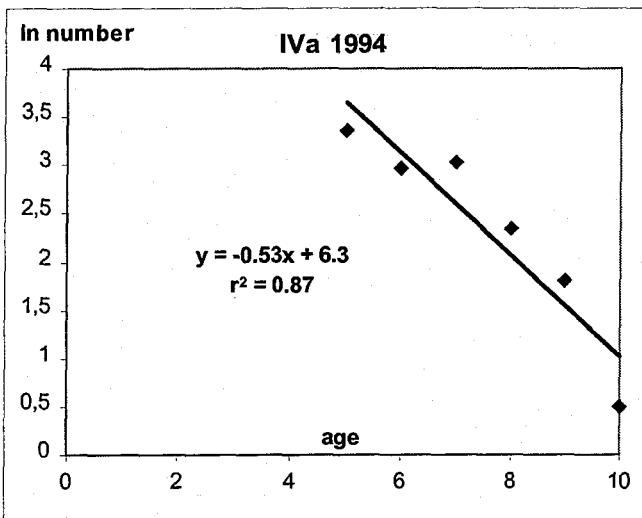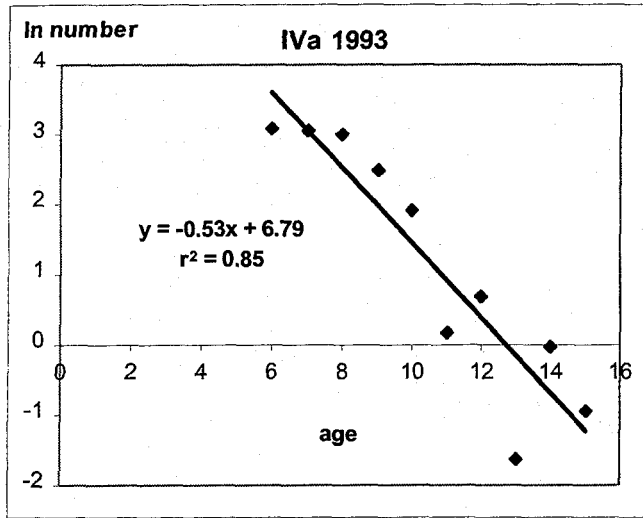
Figure 5.13. Catch curves of ling from longline catches used to estimate the coefficient of mortality, Z.

5.1.7 Length and weight at age

The mean lengths at age of ling from different ICES divisions are given in Figure 5.14 and the mean length-at-age for both sexes combined in Table 5.4. The females grow bigger than the males. The ling in IIa seem to be the biggest and those in VIa the smallest, but for many
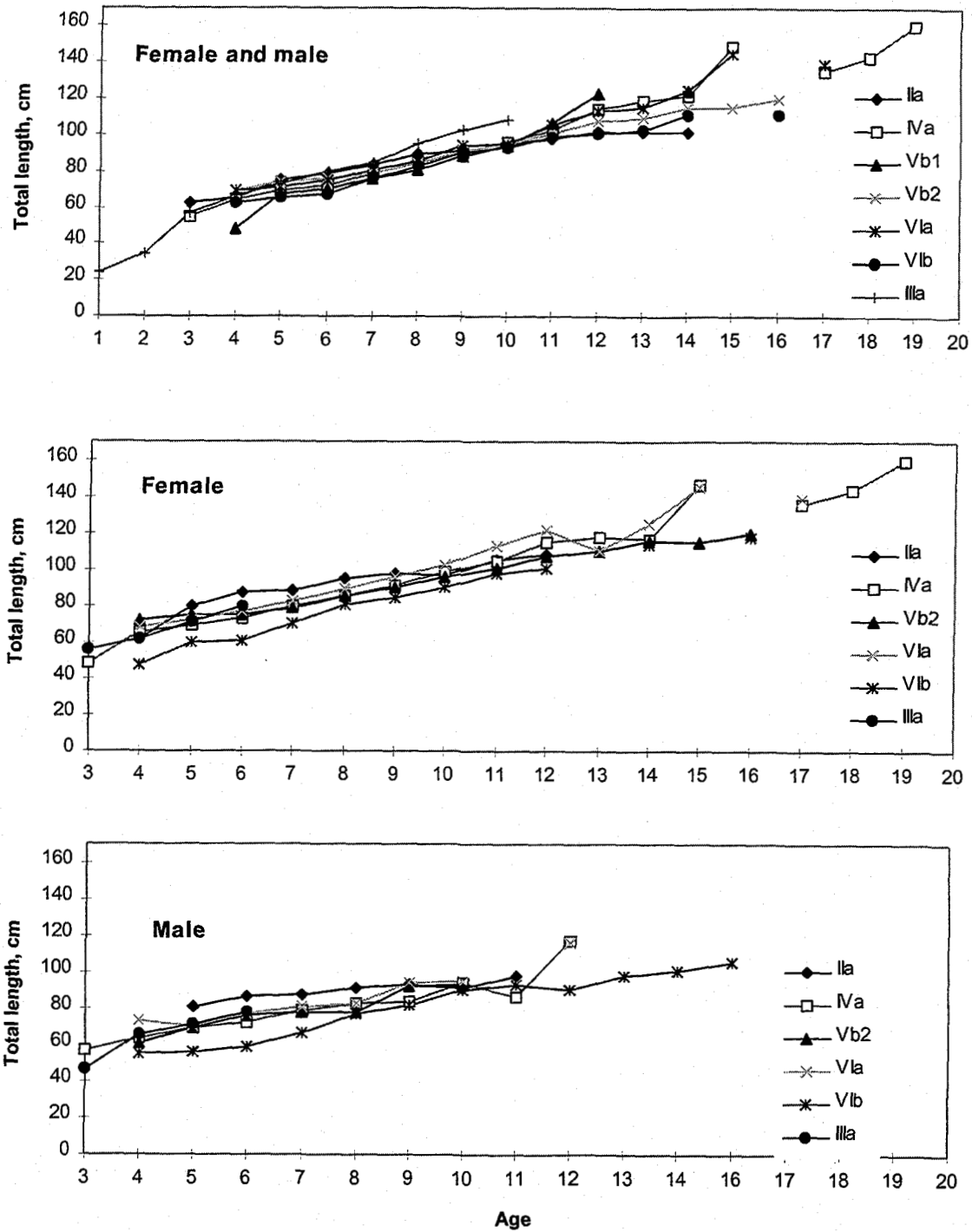
Fig. 5.14 Mean length at age of *ling* from different ICES Subareas.

age-groups the sample sizes were insufficient to draw conclusions on geographical differences. Getting samples of 1-3 year old ling was a problem in all areas, and the data on 1 and 2 year old ling from IIIa were taken from Molander (1956).

Mean weight at age of female and male ling is plottet in Fig. 5.15. The considerable variation observed for many areas and ages reflects low sample sizes.

Table 5.4 Mean length at age of *ling*, sexes combined, from different ICES subdivisions. Data from 1988-1995 combined.

Age		IIa	IVa	Vb	VIa	VIb
3	Mean		48.5			
	N		2			
4	St. Dev.		7.5	5.3	7.3	
	Mean	62.0	65.9	72.3	68.4	47.3
	N	1	42	6	22	3
5	St. Dev.		9.4	5.9	6.4	8.1
	Mean	79.3	69.7	75.2	72.2	59.9
	N	3	221	22	117	15
6	St. Dev.	9.0	7.9	5.4	7.1	7.7
	Mean	87.7	73.3	75.4	76.7	61.0
	N	15	244	76	126	18
7	St. Dev.	6.9	9.1	6.5	8.2	8.0
	Mean	88.7	80.2	78.4	82.9	70.6
	N	31	194	86	105	23
8	St. Dev.	9.4	9.3	8.0	8.6	7.3
	Mean	94.8	85.2	85.8	89.6	80.9
	N	35	145	55	56	23
9	St. Dev.	9.3	10.7	6.7	11.4	4.8
	Mean	98.2	91.5	90.7	96.2	84.4
	N	13	66	42	34	19
10	St. Dev.	8.9	13.7	7.8	12.5	6.5
	Mean	97.3	99.0	95.8	103.0	89.8
	N	8	40	17	15	20
11	St. Dev.		8.8	6.5	17.3	7.1
	Mean	105.0	104.4	100.5	112.9	97.9
	N	2	20	10	9	14
12	St. Dev.		17.6	4.0	4.2	4.9
	Mean	108.0	114.9	107.1	121.6	100.6
	N	3	13	7	5	9
13	St. Dev.		6.7	4.7		
	Mean		118.0	109.8	110.0	
	N		6	6	1	
14	Mean		116.5	115.7	125.0	114.3
	N		4	3	1	4
15	Mean	139.0	146.0	115.0	145.0	
	N	1	1	2	1	
16	Mean		119.7			118.0
	N		3			1
17	Mean		135.5		139.0	
	N		2		1	
18	Mean		143.0			
	N		1			
19	Mean		160.0			
	N		1			
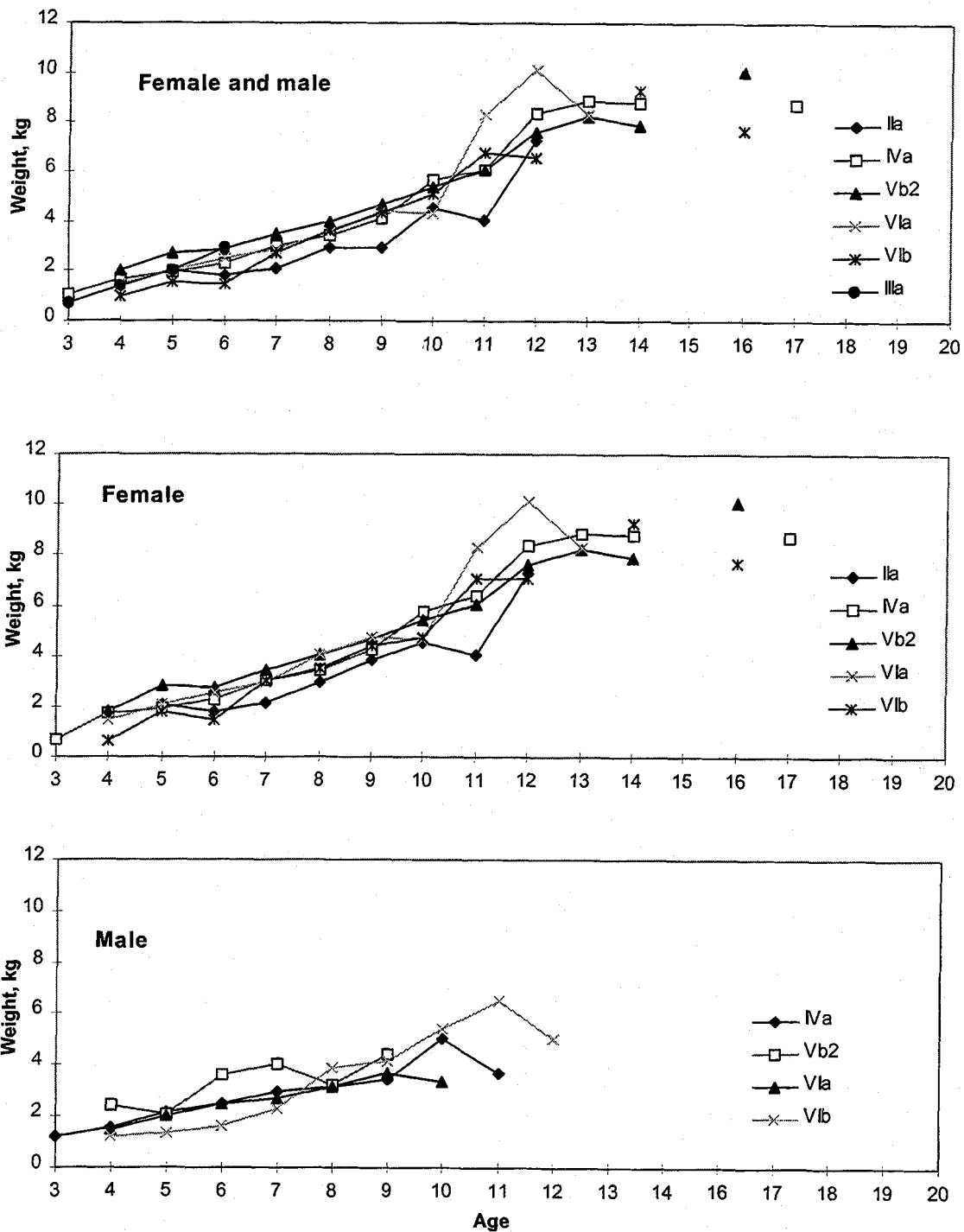
Figure 5.15 Mean weight at age of *ling* from different ICES Subareas.

5.1.8 Age and length at maturity

Figure 5.16 and 15.17 show maturity data from samples collected in the months March-June. The ling appears to become mature at age 3-8 years (Fig. 5.16). Fifty percent of the fish have become mature at age 5 years. The males may mature at a slightly lower age and length than the females. The lengths at which 50 % of the males and females mature are approximately

52 and 67 cm respectively (Fig. 5.17). There were no indications of geographical variation in the available data.
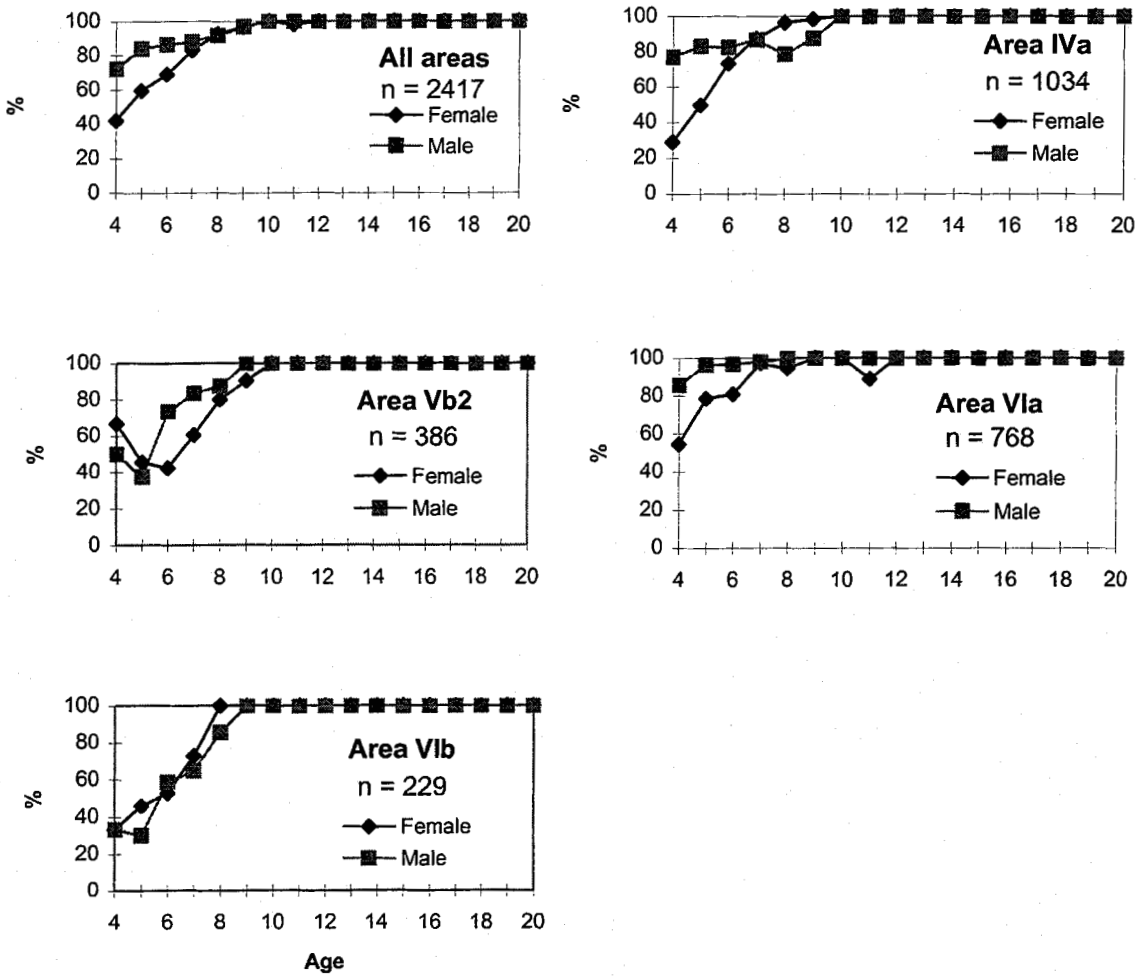
Figure 5.16 Percentage mature ling by age in different ICES subareas.
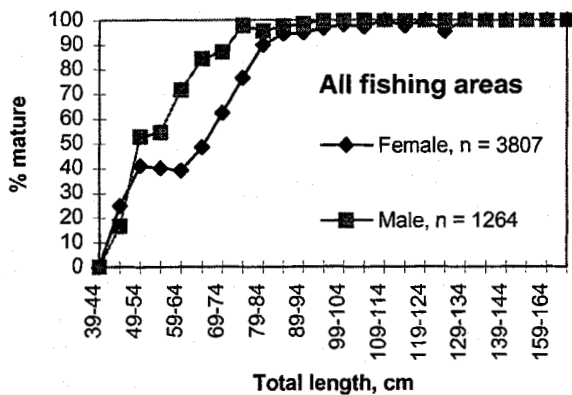
Figure 5.17 Percentage mature ling by length. Data from all ICES Subareas sampled.

5.2 Blue ling

5.2.1 Distribution of eggs and larvae

The eggs of the blue ling have not been described (Russell 1976). Schmidt (1906,1909) reported blue ling larvae and juveniles from west and north of Scotland, at the Faroes and south-east Iceland, also in oceanic waters between Iceland and Scotland. No catches were made in the North Sea and only a single one in the Skagerrak. Blue ling was not reported from more recent surveys, probably due to low effort at the relevant depth and time.

5.2.2 Ageing

Blue ling otoliths show growth patterns which are quite different from those seen in ling otoliths. A problem has been the interpretation of the first few annuli, simply because of lack of small fish in the samples. Only at Iceland have significant numbers of small juveniles been caught.

Several attempts were made to read blue ling otoliths in the past, and the methods have varied from the reading of broken surfaces (Magnusson 1982) to various forms of sectioning (Engås 1983; Ehrich and Reinsch 1985; Thomas 1987; Bergstad 1991, also recently French workers). There has been no co-ordinated effort towards developing a common accepted method, however, nor any evaluation of the scattered early trials. In the Norwegian project the method and interpretation of Engås (1983) was considered the most promising and this is similar to that adopted by the Faroes. However, the Nordic project has not yet reached a conclusion on what technique and interpretation is preferable.

In the Arendal workshop in 1995, Icelandic length frequency distributions from March groundfish surveys were presented. In these distributions modes which probably represent age-groups appear among the smallest fish. Age readings of transverse otolith sections from fish of TL< 60 cm indicated that the two first identifiable modes were most probably 1- and 2-group. The 1-group were in March mostly less than 20 cm, the 2-group very variable between 20 and 40 cm.

