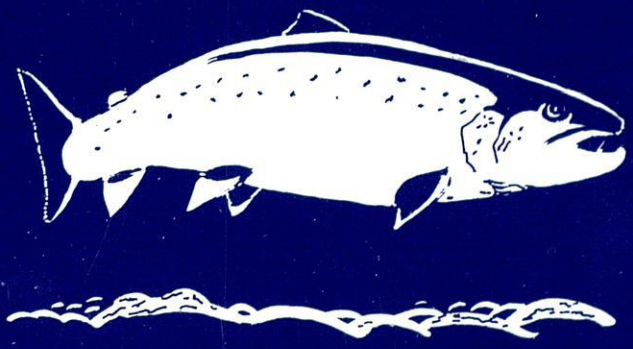
ATLANTIC SALMON TRUST

THE INDUSTRIAL FISHERY FOR SANDEELS

TONY HAWKINS, JENNY CHRISTIE
and KEN COULL



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THE INDUSTRIAL FISHERY FOR SANDEELS

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FOREWORD

With the advent in the 1950s of industrial fishing for such species as sandeels and sprats to cater for the need for animal feeds and fish oil, there has been growing concern for the survival of marine fauna which depend heavily on these species for their food. As the annual landings of industrial fish have continued to rise and the survival of certain sea birds has declined in certain years, in some areas there has been a degree of pressure from some conservation bodies to curtail industrial fishing. Furthermore, the drop in sea trout catches in Shetland and in some Scottish west coast rivers has led some to relate this also to the sandeel fisheries in these areas. It is all too easy to explain these declines in numbers of some sea birds and sea trout catches to such fisheries and difficult to refute such allegations. It is also difficult to remove the uncertainty over whether or not some salmon smolts form part of the by-catch of these fisheries.

The Atlantic Salmon Trust is therefore grateful to the authors of this Blue Book for providing us firstly with factual information in the form of an insight into the operation of a Danish sandeel fishery, an account of the controls imposed on a sandeel fishery and a description of local Scottish sandeel fisheries. Secondly, the authors give an objective assessment of interactions of these sandeel fisheries with other fisheries and with predators and also the relationship between sandeels and salmon.

Finally, the authors consider the future management of the sandeel fisheries. They refer in their penultimate sentence to the proposal by the European Commission to impose precautionary TACs upon the sandeel fisheries and refer to this being an important step. However, as the 1998 sandeel TAC is 970,000 tons of which the United Kingdom has been allocated 20,000 tons, one wonders how cautious this allocation is likely to be, and whether the reduced quotas will result in any improvement in sea trout survival.

(The Atlantic Salmon Trust provided financial support to enable Jenny Christie to sail on the Danish vessel *Morthorst* in July 1996.)

Dr Derek Mills
Chairman, Honorary Scientific Advisory Panel
Atlantic Salmon Trust

The Industrial Fishery For Sandeels

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THE INDUSTRIAL FISHERIES

World-wide, about one third of all the fish removed from the sea are used for the production of oil and meal for processed foods and animal feeds rather than sold for human consumption. Many of these 'industrial' fisheries are based in the productive upwelling zones of the world's oceans, but similar fisheries for sandeels and other small fish species also take place in the North Sea.

The industrial processing of fish from the North Sea originally developed from the conversion of waste products, including fish offal, trimmings and unsold fish, into commodities such as fertilisers and animal feeds. In the 1950s, with the growth in the pig and poultry industries, fish meal and fish oil became so valuable that it became profitable to catch fish which would otherwise not be exploited, to reduce them to meal and oil. In the early days herring made up the bulk of the industrial landings, but gradually the smaller short-lived species of fish became more important. Three kinds of fish, sandeels, Norway pout and sprat now make up the bulk of the North Sea landings, with sandeels contributing up to 70% of the total. Herring, mackerel, blue whiting, horse mackerel and argentines also make a contribution. The fisheries for each type are seasonal, with vessels moving from one to another through the year. More than half the total North Sea landings by weight is now generated by the industrial fisheries, with an average of more than a million tonnes taken annually from this region.

Denmark accounts for 80% of the landings, with Norway taking most of the remainder. A few Scottish vessels participate in the fisheries.

THE SANDEEL FISHERY

The largest industrial fishery in the North Sea is for the sandeel. There are several species, but the most important one is Raitt's sandeel, *Ammodytes marinus*, which makes up 95-98% of the sandeel catch. Though the fish resembles a true eel in being long and thin, reaching a length of about 25 cms, it is from a different family and is completely marine in its habits. In summertime, adult sandeels form large dense shoals, swimming just above the seabed, feeding mainly on planktonic copepods and crustacean larvae. Sandeels are eaten by a range of predators, including fish like the cod, haddock, sea trout and salmon, and also sea mammals and seabirds.

Sandeels are inactive for most of the winter. The fish bury themselves in the seabed but emerge to spawn in December to January. Most of the spawners are two years old or older though some one year old fish also spawn. Their eggs are heavier than water and remain on the seabed adhering to sand grains. The larvae hatch out in the period from February to April and move up from the seabed to appear in the plankton. By May and June they have metamorphosed from larvae into small needle-like fish, the '0' group fish, which then settle back on the seabed in June and July. From this time onwards, when

they are about 6 cm long, they begin to appear in the commercial catches.

Over winter, from October to March, the adult sandeels, buried in the seabed, are believed to be in a non-feeding, dormant state. Survival through this period is dependent upon a build-up of fat reserves throughout the summer feeding period (Hislop, Harris and Smith, 1991). Even during the summer, the older sandeels may spend much of the night buried in the sand, emerging at dawn to feed (Gauld and Hutcheon, 1990).

During the fishing season, sandeels are found close to the seabed mainly at depths of 20 to 70 metres. Contrary to popular belief, they are not caught by 'hoovering' (Aikman, 1997), but in a light, small-mesh otter trawl which is towed along in contact with the ridges of sandbars or on the edges of sand banks. The sandy areas where sandeels are abundant have a patchy distribution and are generally found where there are quite high current speeds. The small mesh nets are vulnerable to abrasion on rough or shell-covered grounds, and this restricts the areas which can be fished. The fishery is a seasonal one, taking place off the Scottish coast in the late spring/early summer, and fishing generally occurs only during daylight hours. The mesh size of the cod end of the net, which retains the fish, is usually smaller than 20 mm and may be as small as 10 mm. The fishing vessels are not permitted to have more than 10% of their catch made up of other non-target species, and this by-catch limit restricts the fishery to areas and times

where non-target species are less abundant (Anon, 1994). In particular, there are large areas off the Danish