The first annulus appears many times to be split into fairly distinct sub-zones. It seemed important to consider the relative width of the opaque zones. Accepting these observations, much better agreement was achieved, also with the Icelandic readings which were in line with the age-groups indicated by the length data.

With larger fish, there still seems to be problems, and both low precision and inconsistencies must be expected during independent reading of otoliths. More otoliths should be regarded as unreadable and be excluded. Overall, however, some progress was made on the ageing of small fish, and at least from Iceland there was some support by the length frequency data for the interpretation of the otoliths of 1-2-group fish.

It was suggested that mounting of the sections in clear resin would be beneficial in stead of the black resin used by Iceland and the Faroes. This is crucial if the sections are to be examined by a compound microscope. Using a compound microscope may be especially helpful when reading sections from large fish.

5.2.3 Size and age distributions, recruitment, growth and maturation

Blue ling is mostly caught by trawl and in some areas gill-nets, and it is a minor by-catch in the longline fisheries. It is much less important to Norwegian fleets than ling and tusk, and it has proven difficult to obtain sufficient samples from the fisheries in the project period. This species was thus given relatively low priority. In addition, the ageing problem has not been solved, and little new information on central aspects such as age composition, growth and age at maturation was obtained. The Nordic project focuses stronger on blue ling, partly because this species is more abundant in Faroese and Icelandic waters and targeted in national fisheries there.

The literature on blue ling is relatively rich (Ch. 4), and some data are also available from Norwegian waters. The only directed fishery in Norwegian waters is the gillnet fishery at Storegga (Ch. 3). This started as a blue ling fishery in the late 1970s, but has gradually changed into a ling fishery. Data from the early 1980s were analysed by Engås (1983). Other scattered data from Norwegian waters come from trawl surveys, e.g. in IIa (Joenoes 1961) and in the Norwegian Deeps (IVa and IIIa) (Bergstad 1988, 1991). These reports contain catch and distribution data, length and age distributions, length-at-age data and length-weight relationships.

The few length distributions from samples collected in 1976 and in this project are shown in Fig. 5.18. Age samples are also available but have not been processed due to the unresolved ageing problems.

Engås' and Bergstad's age readings suggested that the blue ling catches in the 1980s were dominated by large and old fish. In the trawl catches from the Norwegian Deeps as much as 20 age-groups occurred and about 20 % of the fish were older than 20 years. It is unclear, however, whether the otolith zones counted were actually annuli.

Joenoes reported length at maturity data which showed that 50 % of the blue ling were mature at a total length of about 75 cm, males at a slightly lower length than females.
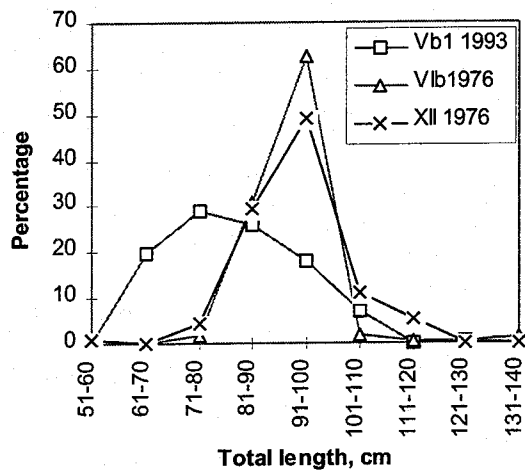
Figure 5.18 Length distributions of *blue ling* from longline catches, 1976 and 1993.

5.3 Tusk

5.3.1 Distribution of eggs and larvae

Ehrenbaum (1909) reported catches of eggs from the northeastern North Sea (Greater Fisher, The Norwegian Deep) and the Skagerrak in April, May and June. Dannevig (1947) also caught many eggs in late May in the inner Skagerrak. Schmidt (1909) provides a chart of the egg catches and the distribution includes waters to the north and west of the British Isles, the Faroes and south and west Iceland. Dannevig (1919) recorded many tusk eggs in Vestfjorden of Northern Norway in the spring, as did Wiborg (1950, 1952, 1954, 1957) who also found eggs further south to the Shetlands and north to Fugløy on the north Norwegian shelf. Wiborg regarded april-may to be the months with most tusk eggs. In Gulf III surveys in April 1976-1980, Bjørke (1981) recorded tusk eggs in the depth interval 0-60 m on the Norwegian shelf from Sognefjord (approx. 61° N) to Lofoten and catches varied from 1 to 136 eggs·m^{-2}. Russian egg data have shown a distribution even further to the north in the soutwestern Barents Sea and eastwards to the Kola peninsula (Lukmanov *et al.* 1985). The data available show that spawning occurs over the entire range of the species and primarily in shelf waters.

According to Schmidt (1905, 1909) tusk larvae and juveniles are mostly absent from all but the northernmost areas of the North Sea , but otherwise widespread from the Hebrides and Rockall, the Shetlands and Faroes to Iceland. At Iceland catches were also made along the northern shelf. Again there is little or no data from more recent sources.

5.3.2 Ageing

Most of the effort on ageing in the project was focused on tusk. The tusk otolith is best viewed *sulcus-side up* by reflected light (against a black background). The otoliths from specimens of TL >70 cm must be sectioned.

The interpretation problems are serious and in most tusk samples 20 - 30 % of the fish in the length range 40 - 70 cm have unreadable otoliths and only very few big fish can be aged with confidence. The age readings will probably remain comparatively imprecise. Age readings obtained with the present technique may be useful for general studies of population biology, but to form a basis for analytical assessments a higher level of precision must be achieved.

At the onset of the project, there were systematic differences between the readings of Møre and Romsdal Research Foundation (MF) and the IMR readers. In national and Nordic workshops the interpretation of the growth zones have been discussed and compared, and consensus on a common interpretation principle reached. In the exchange experiment prior to the Arendal workshop in 1995, plots of the frequencies of differences between different readers showed that mostly unsystematic differences between readers were 1-3 zones (of fish

7-15 yrs old) with only limited bias (Fig. 5.19). In some cases differences were much larger, however, indicating more serious interpretation problems or that the otoliths were of poor quality and should have been excluded as unreadable. The participants agreed that it would probably be difficult to achieve better results and with tusk of medium size (as found in long-line catches), errors of at least 1 - 2 years would probably have to be accepted during routine ageing. Questions were raised about the expected stability with time of the interpretations, and it was decided to exchange the same set of otoliths again to test this. This exchange is now in progress.
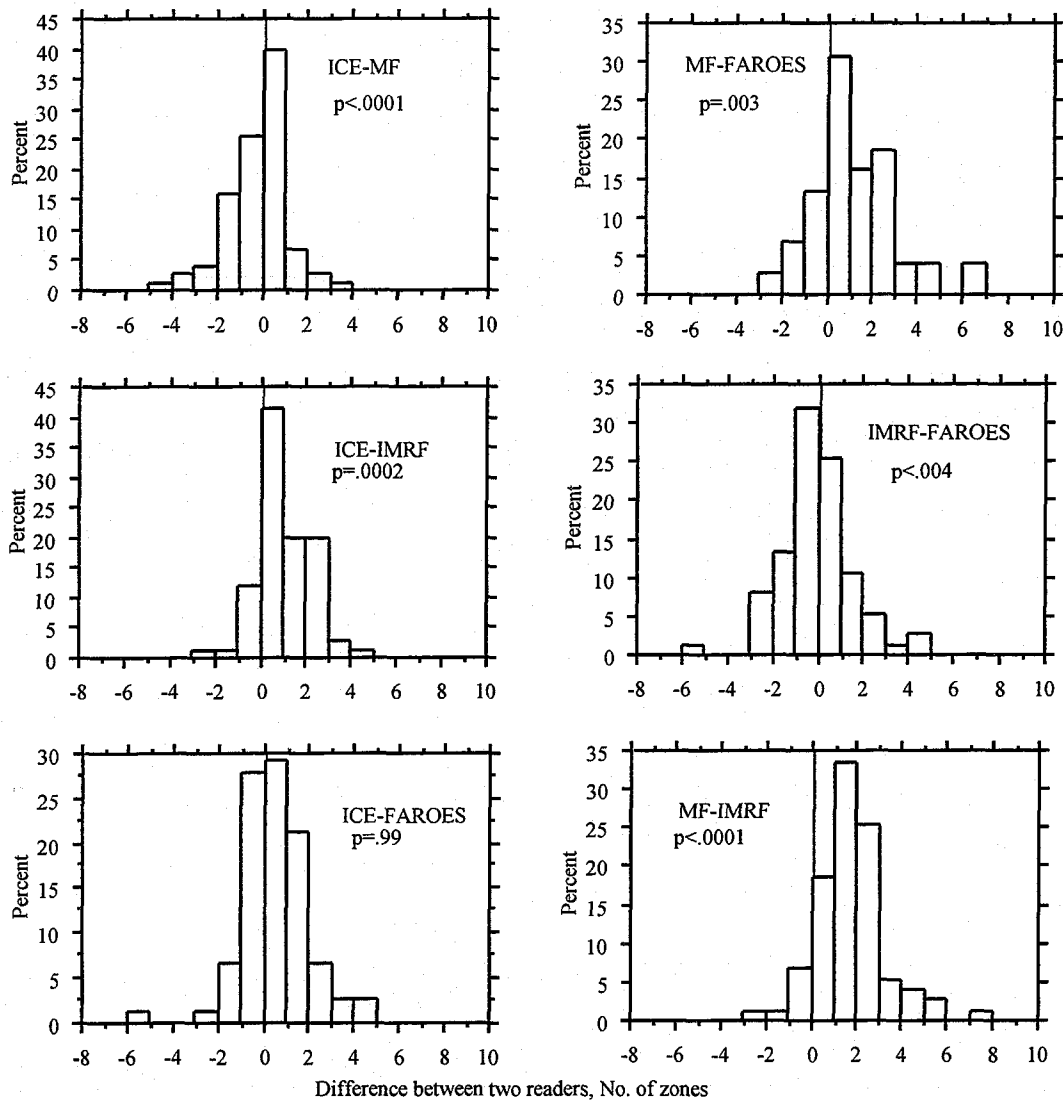
Figure 5.19 Comparisons of age readings of 75 Norwegian tusk in 1995. Histograms show the difference between readings by two readers. p-values are probabilities from pairwise Wilcoxon Rank Sum tests. Length range: 37-82 cm. Cases where one or more readers had not recorded the age were excluded prior to the analysis (n=13).

At the same workshop, the Icelandic partners reported on the analyses of length distributions of tusk from groundfish surveys and corresponding age-readings of specimens less than 40 cm TL. There was overall very good correspondence between the modes and the mean length of successive age-groups obtained by otolith ageing in the age-range 2-4 yrs. The unexpected result was that the first mode of mean length around 15 cm represented 2-group and that the 1-group were probably only 7-8 cm in March. These results were very promising since they largely confirmed that the agreed definition of annuli of young fish was correct.

5.3.2 Size distribution of catches

Division IIa.

In Division IIa the mean length of tusk in Norwegian longline catches has varied between 50 and 55 cm in the period 1988-1995, with a decrease in the years 1993 to 1995 (Table 5.5). The tusk is mostly a by-catch in this area. In 1995 there was apparently a relatively good recruitment of 35-45 cm fish (Fig. 5.20).

Division IVa.

In Subdivision IVa the tusk is mostly a by-catch in the ling fishery in the Norwegian Deeps and north of the Shetlands. The mean length has decreased considerably from 60 cm in 1976 to 50-55 in 1988-1995 (Table 5.5). Length-distributions are given in Figure 5. 21.

Table 5.5 Mean length of *tusk* from longline catches by ICES Subdivision and year.

Year	Data	IIa	IVa	Vb1	Vb2	VIa	VIb	XII	total
1976	Mean length		60.53	65.44	63.76	65.08	67.28	68.26	65.62
	N		377	289	142	150	853	337	2148
1988	Mean length	63.14	49.89						50.08
	N	14	976						990
1989	Mean length	50.80	52.69	57.55	55.78	57.00	53.33		53.12
	N	1231	1329	107	470	385	954		4476
1990	Mean length	55.39	53.45		56.64	60.34			56.64
	N	1273	636		852	973			3734
1991	Mean length	54.81		54.23					54.73
	N	865		139					1004
1993	Mean length	50.72	46.80	48.24		54.18	49.02		49.84
	N	1374	336	466		190	341		2707
1994	Mean length	49.78	49.87	52.07		53.67	54.96		51.13
	N	1837	1379	201		206	916		4539
1995	Mean length	49.51	54.62			54.39			53.45
	N	377	1209			72			1658
Mean length		51.81	52.24	54.54	57.06	58.55	57.22	68.26	54.12
N length		6971	6242	1202	1464	1976	3064	337	21256
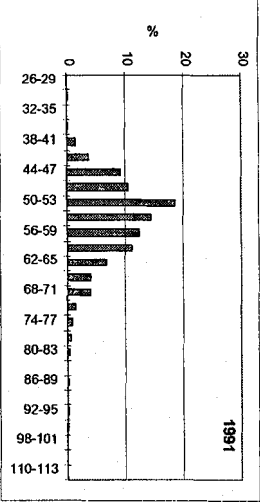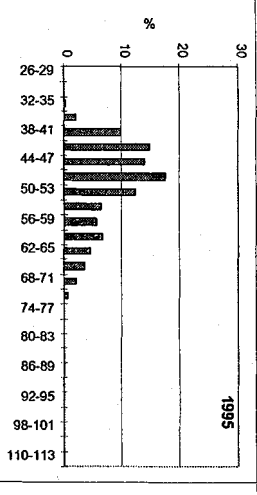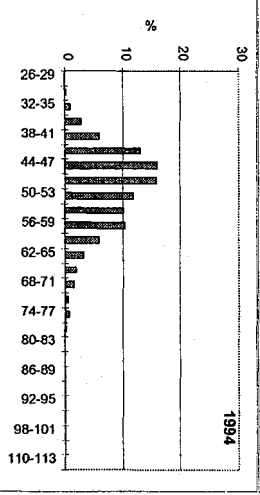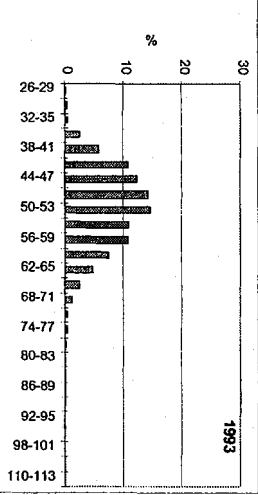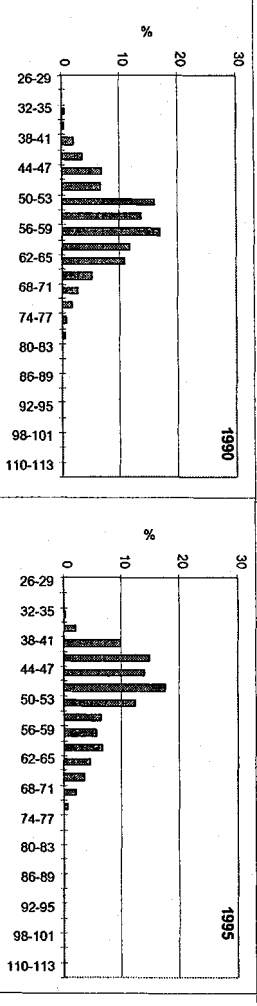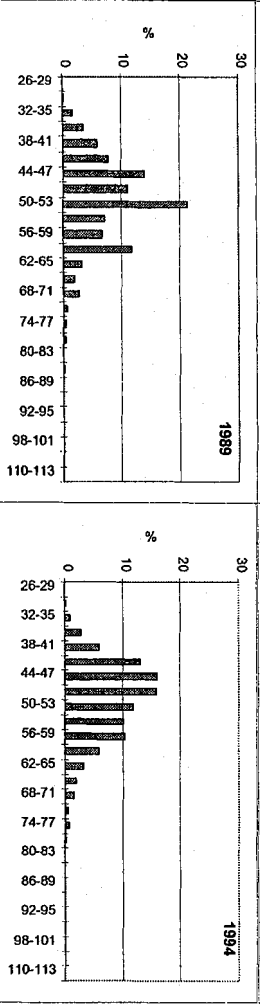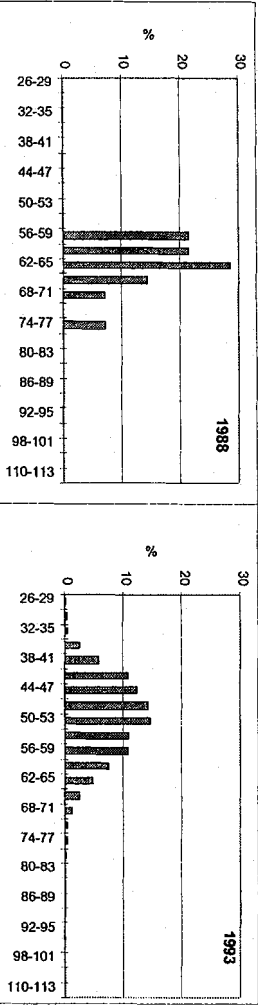
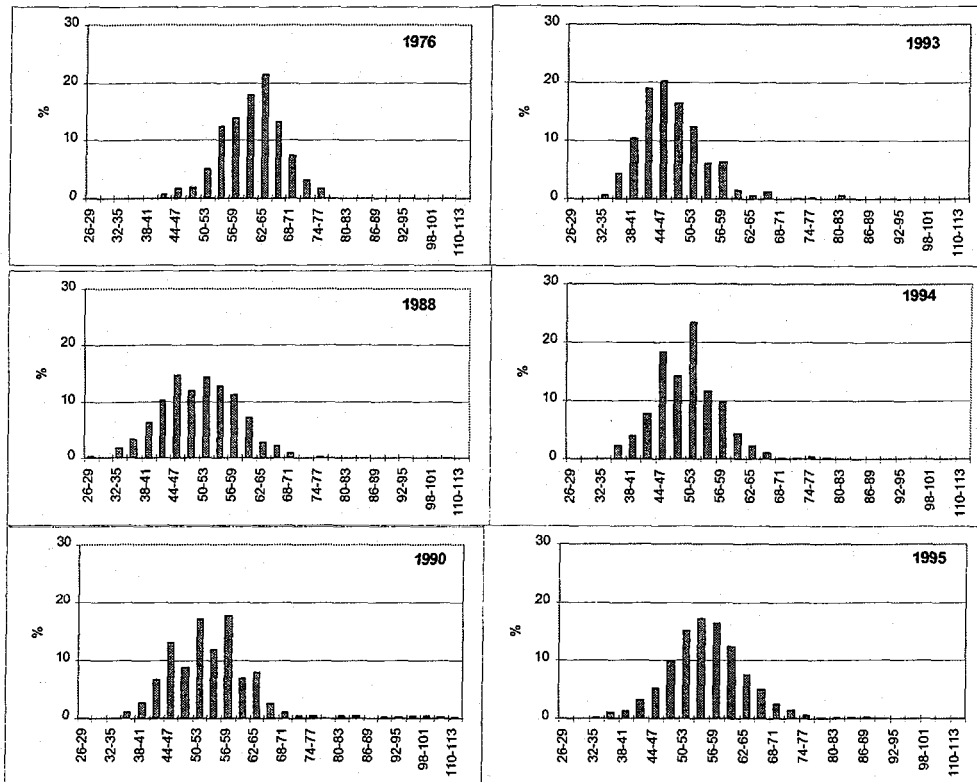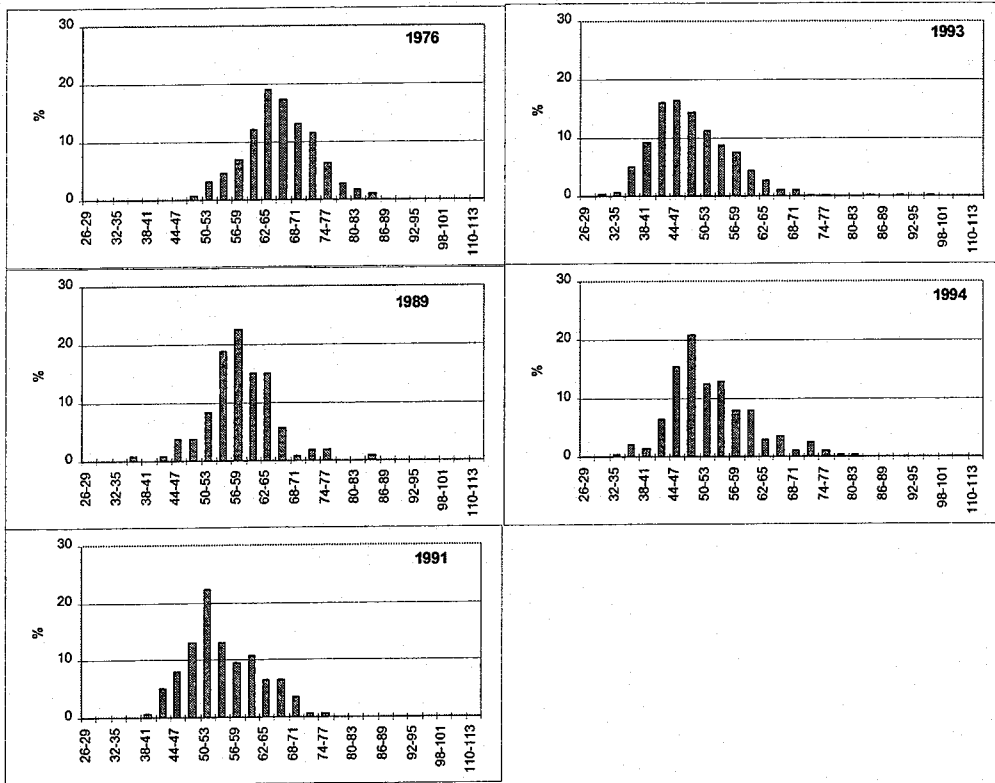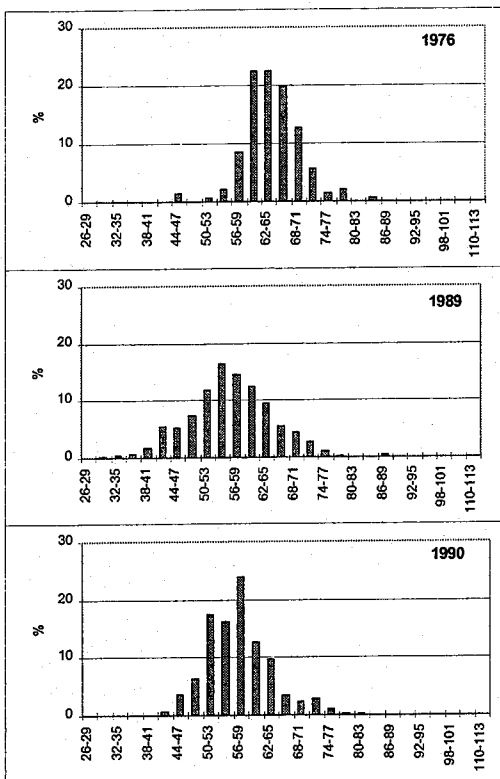Figure 5.20 Length distributions of *tusk* from ICES Subdivision IIa.

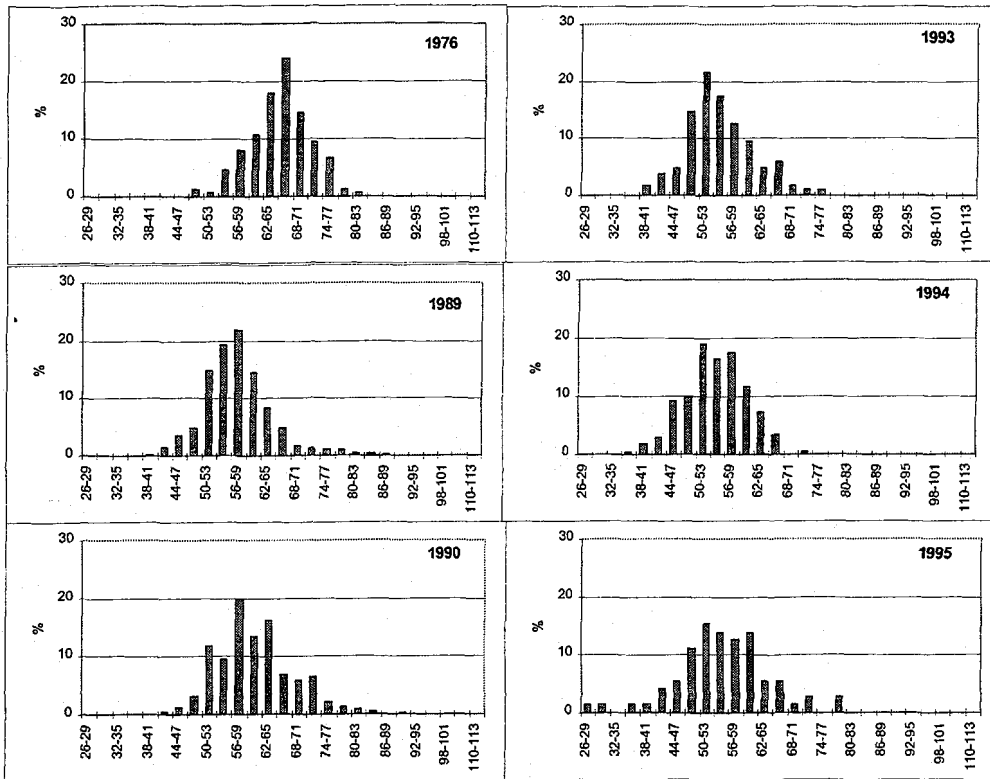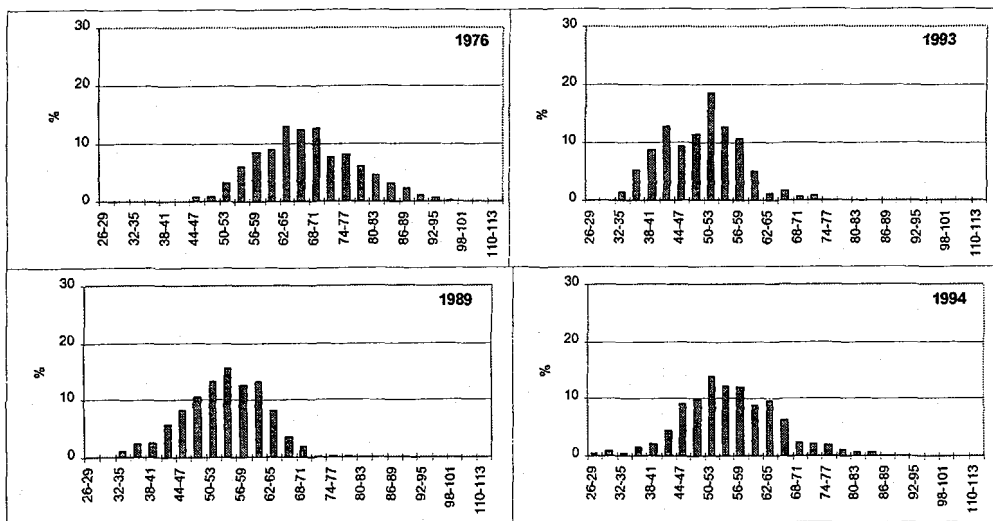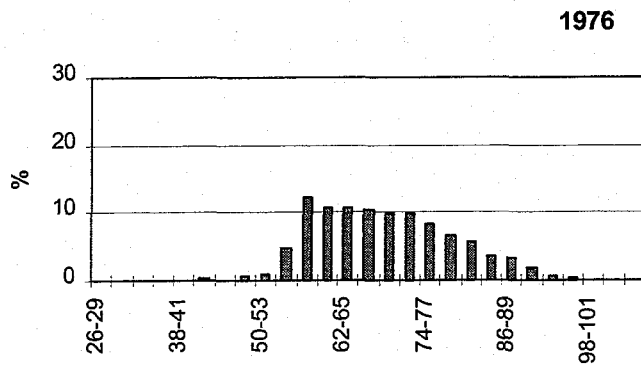Fig. 5.21 Length distributions of *tusk* from ICES Subdivision IVa

Subdivision Vb1 and Vb2

As in IVa, the mean length of the tusk catches has decreased in Faroese waters since 1976. Figs 5.22 shows the changes in the size distributions. The contribution of fish longer than 70 cm was near 20 % in 1976, but only about 5 % in 1989-1995.

Subarea VI

In west of Hebrides waters no data were available from 1976. No significant changes were observed in the length structure since 1989 (Fig. 5.23). At Rockall, the proportion of big tusk has decreased markedly since 1976 (Fig. 5.23b).

Subarea XII

Only a 1976 sample from south of Iceland was available. The abundance of big fish in the catches at that time is illustrated (Fig. 5.24).

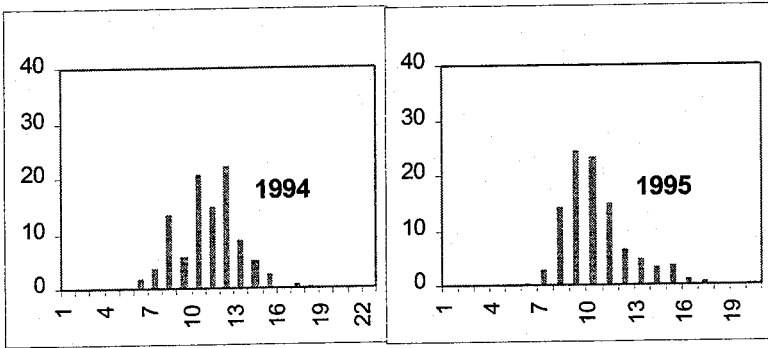Figure 5.22a Length distributions of *tusk* from ICES Subdivision Vb1.

Figure 5.22b Length distributions of *tusk* from ICES Subdivision Vb2

Fig. 5.23a Length distributions of *tusk* from ICES Subdivision VIa.

Figure 5.23b Length distributions of *tusk* from ICES Subdivision VIb

67

1976

Figure 5.24 Length distributions of *tusk* from ICES Subdivision XII.

5.3.3 Age distributions

Age distributions from longline catches in different ICES subareas are shown in Figs 5.25-5.30. In all cases, except for Subdivision IIIa, the distributions were based on conversion of length distributions by area-specific age-length keys. In IIIa most of the tusk are caught as by-catch in halibut longline fisheries and the age-distributions came from by-catch samples.

The tusk recruit to the longline fisheries at age 7-9 years. Up to about 11 age-groups occur in the age-distributions. The lack of good ageing methods for old fish may however affect the distributions and the proportions of fish older than 12-13 years may be underestimated.

No recruiting year-classes appeared particularly prominent in any of the sub-areas. This may indicate that the recruitment variation is limited.

5.3.4 Mortality

The coefficient of mortality, Z, was estimated from catch curves from longline age-distributions from Subdivisions IIa, IVa, Vb, VIa and VIb for each of the years 1993-95 (and 1988 for IVa). The average Z was 0.6 (S.D.=0.2, n=12). As for ling, this indicates that the fishing mortality is at a high level in all the fishing areas.

Figure 5.25 Age distributions of *tusk* from ICES Sub-division IIa.
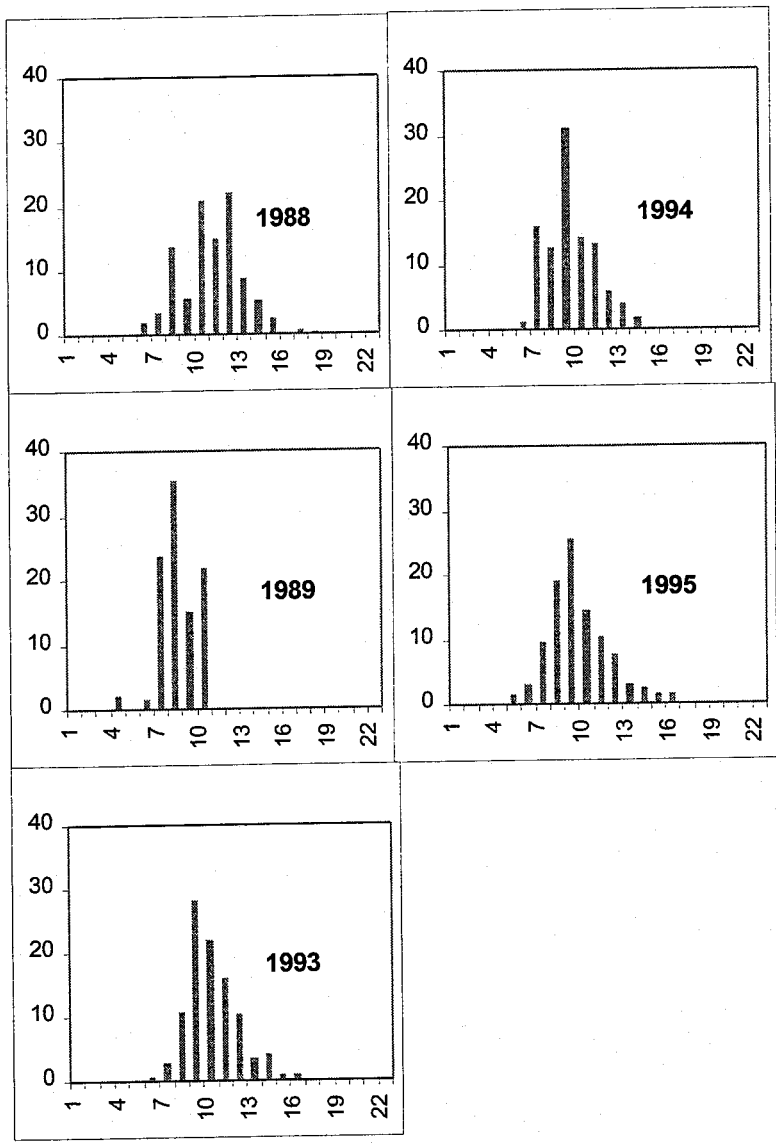
Figure 5.26 Age distributions of *tusk* from ICES Subdivision IVa.
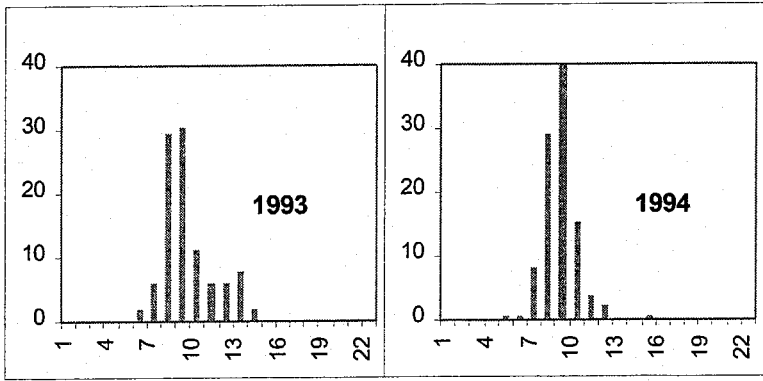
69

Figure 5.27 Age distributions of *tusk* from *halibut longline* catches in ICES Subdivision IIIa.
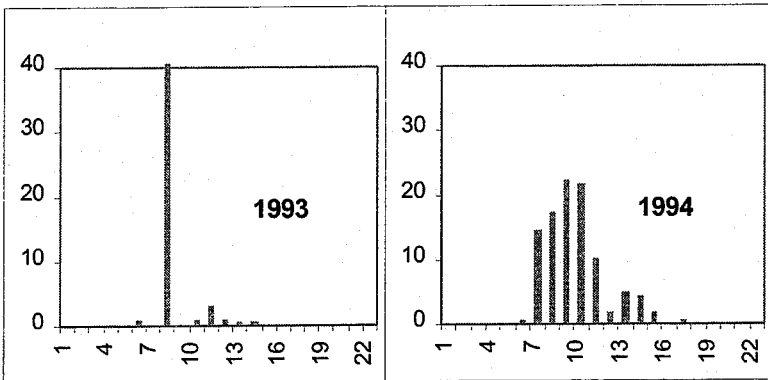

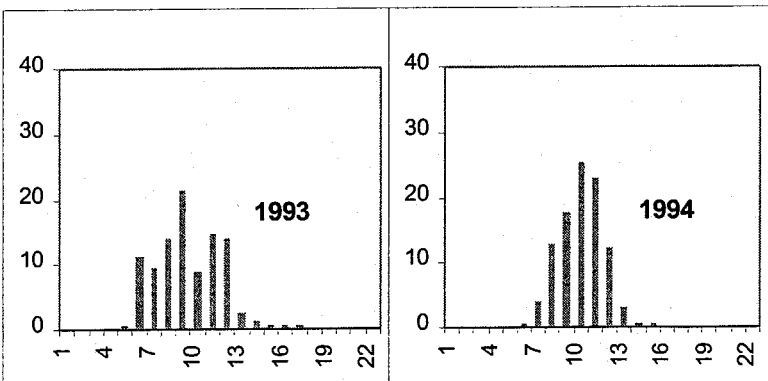Figure 5.28 Age-distributions of *tusk* from ICES Subdivision Vb1.

Figure 5.29 Age distributions of *tusk* from ICES Subdivision VIa.
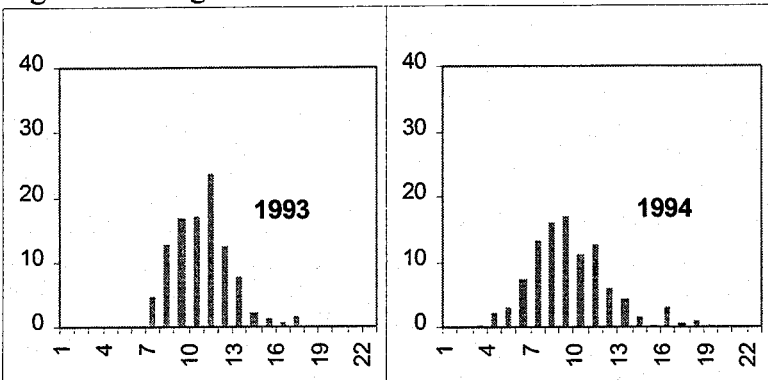

Figure 5.30 Age distributions of *tusk* from ICES Subdivision VIb.

5.3.4 Length and weight at age

The mean length and weight at age of tusk from different ICES Subdivisions is given in Figs 5.31 and 5.32. The low abundance of the smallest fish in the catches again limited the study of growth. There is no strong sexual difference in growth. The geographical variation within the area sampled seems minor, but the data from the Skagerrak (IIIa) indicate that tusk in this area has a higher mean length and weight at age than tusk in all other areas. This result is uncertain because all the data from this area come from halibut longline, i.e. a gear with greater hook and bait sizes than those used in the other areas. This may have resulted in a selection in favour of the big fish within each age group. On the other hand, the fishing pressure is much lower in the Skagerrak than elsewhere and big fish may be more abundant there than in heavily fished areas.

Table 5.6 gives the coefficients a and b of the length-weight relationship, $W=aL^b$, for several fishing areas.

Table 5.6 Estimates of the coefficients a and b of the length-weight relationship, $W=aL^b$, from different ICES areas. r^2= the coefficient of determination, n= sample size.

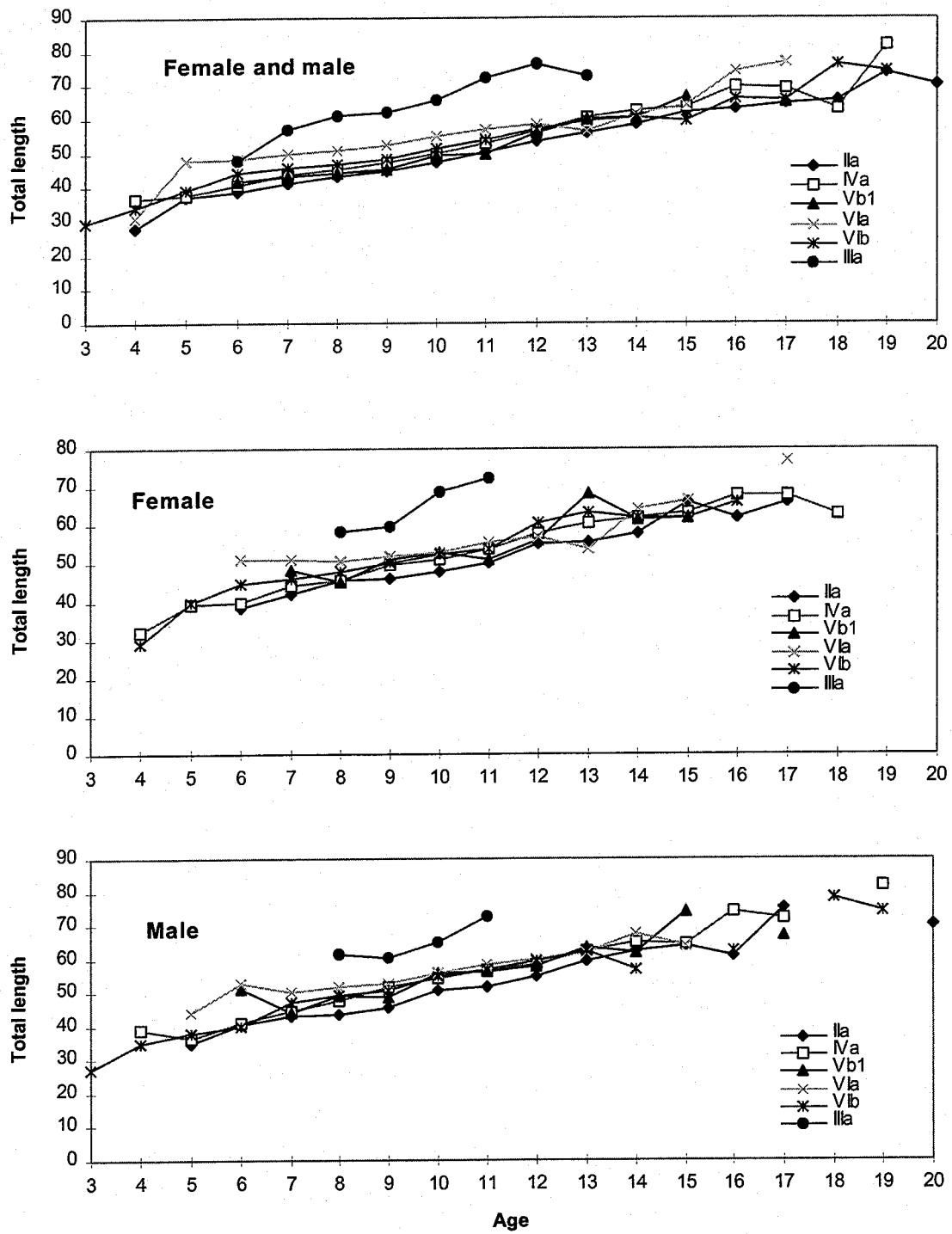|	a	b	r^2	n
All areas	0.0055	3.15	0.966	1506
IIa	0.0048	3.23	0.965	416
IVa	0.0055	3.15	0.983	25
Vb	0.0054	3.16	0.935	199
VIa	0.0066	3.06	0.964	239
VIb	0.0060	3.10	0.983	1447

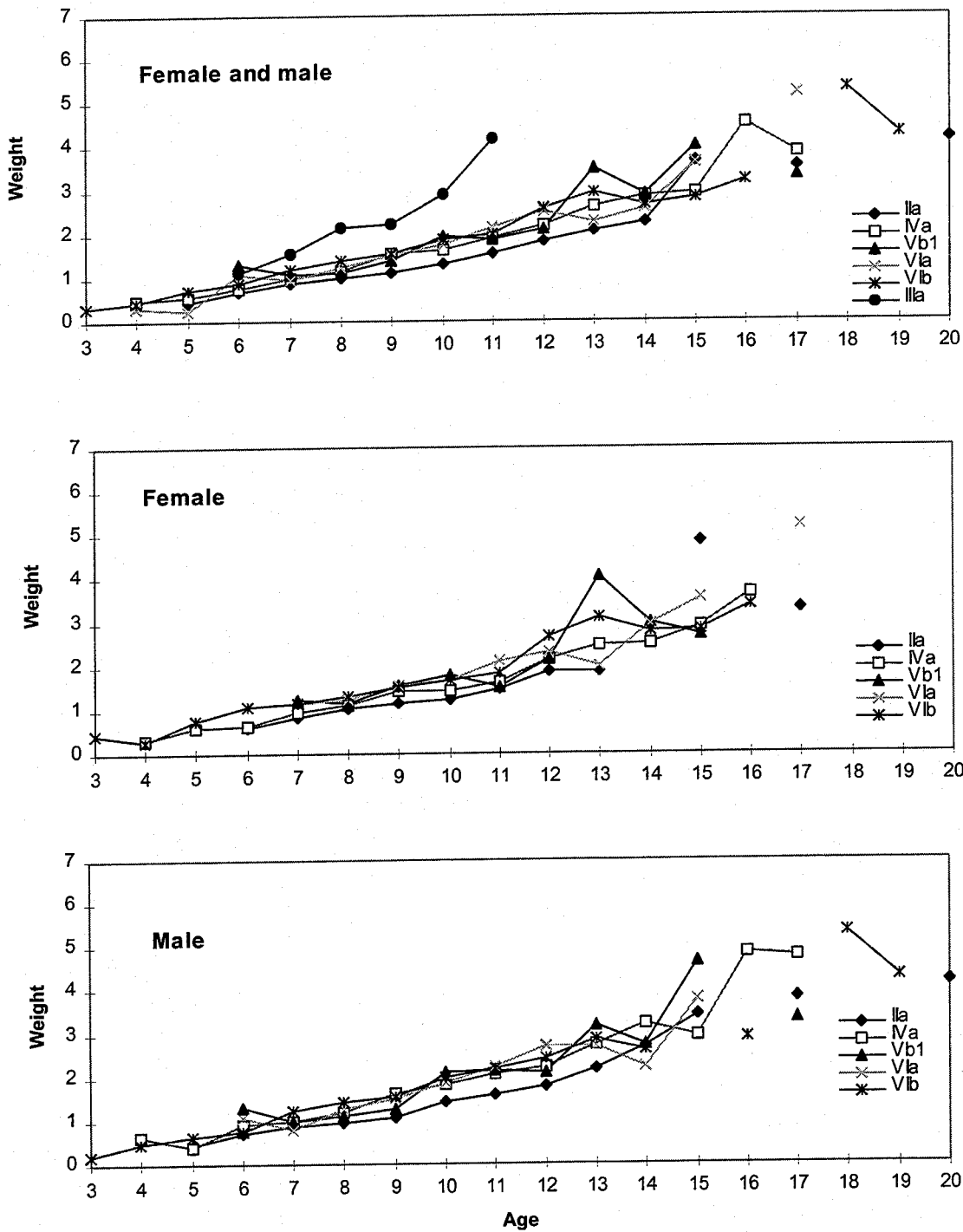Figure 5.31 Mean length at age of *tusk* from different ICES Subareas.

Figure 5.32 Mean weight at age of *tusk* from different ICES Subareas.

5.3.5 Age at maturation

The age at sexual maturation was determined for some sub-areas. In Figure 5.33 data based only on samples collected in the period March - June were included. Distinguishing mature and immature fish based on macroscopic examination of the gonads may be difficult during the resting/recovering period. Overall, the data suggest that 50% of the tusk have become mature at age 6-7 years, females perhaps a year before the males.
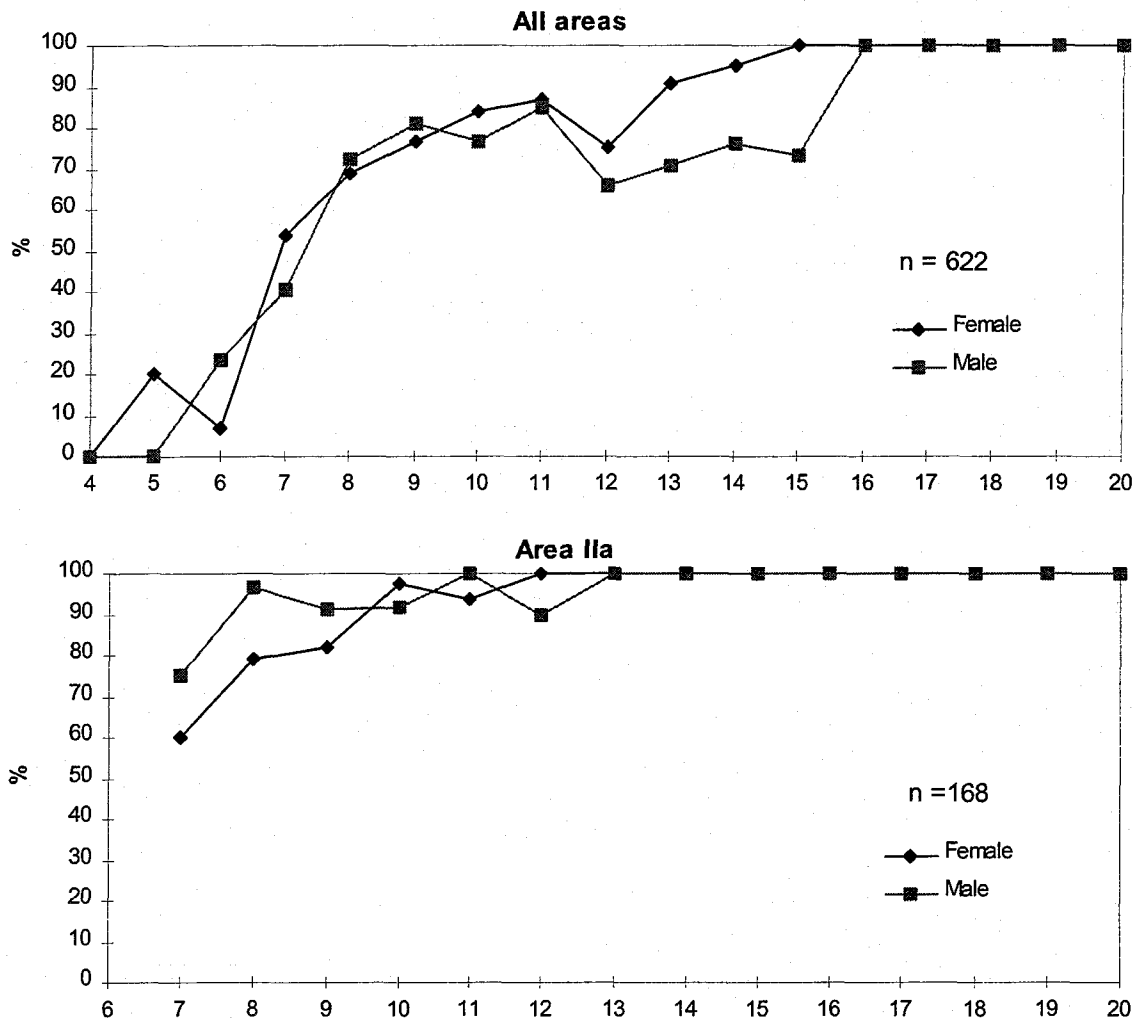

Figure 5.33 Percentage mature *tusk* by age in different ICES Subareas. n = number of individuals sexed and staged.
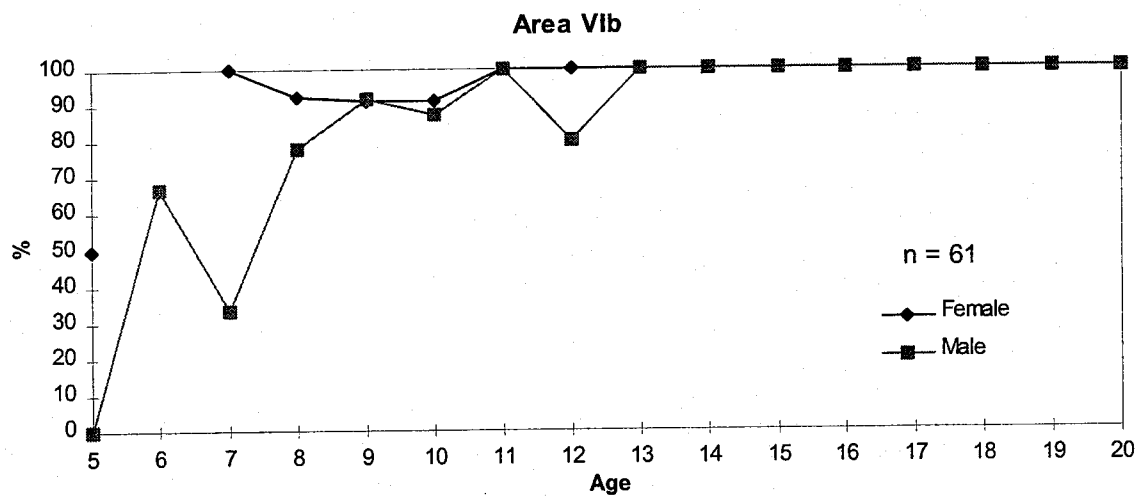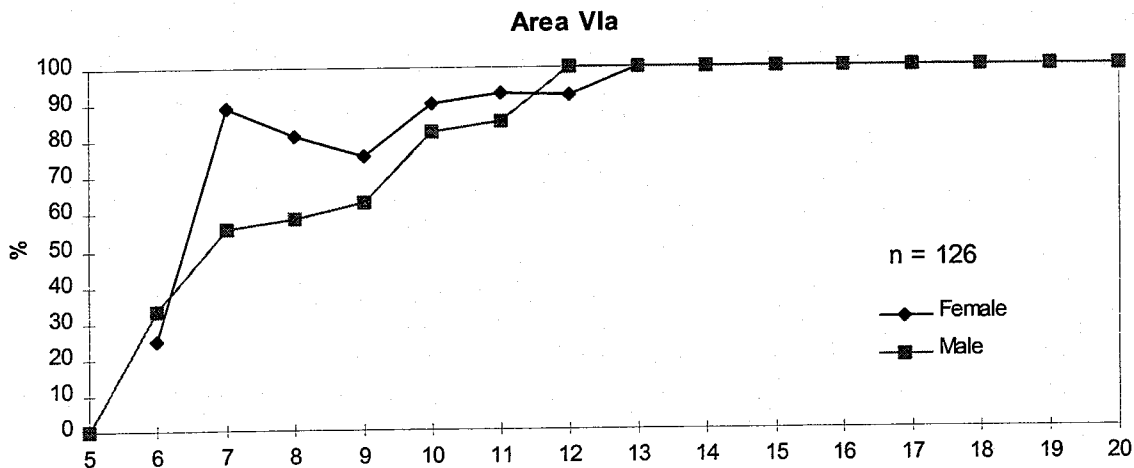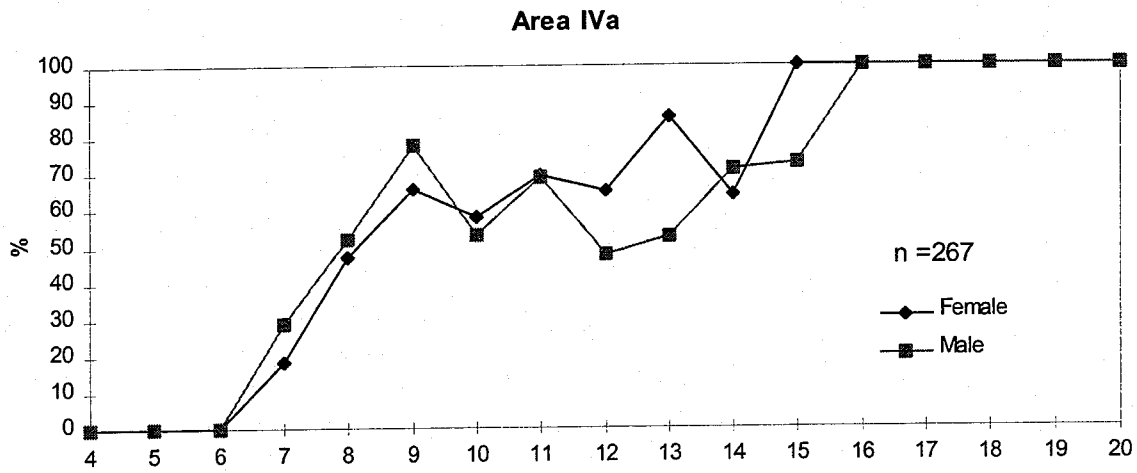
Area IVa

Area VIa

Area VIb

Figure 5.33. Continued

5.4 Population structure

5.4.1 Tusk

Hemoglobins

Hemoglobin polymorphism in tusk was described by Møller and Nævdal (1969), and was confirmed in the present study. The results were considerably improved using the Smithies buffer. The variation observed is illustrated in Figure 5.34. This variation was interpreted as the segregation at one locus with three alternative alleles. The alleles were called $Hb*a$, $Hb*b$ and $Hb*c$ in order of increasing cathodic mobility of their gene product. The seemingly three banded pattern does not conform with this interpretation, but it is tentatively explained as a combination of the slowest and fastest moving component, and thus to represent one of the three heterozygotes. However, this interpretation may be incomplete, and possibly the observed variation may be explained as combined variation on two hemoglobin controlling loci. If this is correct, the hemoblobin variation in tusk is hitherto not utilised properly, although the conclusions drawn (see later) seem justified.

Observed and expected distributions of the hemoglobin phenotypes, calculated gene frequencies and chi-square values are given in Table 5.7 for the samples which could be determined for hemoglobin phenotypes. For sample no 6, 7 and 10 significant differences between observed and expected distributions were observed, and this observation indicates that the interpretation may be wrong or incomplete, and further studies are needed to solve

Table 5.7 Distribution of haemoglobin phenotypes in tusk together with gene frequencies and Chi-square test, with Levene correction for small samples (Levene 1949), for deviation from Hardy-Weinberg equilibrium. Sample no. 1=St. Kilda, 2=Storegga, 6= East Greenland, 7= Kragerø, 8= Øygarden, 9= Vesterålen, 10= Shetland, 11= Island. ** $p < 0.001$.

Sample no.	N	$Hb*a/a$ obs.	$Hb*a/a$ exp.	$Hb*a/b$ obs.	$Hb*a/b$ exp	$Hb*b/b$ obs.	$Hb*b/b$ exp.	$Hb*b/c$ obs.	$Hb*b/c$ exp.	$Hb*a/c$ obs.	$Hb*a/c$ exp.	$Hb*c/c$ obs.	$Hb*c/c$ exp.	q_a	q_b	q_c	χ^2	DF	P
1	94	15	14	25	26	10	12	23	17	17	18	4	6	0.38	0.36	0.26	3.139	3	ns
2	82	6	9	26	21	12	13	16	18	15	15	7	6	0.32	0.40	0.27	2.196	3	ns
6	90	3	2	12	17	50	44	14	21	6	4	5	3	0.13	0.70	0.17	9.705	3	**
7	59	8	12	31	24	11	12	1	5	6	5	2	1	0.45	0.46	0.09	11.54	3	**
8	68	15	17	30	28	10	11	5	5	8	7	0	1	0.50	0.40	0.10	0.826	3	ns.
9	249	56	64	113	102	37	40	13	17	29	22	1	1	0.51	0.40	0.09	6.093	3	ns
10	337	66	78	141	133	57	56	21	29	52	35	0	3	0.48	0.41	0.11	16.89	3	**
11	224	29	39	87	79	37	38	26	30	44	30	1	5	0.42	0.42	0.16	14.28	3	ns?
total	1203	198	235	465	430	224	226	119	142	177	136	20	26						

Table 5.8. Distribution of *GPD-1, PGM* and *MDH-2* phenotypes in tusk together with gene frequencies. No significant deviation from Hardy-Weinberg equilibrium was found when testing with Chi-square test with of Levene index for correction of small samples. Sample no. 1= St. Kilda, 2= Storegga, 3= Faroe Islands, 4= Rockall, 5= Davis Strait, 6= East Greenland, 7= Kragerø, 8=Øygarden, 9= Vesterålen, 10= Shetland, 11= Island.

Sample no.	GPD-1				PGM			MDH-2		
	N	q_{70}	q_{100}	q_{130}	q_{70}	q_{100}	q_{150}	q_b	q_a	q_c
1	248	0.02	0.98	-	0.007	0.993	-	0.01	0.94	0.06
2	271	0.01	0.98	0.01	0.006	0.994	-	0.03	0.92	0.06
3	96	0.01	0.98	0.01	0.021	0.979	-	0.01	0.98	0.01
4	50	0.00	0.98	0.02	-	0.991	0.009	0.04	0.88	0.08
5	80	0.01	0.98	0.01	0.006	0.994	-	0.05	0.95	-
6	102	0.01	0.98	0.00	0.010	0.990	-	0.03	0.97	-
7	68	0.02	0.96	0.03	-	-	-	0.08	0.92	-
8	44	0.05	0.95	-	-	1.000	-	0.07	0.91	0.02
9	398	_	0.98	0.015	0.012	0.986	0.003	0.07	0.92	0.004
10	276	0.007	0.99	0.004	0.006	0.993	0.002	0.06	0.93	0.009
11	344	0.01	0.98	0.01	0.014	0.984	0.001	0.047	0.939	0.014
total	1977	0.01	0.98	0.01	0.007	0.992	0.001	0.03	0.94	0.03

this problem. The distribution of phenotypes were significantly different between samples from the east and west side of the Atlantic.

Tissue enzymes

With one or two exceptions the enzymes stained for in the present study showed reasonably good activity and technically satisfying results at least by use of one buffer system, and the individual variation which could be interpreted as genetic polymorphisms are briefly described below.

Glycerophosphate dehydrogenase (GPD). The highest activity was found in muscle extract, and the best result was obtained by histidine buffer. The patterns are outlined in Figure 5.35, where also the designation given to each pattern and assumed controlling alleles are shown. They were found to be tissue specific, and suggest that this enzyme is encoded by at least two loci, designated GPD-1 in muscle and GPD-2 in liver. The three-banded pattern found in the assumed heterozygotes in both tissue show that GPD in tusk is a dimeric enzyme. In each tissue the observed variation could be explained as segregation of three alleles, of which only

one in each system is common. Calculated gene frequencies based on distributions of GPD-1 phenotypes are shown in Table 5.8. Good accordance between observed and expected Hardy-Weinberg distributions was found, indicating that the interpretation was correct. The assumed heterozygotes of the GPD-2 system were only found in sample no 1. No significant difference between samples were found concerning the GPD-systems.

Phosphoglucoisomerase (PGI). Moderate to strong pattern of activity were found in both tissues. The following description is based upon the result obtained by the histidine buffer system. This enzyme was also analysed by isoelectric focusing although without obtaining any further information. The patterns may be explained by assuming three loci controlling
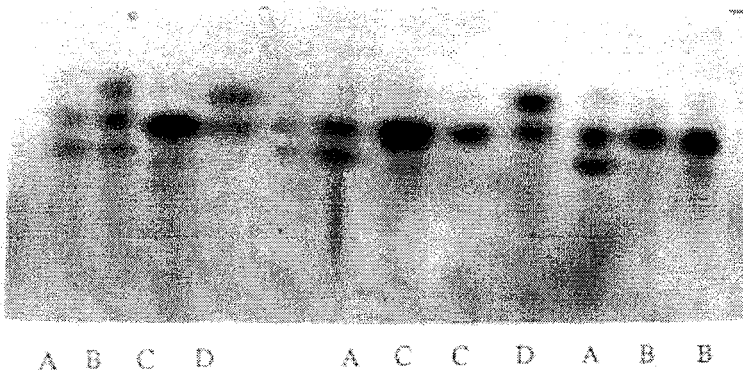

Figure 5.34 Hemoglobin variation in tusk analysed by Smithies buffer pH 8.6
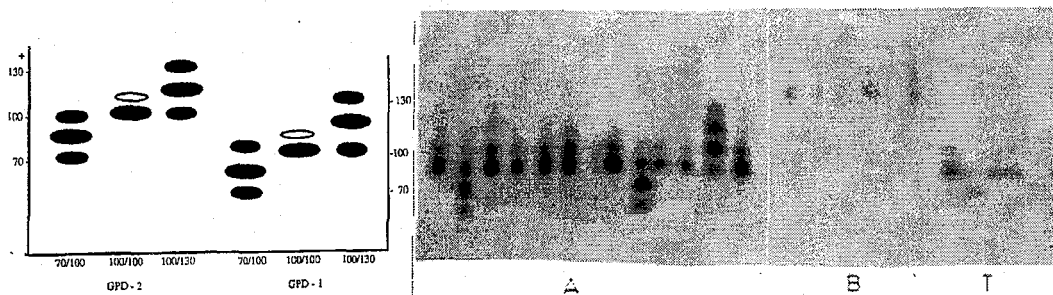A: *Hb*a/b*, B: *Hb*a/c*, C: *Hb*b/b*, D: *Hb*b/c*

Figure 5.35 GPD phenotypes of tusk identified by starch gel electrophoresis.
To the left a schematic drawing. The GPD-1 phenotypes, found in muscle, consisted of one homozygote and two different heterozygotes. The GPD-2 phenotypes, found in liver, showed similar variation. To the right a picture of gels stained for GPD. A: muscle patterns, B: liver patterns, T: cod muscle patterns for comparison.
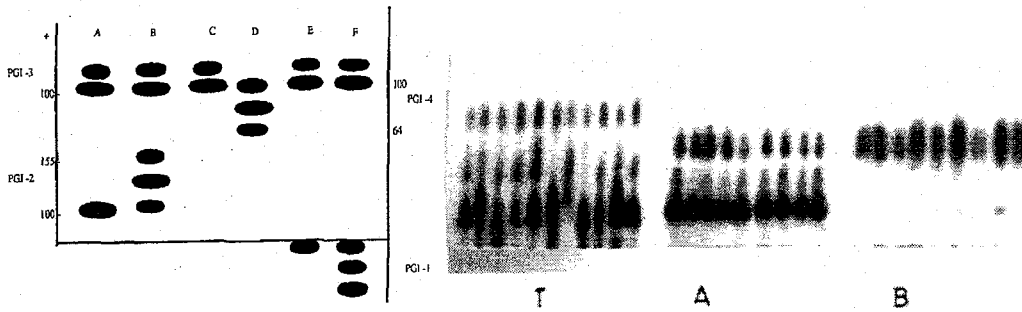
Figure 5.36 PGI phenotypes in tusk identified by starch gel electrophoresis.
To the left a schematic drawing; A and B show muscle patterns with the
variants PGI-2*100/100 and PGI-2*100/155. C-F show liver patterns. C and D
represent the variants PGI-4*100/100 and PGI-1*100/100 and PGI-1*100/200.
To the right a picture of a gel stained for PGI. A: muscle, B: liver, T:
cod muscle for comparison.

this enzyme, two expressed in muscle, called PGI-2 and PGI-3, and one, called PGI-4, expressed in liver. The patterns are outlined in Figure 5.36 together with a photo of a typical gel obtained by routine analysis. In liver components probably representing a fourth loci, PGI-1, were seen. However, these component did not occur regularly; only in about 8 % of the individuals of sample no 1.

Migration rate of PGI-3 and PGI-4 were identical, but variation was only seen in PGI-4 showing that they must be controlled by different loci. The patterns indicate control by two alleles in the PGI-2 system, and the alleles were named PGI-2*100 and PGI-2*155, the latter being rare and only found as heterozygotes. No significant differences among samples were found.
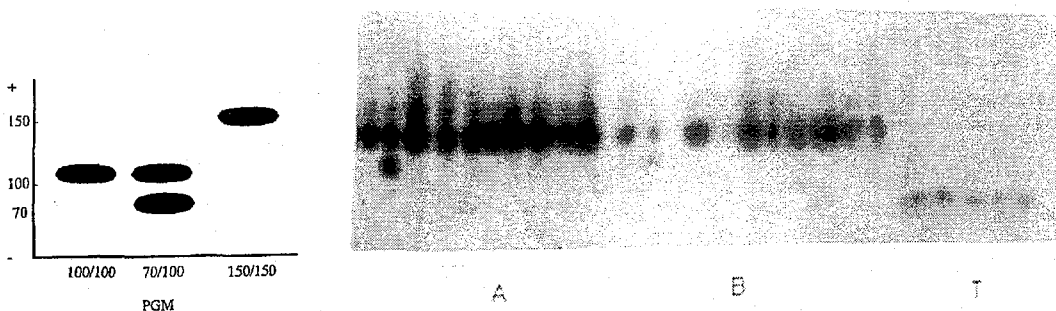

Figure 5.37 PGM phenotypes in tusk identified by starch gel electrophoresis.
To the left a schematic drawing. Muscle and liver gave identical patterns.
To the right a picture of a gel stained for PGM. A: muscle, B: liver, T: cod muscle for comparison.

79

Phosmoglucomutase (PGM). Strong patterns of activity were found both in muscle and liver tissue after starch gel electrophoresis, and isoelectric focusing gave no further information. The patterns obtained by using the histidine buffer system are shown i Figure 5.37. The PGM patterns were nottissue specific, and segregation of alleles at one locus may explain the variation. One common allele, named *PGM*100*, was found in all samples, and a more rare one, named *PGM*70* was found in a heterozygotous state in most samples. Sample 4 (Rockall) did not contain the *PGM*70* allele, but a phenotype apparently representing a rare homozygote, named *PGM*150/150*, was found. Calculated frequencies of the assumed PGM-controlling genes are shown in Table 5.8. The expectance of finding one homozygote of the assumed *PGM*150* allele is very low, and no plausible explanation of this phenotype can be found at present.

Isocitrate dedydrogenase (IDHP). Reasonable high activity was found in both tissues, and the enzyme patterns were tissue specific and suggested two loci; IDHP-1 in liver and IDHP-2 in muscle (Figure 5.38). At each locus two alleles seem to exist, one common (*IDHP-1/2*100*) and one rare; named *IDH-1*130* in liver and *IDHP-2*60* in muscle. The latter allele was found only twice, and the calculated frequencies of the assumed IDHP-1 controlling alleles did not occur at significantly different frequencies in the samples from different areas.
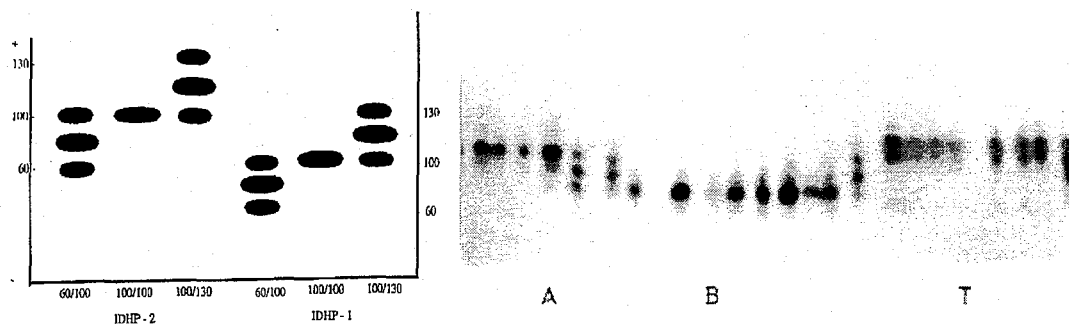

Figure 5.38 IDHP phenotypes of tusk identified by starch gel electrophoresis.
To the left a schematic drawing. The IDHP-1 patterns were found in liver
and the IDHP-2 patterns in muscle. To the right a picture of a gel stained
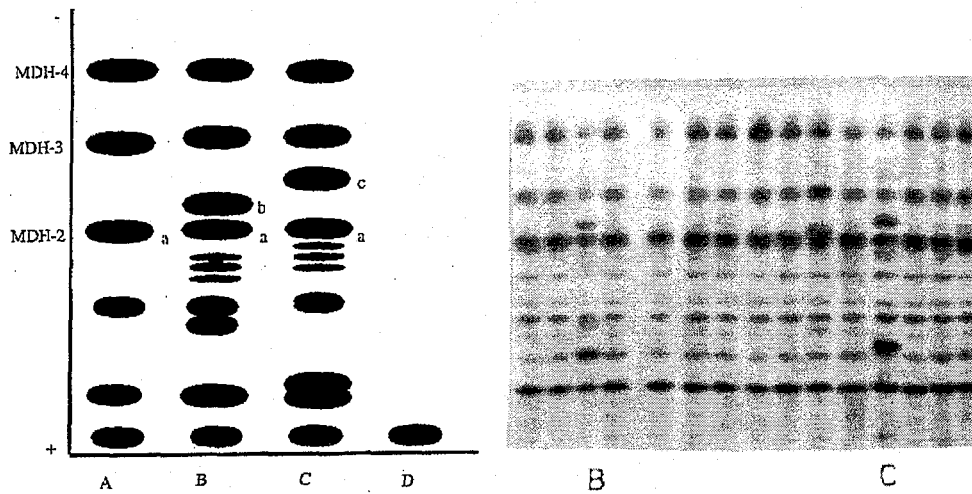for IDHP. A: muscle, B: liver, T: cod for comparison.

Figure 5.39 MDH phenotypes of tusk identified by isoelectric focusing pH
3.5-9.5. To the left a schematic drawing. To the right a picture of a gel
stained for MDH. A: *MDH-2*a/a*, B: *MDH-2*a/b*, C: *MDH-2*a/c*, all in muscle.
D: *MDH-4* found in liver.

Malate dehydrogenase (MDH). The best technical and most informative banding patterns of
this enzyme were obtained by isoelectric focusing (pH 3.5-9.5), Figure 5.39. The patterns
were tissue specific and indicated at least four loci; one expressed in liver (MDH-1) and three
in muscle (MDH-2, MDH-3 and MDH-4). Variation was seen in MDH-2, and the observed
patterns were interpreted as one common homozygote (*MDH-2*aa*) and two rare
heterozygotes indicating three alleles at this locus. For designation of the patterns and their
controlling alleles see Figure 5.39. Calculated gene frequencies are shown in Table 5.8. Good
accordance between observed and expected Hardy-Weinberg distributions (not shown in the

Table 5.9 Unbiased genetic distance (Nei 1978) estimated for 9 loci .

Genetic distance;	1	2	4	5	6	7	8	9	10
1 St. Kilda	*								
2 Storegga	.000	*							
4 Rockall	.006	.007	*						
5 Davis Strait	.005	.007	.000	*					
6 East Greenland	.011	.008	.012	.012	*				
7 Kragerø	.002	.003	.000	.001	.010	*			
8 Øygarden	.002	.004	.001	.001	.014	.000	*		
9 Vesterålen	.003	.004	.001	.001	.015	.000	.000	*	
10 Shetland	.002	.003	.001	.001	.013	.000	.000	.000	*
11 Island	.001	.001	.002	.002	.010	.000	.0002	.001	.000

table) indicate that the genetic model is correct. Significant heterogeneity was found among samples, mostly caused by the absence of the allele *MDH-2*c* in the Northwest Atlantic.

Other enzymes. The enzymes lactate dehydrogenase (LDH), malic enzymes (MDHP), esterase (EST) and alkaline phosphatase (ALP) did not show any clear variation. Variation was indicated in LDH, but probably because the gene products of two loci covered each other on the gel, the variation was difficult to interpret.

Genetic distance. The genetic variation between the samples are summed up in Table 5.9. Genetic distance are calculated on bases of the minimum estimate of number of loci involved. Generally, tusk show low degree of genetic variation, and the genetic distances are small. The only sample analysed for hemoglobins variation from the West Atlantic showed a different distribution of hemoglobin types than the rest of the samples indicating different gene pools in the eastern and western parts of the ocean. This conclusion is supported by the distribution of variants of the enzyme malate dehydrogenase (MDH), although the results are not consistent. The other enzymes by and large showed little variation between sampling areas in distribution of genotypes and their controlling genes.

5.4.2 Ling

Altogether 17 different enzymes have been analysed for ling, and a variety of buffers have been tried. Five of these enzymes did not show any activity at all while a conservative minimum estimate of 19 loci were indicated for control of the 12 ones which gave adequate staining. However only one, PGM, showed any clear genetic variation. Here an alternative allele to the common *PGM*100* allele was found at low frequency in both tissues. Thus ling seem to be a species with exceptional low degree of genetic variation in the enzymes commonly used for population studies. The only potential which is seen at the moment is esterase which shows individual variation although the genetic background for these variations have not yet been possible to work out.

5.4.3 Blue ling

This species has been given lowest priority of the three species treated here, and it also has showed up to be the most difficult to sample. One sample was collected southwest of Iceland in 1993 (95 specimens, liver and muscle).

Hemoglobins were analysed during field work in summer 1993 (54 specimens)and 1994 (34 specimens) in the Denmark Strait between Iceland and Greenland. This species showed up to possess a polymorphic hemoglobin system comparable to cod and tusk, and thus the variation is interpreted as segregation of two alleles giving three expected genotypes of which two were found. Because both samples are collected more or less in the same area, these results gave no possibilities of comparing blue ling from different areas. However, the hemoglobin polymorphism may become a useful tool for further studies of this species, providing that fresh samples maybe brought to the laboratory or the analyses may be conducted at sea.

Blue ling appeared to be nearly as monomorphic as ling in tissue enzymes. Technically good analytic results were obtained for the enzymes PGI, GPD, LDH, MDH and IDH, and reasonable good results were obtained for Esterase. Variations were found in GPD and (somewhat unclear) in esterases. However, the variants in GPD consisted of one common and two rare genotypes. The esterase variations consist of complicated patterns of several components spread over the gels. Tentative interpretation of the most cathodic part of the gel indicate a genetic system of four alleles, and the observed distribution of phenotypes seems to confirm this interpretation. For proper classification of the specimens very good technical analyses are needed, and therefore we have been a bit careful to place to much on these variations.

5.4.4 Discussion

Sampling onboard fishing boats, either to follow long liners and collect samples immediately after the fish are being caught, or to ask the fishermen to collect fish heads with liver, freeze them, and then collect the samples in the laboratory after thawing, have worked well for collection of tissue samples for population genetic analyses. However, for blue ling hemoglobins have shown up to be the only system which are really promising for population genetic studies, and hemoglobin variation is informative also for tusk. Freezing of hemolysed blood in the presence of glycerol have been tried for preserving hemoglobins for later analyses, but until now this method has not given satisfactory results. Thus hemoglobins have to be analysed fresh, i.e. within 5 days after sampling. Analyses onboard the fishing boats have worked well in the present study, provided that spare room for analytic work is available onboard.

Concerning ling and blue ling very little variation in tissue enzymes has been found, although, with a few exceptions, technically good results were obtained by one or more of the applied methods, and thus no more efforts should be put on such analyses. One or more of the rapidly developing DNA-analytic methods should be explored for further population studies on the species in question. The hemoglobin polymorphism described in blue ling could also be further utilised. This species has not been given high priority in the present project, and hemoglobin analyses have thus not been fully explored. For tusk hemoglobin and possibly the enzyme MDH seems to be useful for population studies indicating different gene pools in the western and eastern parts of the North Atlantic. No clear indication of separate gene pools in the Northeast Atlantic has been found.

Of more principal interest is the question about the biological significance of protein polymorphisms. This question is related to the discussion about neutrality or selectivity for such variation, and it is widely accepted that a trait must be sufficiently neutral not to be influenced by measurable selection over at least a few generation. It is difficult to imagine that a trait should be completely neutral if it has any function in the organism, but the difference in fitness may be very small and result in minor changes compared to the intra-specific variation. Concerning cod hemoglobins genotype dependent growth rate has been indicated (Mork *et al.* 1984, Nævdal *et al.* 1992), and recent studies on oxygen binding capacity also have indicated such differences (Ole Brix, personal communication). However, old and recent data on cod hemoglobin gene frequencies have revealed no indication of directional selection during 30 years. This indicate that if hemoglobin types are subjected to selection, this must be stabilising selection which tend to conserve genetic variation. In this way gene frequencies are also conserved, but selection coefficients may change with changes in the physical environment, and thus gene frequencies may change accordingly. This may result in minor changes over time, even temporal ones, but the overall value of the gene frequencies will represent population parameters which may be used to identify population

units. Anyhow, there is no reason to believe that protein polymorphism is less stable than any other characteristics of the individuals or the populations.

For all three species the possibility of utilising techniques of DNA-analyses should be explored.

6. OCCURRENCE OF CONTAMINANTS

The analyses included ling and tusk from the Shetlands/Northern North Sea (ICES Division IVa), the Skagerrak (IIIa) and the Faroes (Vb). The results are given in Table 6.1. The observed values of PCB from all areas except the Skagerrak are at the level normally observed in fish from relatively uncontaminated oceanic waters. In the Skagerrak the levels of PCB were slightly elevated compared with oceanic waters. This indicates that the Skagerrak receives a higher contaminant load. The PCB concentrations in the fish from the Skagerrak are comparable to levels often observed in fish from coastal areas around Norway receiving only diffuse inputs of contaminants.

Table 6.1. The concentrations of different PCB congeners in ling and tusk from the Skaegerrak (St. 16) , Shetland/Northern North Sea (St. 9 & 13) and the Faroes (ng/g wet weight)

PCB	Ling			Tusk			
	St. 16	St.9	Faroe	St. 16	St.9	St. 13	Faroe
28	4.7	3.8	2.2	2.2	1.9	1.6	1.9
31	2.3	2.5	1.8	.6	1.2	1	1.4
52	16.3	12.8	7.7	8.2	6.9	5.3	6.4
101	67.1	50.4	19.7	31.8	25.6	15.1	14.7
105	27.4	8.7	4.1	8.7	4.6	2.8	1.9
118	77.9	51.6	16.6	24.2	32.9	17.9	14.1
128	25.6	4.6	2.3	12.6	2.3	1.7	1.1
138	179.6	99.7	25.9	94.7	62.4	35.4	23.7
149	64.1	44.8	8.3	27.4	17.1	7	4.7
153	237.0	135.4	37.3	141.1	99		38.4
156	9.5	4.7	1	3.0	3.1	1.6	0.9
170	13.5	9.2	1.9	4.7	5.8	3	1.7
180	53.11	34.6	7.6	21.6	23	11	7.6
Sum	778.1	462.8	136.4	380.8	285.9	103.4	118.5

7. POPULATION CHANGES IN TIME (CPUE results)

The application of catch per unit of effort (CPUE) analysis in stock assessment is based on several general assumptions (Godø 1994) related to:

- standardisation of fishing effort
- standardisation of fishing strategy - fishing operation
- geographic integrity and stability of the target species and the distribution of the fleet
- stability and homogeneity in fish behaviour related to the applied gear.

Further, there are particular problems related the use of longline catches as indicator of fish density (Engås and Løkkeborg 1994):

- gear saturation, i.e. fish density will be underestimated at high densities due to the limited number of hooks available.
- species, size and temporal variation in feeding activity
- species competition for hooks

A broad overview of the material available for these analysis was given in Section 4.2. Data are based on private logbooks from three different vessels as well as records from official logbooks, and official effort and catch statistics.

The objectives of this section are three:

1. To analyse the consistency and integrity of the available data sets, and their applicability for stock assessment purposes.
2. To study factors of importance for the variability in CPUE data, and test if additional information, when available, can be included in analyses to improve the use and ability of CPUE analysis to reflect temporal population density changes.
3. Based on the above, to analyse temporal and geographic changes in abundance of the ling and tusk stocks.

7.1 Consistency and integrity of the CPUE data

Five points of importance for the consistency and integrity of the CPUE data have been considered:

1. *Standardisation of fishing effort.* Due to a continuous technical development of vessels in the fleet, mainly caused by introduction of baiting machines and new hook systems, catch per hook data cannot be used uncompensated over time (see Ch. 4.1).

Detailed information on temporal and technical changes (introduction of baiting machines, swivels and EZ-hook) for the three selected vessels has been carefully recorded and were applied to compensate for changes in the effort unit (1000 hooks). Similar compensations were used for the official logbooks, based partly on official statistics on the introduction rate of baiting machines (see Table 3.1) and general knowledge on introduction rates of new hooking systems (gradual introduction over three years, see Table 3.3). Compensation for changes in efficiency was made in accordance with published data.

2. *Standardisation of fishing strategy - fishing operation.* The high-seas longline fleet of Norway target either ling/tusk or cod/haddock. The cod/haddock fishery is preferred when quotas are available. Table 3.1 showed the variation in the proportion of the total effort dedicated to the ling/tusk fisheries since 1974. This variability in strategy may cause two types of errors in our analysis:

- Significant changes in effort over a short period may change the catchability of the gear. E.g. a sudden decrease in cod quotas will immediately lead to an increased effort on ling/tusk and unexpected effects on CPUE may occur. The relationship between effort and CPUE is not known, hence this phenomenon cannot be compensated for. This problem is discussed in greater detail below (see Ch. 7.2).

- If cod and haddock are target species and ling and tusk occur as bycatch, consistently underestimates of CPUE of ling and tusk is expected. Further, if the two groups of species are targeted during separate parts of the same trip, the variability of CPUE by species is expected to increase. Further, the procedures used to calculate species compositions (see section 4.2) is particularly inefficient under such strategies and will produce erroneous CPUE by species. Similar problem may occur when a vessel target ling and tusk during different periods of the same trip. These effects are not compensated for in the standard analysis, however, they are analysed and discussed in a later section (see Ch. 7.2).

3. *Geographic integrity and stability of target species.* For highly migratory species temporal or permanent changes in CPUE may occur due to periodic immigration or emigration, or an overall change in distribution of the stock. The present analysis assumes distributional stability. The problem is analysed further in Ch. 7.2 by comparing changes in CPUE in neighbouring areas. Also, if the fleet substantially expand the area of fishing due to catch rate reductions, misleading estimates of stock sizes might be produced. No quantitative data are available to study this phenomenon, but it is known to exist to some degree in some areas.

4. *Stability and homogeneity in fish behaviour related to the applied sampling gear.* Violation of this assumption may be connected to changes in vertical distribution, variation in forage species composition and density. This may affect attraction of fish to the longline baits but the impact is impossible to evaluate from the available data (see also Engås and Løkkeborg 1994). Also, effects of gear saturation and changes in feeding cannot be studied from the available data.

5. *Comparison with other catch and effort measures.* When applying present knowledge and adjusting available effort measures as under pt. 1. above, the CPUE from the three vessels are expected to develop similarly and should roughly show the *same temporal variation as the measures* based on the official logbooks. Further, combining the observed changes in efficiency from the private logbooks (i.e. number of hooks per day (HPD)) with changes in the officially recorded effort (weeks*vessels spent in the fishery), should provide another control or an alternative CPUE measure (see 4.2.3).

The improved vessel efficiency is clearly demonstrated in Fig. 7.1a as a continuous increase in hooks per day for the whole period. This result underlines the importance of our detailed adjustments of the CPUE data. This increase has been accompanied by a simultaneous reduction in effort when measured in number of weeks spent by the whole fleet in the western areas (Fig. 7.1a). When changes in efficiency is combined with this measure of total effort (see 4.2), a standardised measure of effort over time emerge (hooks per year in Fig. 7.1a). This effort vary considerably from year to year, although a substantial increase over time is indicated. The dramatic year to year changes in the last decade is partly connected to target species preferences and quota regulation of cod as high quotas of cod lead to reduced effort on ling and tusk in the western areas (Table 3.1).

The total effort in hooks by year from Fig. 7.1 a can be combined with total catch from official statistics to give another control of the validity of using data from few vessels. Fig. 7.1 b show that the three vessels' combined CPUE of ling and tusk from the western areas developed similarly to the total catch - fleet effort assessed over years. In the last decade the measures are almost identical, whereas there is an increasing gap for earlier years with the private logbooks giving higher CPUE. Several factors may be responsible for this development. Effort measures in weeks will systematically overestimate effort from earlier years because the fleet has continuously been renewed and days lost due to bad weather and transport to and from the fishing grounds has been reduced accordingly. When compensating for this (see Ch. 4.2) the graphs become very similar (Fig. 7.1 b). In spite of all the known sources of variation, which potentially could have invalidated our time series, the

observed consistency of Fig. 7.1 encouraged us to proceed and investigate further how available knowledge can be applied to improve our CPUE measures.
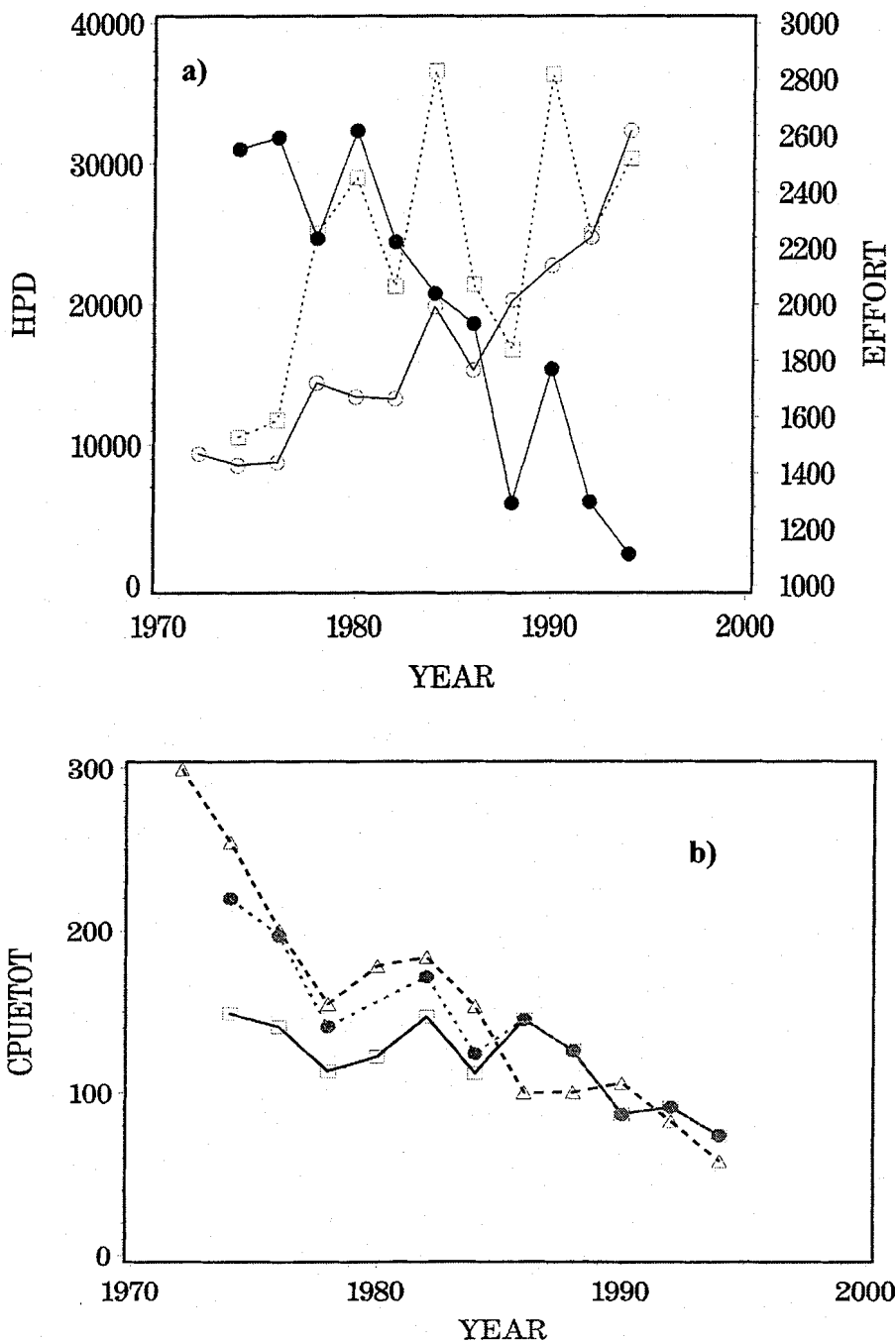

Figure 7.1. **a, upper**) Development in efficiency as measured in hooks per day (HPD, circles) and weeks (dots), compared to the total effort (EFFORT) as measured in hooks per year (* 10^{-5}, squares). **b, lower**) CPUE calculated from total catch and effort from official statistics (triangles) compared to CPUE measures from the private log books (circles). CPUE after adjustment for changes in fleet efficiency are indicated (squares). See text for further explanations.

7.2 Factors affecting the variability in CPUE data

Based on the corrections and adjustments described above and in Ch. 4.2, the data from the three private log books are expected to be comparable, and, if the various adjustments are relevant, these data can be compared with the data form the official logbooks. In the following the three vessels are named Vessel 1 - Vessel 3 while the official data are represented by the name FDIR (Directorate of Fisheries). When nothing else is mentioned, the analysis and presentation is done after averaging CPUE by trip. The frequency of observations by trip is used as a weighting factor. At least four major factors are supposed to affect the comparability of data from the four sources (vessel, fishing strategy, area and temporal effects):

Vessel effect

The vessel effect may be caused by differences in efficiency of the three individual vessels used in the analysis, or differences in the log book recording system between them. Also, comparability between the private and official log books could be invalidated due to the same. To get an impression of the overall variation and tendency of the data, average CPUE data per year for the western areas pooled by species are presented in Fig. 7.2 a. A clear downward total trend in total CPUE (ling and tusk combined) from a maximum of about 500 kg to 100 kg per 1000 hooks in the period studied was found. Ling catches are responsible for the major part of the reduction. When splitting the data by vessel, Vessel 3 appear to be more variable than the others, but otherwise all four sets demonstrate the same reduction in total CPUE (Fig. 7.2 b). Tusk is normally the second target species and the CPUE of tusk is expected to be more variable than that for ling.

A closer study of the vessel effect was made by analysing areas where several of the vessels were represented. For the western areas (Rockall, Faroes, Hebrides, Shetland), we looked at the vessel effect compared with the area and year effect in an general linear model (GLM) (model=CPUEL vessel year area; all class variables, SAS 1988). Averaged data per trip is used. Year and area appear to be dominant variance components in the data compared to the vessel effect (Table 7.1). A vessel effect is expected for the private logbooks because the individual vessels are 'experts' in their particular area and over-represented in this area compared with the others. Vessel 3 is a Faroes-Hebrides expert, Vessel 1 dominates off Rockall while Vessel 2 is a Shetland boat. This is supposed to explain much of the vessel effect which exists in the model. In fact the model cannot fully distinguish between the area and the vessel effects as the data are not balanced between areas and vessels.
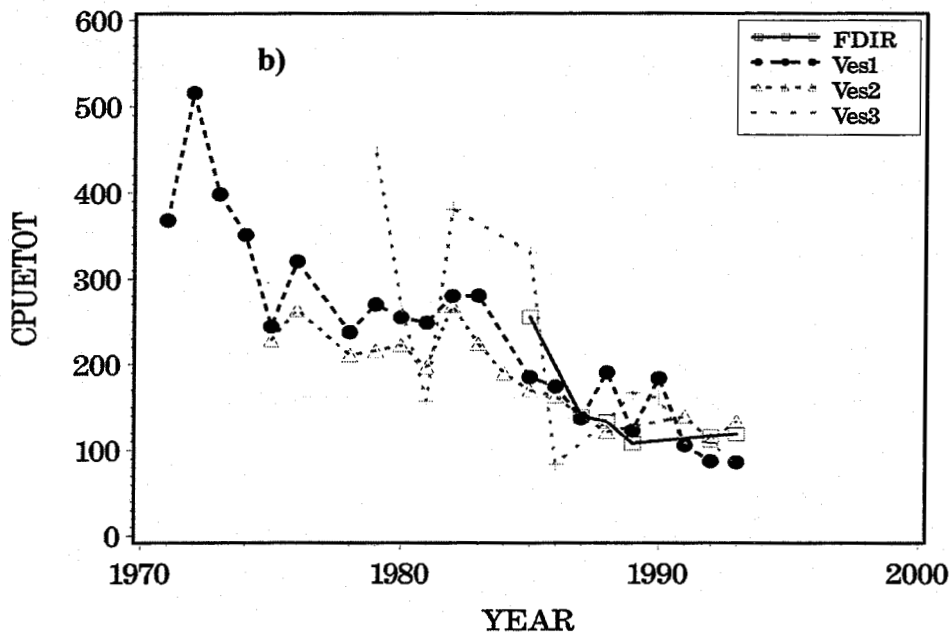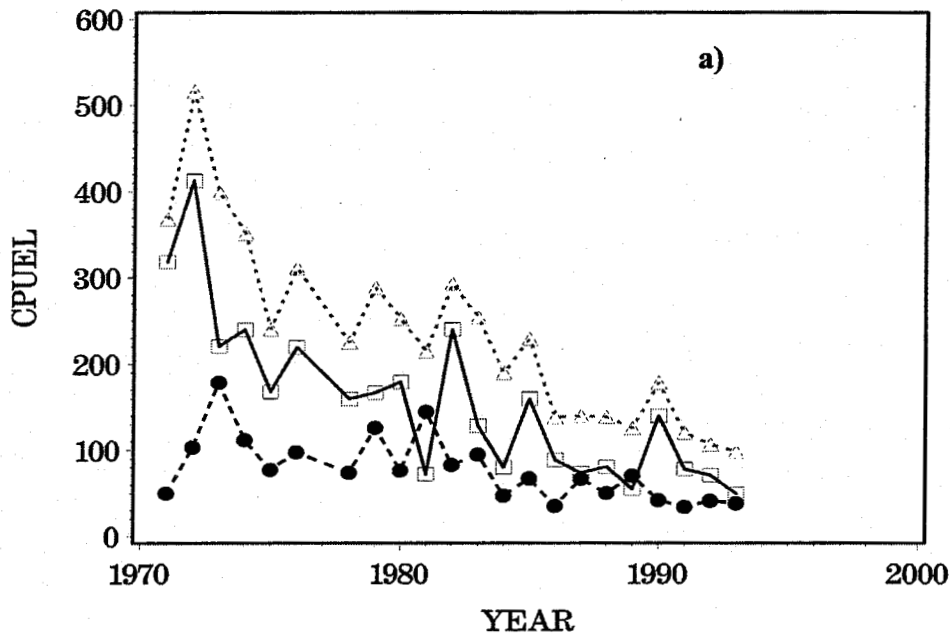
91

Figure 7.2. **a, upper)** CPUE of ling (squares), tusk (dots) and both species (triangles) for all western fishing grounds combined. **b, lower)** Comparison of CPUETOT based on private (Vessel 1, 2, 3) and official (FDIR) log books.

When pooling the private logbooks and comparing them with the official, a similar analysis of variance shows that the vessel effect is substantially reduced compared with the area and year effect (Table 7.2), suggesting that the vessel effect is small (not significant). The variation among the private log books is supposed to reflect the variation in the official data and, hence, level out the vessel effect.

Table 7.1 Use og SAS General Linear Models Procedure in analysis of variance of the CPUE data of ling from the Faroes, Hebrides, Rockall and Shetland. Private log books were pooled.

Dependent Variable: CPUEL

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	25	1607786.95	64311.48	13.84	0.0001
Error	774	3597363.17	4647.76		
Corrected Total	799	5205150.11			

	R-Square	C.V.	Root MSE	CPUEL Mean
	0.308884	68.388872	68.1745	99.6867

Dependent Variable: CPUEL

Source	DF	Type I SS	Mean Square	F Value	Pr>F
YEAR	21	1509288.59	71870.89	15.46	0.0001
VESSEL	1	57.54	57.54	0.001	0.9114
AREA	3	98440.82	32813.61	7.06	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr>F
YEAR	21	1296726.89	61748.90	13.29	0.0001
VESSEL	1	144.28	144.28	0.03	0.8602
AREA	3	98440.82	32813.61	7.06	0.0001

Table 7.2 Parameters in linear regressions of the ling data (CPUE = a*year+b) by area.

AREA	F	P	R^2	a	b
Faroes	16.9	0.0007	0.50	-6.15	12330
Hebrides	42.2	0.0001	0.70	-13.39	2672
Norw. tr.	2.2	0.1636	0.17	-5.4	10806
Rockall	16.7	0.0010	0.53	-5.5	11632
Shetland	10.74	0.0047	0.40	-7.14	14295
Storegga	6.829	0.0281	0.43	-4.22	8440

Table 7.3 Results of run of analysis of covariance (SAS 1988). Western areas and private log books are included. Trip data area used with weighting by frequency of observation behind each trip value. R is the relationship between ling and tusk in the catches.

Dependent Variable: CPUETOT
Weight: _FREQ_

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	7	97194287.2	13884898.2	29.45	0.0001
Error	131	61766692.9	471501.5		
Corrected Total	138	158960980.1			

	R-Square	C.V.	Root MSE	CPUEL Mean
	0.611435	356.1892	686.660	192.779

Dependent Variable: CPUETOT

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
YEAR	1	92869295.1	92869295.1	196.97	0.0001
R	1	453811.9	453811.9	0.96	0.3284
VESSEL	2	1698129.1	849064.5	1.80	0.1692
AREA	3	2173051.2	724350.4	1.54	0.2082

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
YEAR	1	76411745.8	76411745.8	162.06	0.0001
R	1	148893.7	148893.7	0.32	0.5751
VESSEL	2	362981.5	181490.8	0.38	0.6813
AREA	3	2173051.2	724350.4	1.54	0.2082

General Linear Models Procedure

Parameter		Estimate	T for H0: Parameter=0	Pr>|T|	Std Error of Estimate
INTERCEPT		25091.22373 B	12.85	0.0001	1953.291782
YEAR		-12.55033	-12.73	0.0001	0.985863
R		-1.06825	-0.56	0.5751	1.900975
VESSEL	Vessel 2	9.76662 B	0.42	0.6725	23.050988
	Vessel 3	17.58203 B	0.87	0.3848	20.163738
	Vessel 1	0.00000 B			
AREA	Faroes	33.34642 B	1.72	0.0877	19.379134
	Hebrides	12.76275 B	0.61	0.5430	20.924223
	Rockall	-13.38667 B	-0.52	0.6020	25.605645
	Shetland	0.00000 B			

the applied models do not explain more than about 40% of the variability in the data. This is strongly caused by the variability in CPUE between trips. If the same analyses is run with the basic data and including a trip effect, about 65% of the variability is explained although the trip effect is the less important. This is because variability *within* a trip is smaller than *between* trips. The dramatic increase in number of observations in such a model therefore reduce variability.

Fishing strategy

The CPUE of a certain species will depend on its relation to the main target species. Two major effects have to be considered. *Firstly,* the total effort imposed on the ling-tusk populations will be determined by the quotas offered to the longliners of other more valuable species, e.g. North-east Arctic cod and haddock and Greenland halibut. The longliners often record a negative response on CPUE when effort increase, and hence, reduction in CPUE may not necessarily mean a stock abundance reduction but may be caused by an abrupt increase in effort due to strongly reduced quotas on other species. This is in accordance with what Angelsen and Olsen (1987) found for gill nets. *Secondly,* if a vessel change target species during a trip (e.g. from ling to tusk), CPUE by species may change dramatically. These two effects can be demonstrated by looking at CPUE of ling and tusk from *one* trip which have detailed catch information by species. In Fig. 7.3a smoothed CPUE of ling and tusk by set from a Rockall trip demonstrates substantial shifts in the species composition during the trip. Fig. 7.3b shows that strategy may change from year to year, i.e. in some years ling is targeted while tusk is most important in others. The main concentrations of the two species are normally distributed at different locations and/or depths within an area and the year to year change in Fig. 7.3b is mainly due to a determined action by the skipper and not caused by stock abundance changes. Apparently, the change in strategy observed in Fig. 7.3a (i.e. changing target species) follows a reduction in CPUE of ling after fishing the same area for some time. When other species like cod and haddock are targeted during a trip, even more dramatic changes in CPUE of ling and tusk might emerge. Therefore, a detailed information on catch composition is decisive for a successful detailed study on trends in CPUE of ling and tusk.

Area effects

The area effect is apparently smaller among the western fishing grounds than at the grounds close to the Norwegian coast (Fig. 7.4). In home waters changes in fishing strategy will be more likely when quotas of cod and haddock are available. The variation between years as shown in Fig. 7.4 b, makes temporal (over years) evaluation of the data difficult in these areas. From the variance analysis done in Table 7.2, the area effect is significant but smaller than the year effect. Fig. 7.4 a also shows that the catch rates in the western areas developed similarly in the period studied.
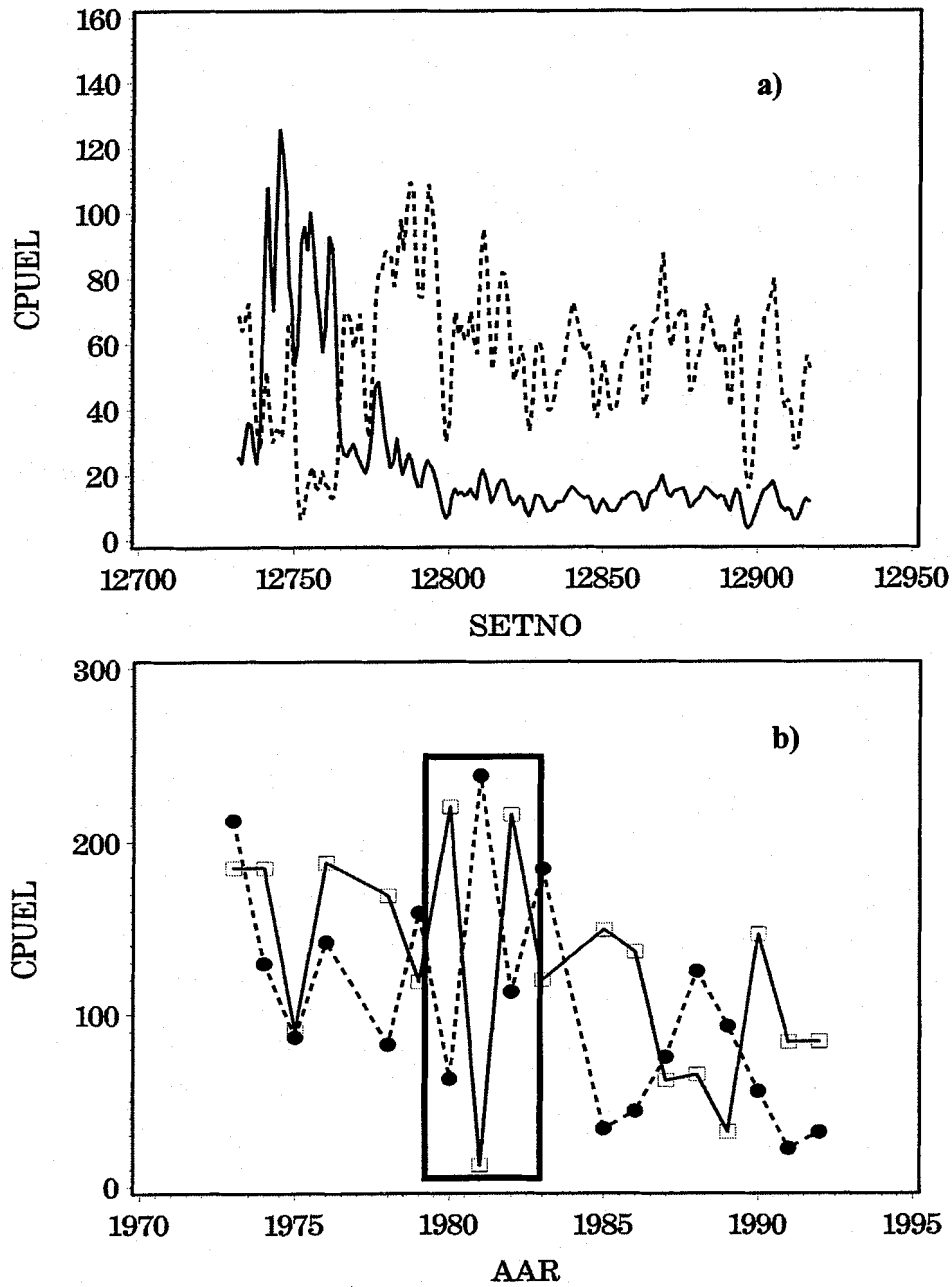
Figure 7.3. a) CPUE of ling (continuous line) and tusk (dotted line) from a single trip to Rockall. b) Changes in species composition in catches from a single vessel by year. Data from the Faroes.
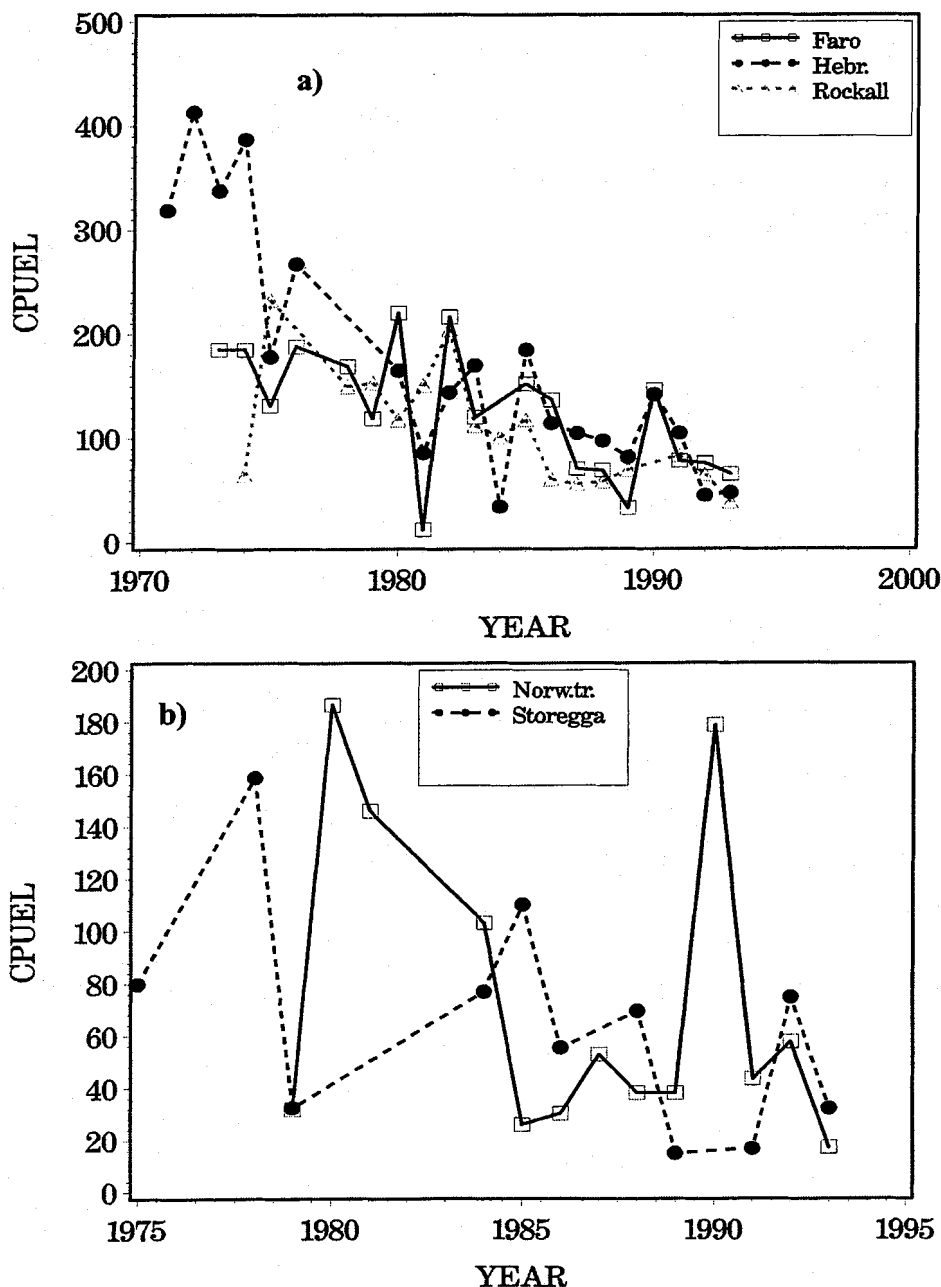
Figure 7.4. a) CPUE from different fishing areas. b) CPUE of ling and tusk from Storegga (IIa) and the Norwegian Trench (IVa).

The fleet exploiting ling and tusk is wide-ranging and will shift among areas to maximise the catch. Consequently, the homogeneity in development among areas on the western grounds is probably due to the geographic flexibility of the fleet and the lack of alternative target species. In contrast, when operating off the Norway coast, the fleet has in addition the options to switch to other target species, and this makes the data more difficult to interpret. Again, this shows that species composition of the individual sets is crucial information for the CPUE analysis.

The database analysed cover more than 20 years. During this period improved equipment, vessels and experience probably also made expansion into new fishing grounds possible. When CPUE decrease, new grounds will be explored and exploited when results are satisfactory. It is difficult to quantify the effect of fishing ground expansion based on available information. More detailed position data by set will be needed for such studies. As species composition is often depth dependent, also depth data by set will be crucial. If CPUE data of ling and tusk are to be used in future assessment, such data must be collected.

Temporal effects

Temporal effects include diurnal and seasonal changes in CPUE. Detailed data from the private log books have been used to study these effects. All data show substantial seasonal variation, but it is difficult to find systematic patterns in these variations. Fig. 7.5 presents seasonal changes (by month) on Faroese grounds when split into three periods. Three different patterns are demonstrated, i.e. no systematic seasonal pattern over the entire period is indicated. From the available data it appears difficult to analyse seasonal effects. Probably a better resolution of geographic information is needed to be able to isolate seasonal effects. Also, the improvements of the vessels with associated effects on fishing strategy, may also have corrupted the data.
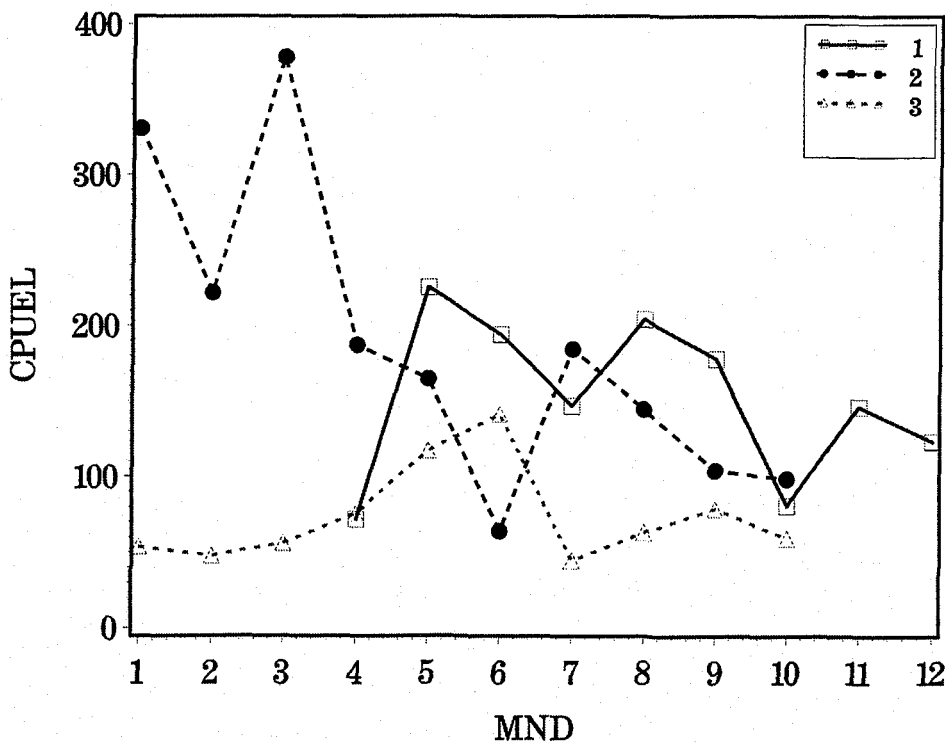

Figure 7.5. CPUE of ling from Shetland as recorded by month for three time periods: 1972-1980, 1981-1986, and after 1986.

In some areas and seasons it appears to be a systematic variation in CPUE by time of day. Fig. 7.6 demonstrates such variation for ling during one trip to the Shetlands, and indicates that day sets catch more than night sets. Species composition, expressed as the fraction of ling in the combined ling-tusk total catch, apparently follows the variation in ling catches, as expected in a fishery targeting this species. As stressed before (in section 4.1), the species composition by set is only available in a few occasions and when collected it is imprecise and can therefore not be fully utilized in the analysis. With autoline, setting and retrieval goes on continuously day and night. In the first part of the time series, when the lines were handbaited, a break was normally taken in the period when catches by experience appeared to be lowest. Thus, the temporal effect might have negatively biased CPUE for later years.

Temporal effects may become important in future analysis but is difficult to evaluate from present data. In an extensive and complete database, the time factor might become important for understanding within trip variability in catch and the species composition.
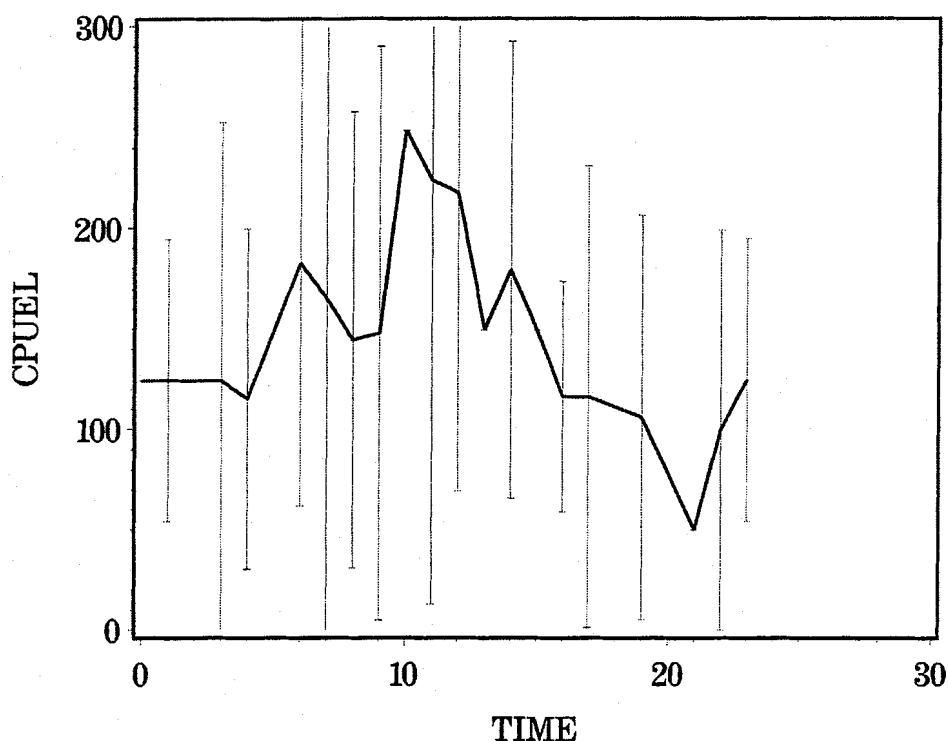

Figure 7.6. Diurnal changes in CPUE of ling during a single trip (time is hours).

7.3 Stock abundance. Temporal and geographic changes in CPUE

A main question asked at the start of the project was: *Do the Norwegian CPUE data on ling and tusk indicate a downward trend in stock size, and if the answer is yes, is this caused by a stock reduction due to over-exploitation?* If CPUE is assumed a reliable measure of stock density, the available data, particularly from the western grounds, strongly indicate a gradual reduction in stock abundance of the main target species, ling (Fig. 7.2a). Apparently, the development has levelled out in recent years and some of the time series even indicate a possible improvement in CPUE in some areas. The variance analysis in Table 1 and 2 strongly indicated the year effect to be dominant, i.e. area differences play a minor role in the variation of the data. The year effect includs both year to year variability and a possible trend in the data. In Table 7.3 gives a linear regression by area to assess the importance of the trend in the data. There is a clear negative linear trend in all areas, although the R^2 =0.17 from the Norwegian Trench gives no support for a reduction in CPUE of ling. Table 7.4 shows results from a GLM run using analysis of covariance (SAS 1989) on combined data for ling and tusk from the private log books from western areas, and Fig. 7.7 compare the model results and observation. Trends caused by effects of year and of catch composition (R equal relationship between ling and tusk) are estimated while ship and area are included as categorial variables. The model explains 61% of the variation in the trip data, and the year effect is totally dominant. The trend in the data appears to be well reflected by the model, but we are not able to recreate the trip to trip variation (Fig. 7.7). This variation is most likely due to between trip changes in location, weather etc. factors which are not included in the model due to lack of data. So far there is no doubt that our data show a reduction in CPUE of the two species combined, and a severe reduction in stock sizes in the western areas is indicated. For the areas close to the Norwegian coast, the variability mask reliable trends, but for Storegga the situation appears to be similar to that on the western grounds (Fig. 7.4 b). The situation for tusk is more difficult to evaluate than for ling, due to its secondary position in the longline fishery. The CPUE measures will never meet the demand on stability in catch strategy. In some areas this will similarly affect the ling data, but normally to a smaller extent. Therefore it is crucial for future analysis to get improved data on species composition by set combined with auxiliary parameters like depth, GPS position, time and weather condition.

If prediction models are to be designed, their performance will be strongly dependent of the ability to understand between trip variation in CPUE. The type of model used here were designed to study past trends in CPUE and will not perform well for prediction. For this purpose nonlinear models should be designed.
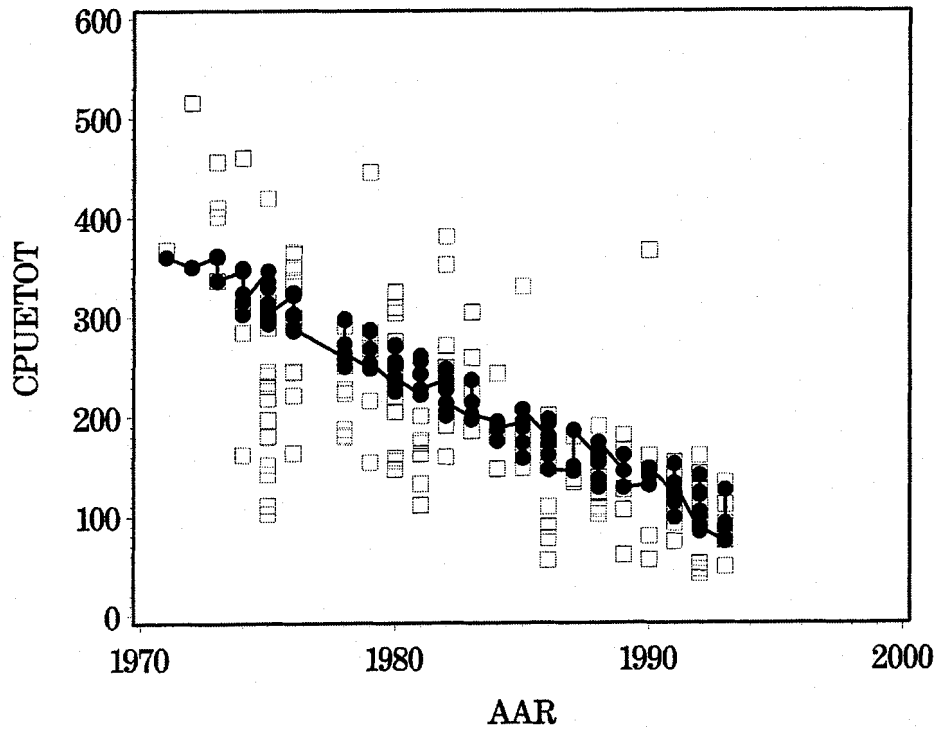

Figure 7.7. CPUE on western grounds. Comparisons of observations (squares) and model results (line and dots).

8. ASSESSMENT AND MANAGEMENT STRATEGIES

8.1 Analytical assessment

Traditional age-based assessments have not been carried out in this project or by the ICES working groups working on ling, blue ling and tusk. The lack of sufficient data, primarily time-series of age structured catch data, remains the greatest obstacle. This and the Nordic project has made significant progress on methods of ageing, and it is now feasible to obtain reasonable age data for ling and tusk. For blue ling, the problems have not yet been resolved.

In principle it should be possible to build up a database on age-structured catches for use in future analytical assessments of ling and tusk. The sampling effort required would be extensive, however, and would require onboard sampling as has been conducted in this project.

A further discussion about stock structure would seem crucial to design a sampling programme and choice of stock units in the assessments. The genetical data for tusk indicate that all the tusk in the northeastern Atlantic belong to a common gene pool, whereas so far the data for ling and blue ling are inconclusive. Spawning and nursery areas are widespread, but we know very little about migration rates between the traditional management areas.

8.2 Monitoring by CPUE. Future data collection and database design

The present analysis shows that CPUE from longlining may become an important tool for assessing changes in abundance of the ling and tusk populations. The analysis presented are based on systematically collected and adjusted data which serve very well as a basis for analysing trends in stock abundance over long periods of time. However, the quality and details in the available material is far from optimal in relation to provide a secure foundation for year to year assessments as a basis for future management of the stocks. By improving the integrity (standardisation) and quality of the collected data it should be possible over time to use data from the fleet as a basis of future management. The data collection must be based on a highly

automated system integrated with the navigation and fish finding instrumentation aboard the vessel, e.g. as demonstrated by the already operating "Line Tec 2000" system (Anon. 1995). A new logbook system must be computer based and strictly standardised so that data from all vessels involved can be easily integrated. The information needed can be categorised as:

1. Geographic location: This information is available from the vessel's GPS

2. Environmental variables (in order of priority):

     - Bottom depth from the vessel's echo sounder

     - Wind conditions from a weather station when available, otherwise entered manually

     - Wave height observation

     -Surface temperature and air temperature from temperature sensors when available. (can also be entered manually).

3. Effort variables: Instrumentation should be available which produce automatic output to the logbook on

     - number and type of hooks in a set

     - baiting percentage and type of bait

     - total length of set

     - time of setting

     - time of retrieval

4. Catch information: An automatic counting and weighing system would be preferable. This system should produce

     - counts of fish by species by set

     - total weight by species by set

     - individual weight by species by set

These data should automatically be stored under the correct set information in the database. Alternatively, the data can be entered manually.

     The system has to be developed in tight co-operation with the fishermen and the management authorities into a standard tool which fully satisfy

     - the fishermen's demand for an easy available catch log

     - the management authorities' demand for a log book for control and regulation purposes

- the scientists' demand for quantitative information on catch and effort, and auxiliary variables of importance for catch variability.

We believe that such an electronic log book system is possible to specify and build, and it will probably be the only way of getting a comprehensive and functional system which produce data regularly and in time to complete necessary analyses for annual assessments.

8.3 Alternative management strategies

The data at hand are insufficient as basis of very precise management advices, but some important conclusions can be drawn from the analyses in this report. It is clear that there has been a substantial reduction in the catch per unit of effort in the ling and tusk fishery over the past two decades, and that the total mortality, Z, of both species in later years was around 0.6. The effort in the longline fleet has shown a steady increase in the sam period, and in recent years the trawling effort has also increased. Assuming that the natural mortality (M) is rather low, i.e. 0.1-0.2, the fishing mortality (F) must be 0.4.-0.5. This is far above the level which would provide the long-term maximum sustainable yield. Preliminary yield per recruit analyses have shown that a reduction in F to around 0.2 would provide substantially greater sustainable yields. The current management regime has undoubtedly resulted in a classical growth-overfishing situation where the production of the stocks is not being utilized optimally because the fishing mortality is too high.

With the present management regime the yield from the fishery will remain lower than what would be possible with a lower fishing mortality, and in periods of low recruitment the yield would drop even further and there is a real risk of severe depletion. The risk of depletion of the stocks increase further if new and even more efficient fishing practices and gears leads to continued fishing at even lower catch per unit of effort levels. The introduction of circular hooks and artificial bait may increase efficiency and perhaps reduce cost and thus compensate for the decline in catch per unit of effort. This may also lead to expansion of the fishery into areas hitherto considered unprofitable. Unprofitable areas may today constitute refuges for

a portion of the mature populations which may be particularly important for the production of recruits at low stock levels.

An alternative management option would be to seek to reduce the fishing mortality to around F = 0.2, either by reducing effort or introducing catch quotas. This would increase the long-term yield and the size of the fish caught. It would also reduce the risk of depletion in periods of low recruitment.

A continuous and improved monitoring of CPUE would yield information on the effects of management actions taken. At intervals, e.g. every 5 years, a full sampling of the stock to determine the effects on age structure and mortality should be carried out.

9. FUTURE RESEARCH

Future research should focus on the following main topics:

Topics immediately relevant to stock assessment:

Catch per unit of effort (CPUE). The project has identified CPUE analyses of the high-seas longline fishery as a promising tool for monitoring of trends in stock abundance, but several aspects of the method could be developed further.

The recording of species-specific catch and effort and factors affecting these variables should be conducted in a more rational and standardised way, preferably partially automatically . The vessels should record the data on computers to ease data collection and retrieval. Legislative measures should be imposed which secures data supply from all vessels. Based on this improved log-book information, analyses of the significance of different sources of variation should be carried out. Further development of models, both retrospective and predictive, should be a priority.

Alternative assessment methods. A search for alternatives to CPUE utilising additional information, e.g. the limited time-series on length and age distributions, should be explored. If the sampling effort is available, traditional analytical assessments may be possible for ling, but probably not for tusk an blue ling for which age-reading is problematic.

Recruitment variation. The utility of data on occurrence of recruits in the long-line catches for monitoring recruitment and forecasting future abundance should be assessed. Such data should become available from revised log-books.

Sex distribution in catches. The maturity ogives indicate that the males may mature at a slightly lower age than the females. When the exploitation rate is high, the spawning stock may become dominated by males. This probable effect of exploitation needs to be considered in greater detail.

Population genetics. Although the results of the enzyme and hemoglobin studies have so far been less successful than anticipated, some effort should be made to obtain more information on the least sampled species, blue ling, from different areas. For all the species, DNA analyses may be possible, but would require considerable technical development and sampling effort.

Traditional population analyses have indicated that particular areas, e.g. Rockall, often yield catches with unusual age structure. Growth curves and maturity data may also seem unusual. Special studies of such phenomena may provide greater insight into the structure of the populations.

Strategic studies of biology:

There are still significant gaps in the knowledge of ling, blue ling and tusk biology. The limited available data on eggs and larvae yield little but rough ideas of where and when the ling, blue ling and tusk spawn and spend their pelagic life. We know nothing about drift of eggs and larvae, and the depth distribution is insufficiently described.

Special well-designed investigations of distribution and growth of demersal juveniles (pre-recruits) of ling, tusk and blue ling should be conducted. Only scattered accounts of the occurrence of juveniles are available, but sytematic exploration of trawl survey data may yield some more information. At present, juvenile blue ling and tusk were only recorded sytematically in the Icelandic groundfish surveys.

Very little is known about migrations of both juveniles and adults, and modern tagging methods (e.g. electronic tags consumed by the fish at depth) should be utilised.

Our data on spawning areas and times, and age- and size at maturation are still limited, and further studies, including analyses of data collected during the fisheries (e.g. amount and quality of roe) should be carried out. An intensive seasonal study at a selected fishing ground would provide clearer data on gonadal development and

spawning time. Studies conducted thus far have considered many fishing areas at the same time and the effort has been insufficent to obtain reliable maturity ogives and data on seasonal patterns.

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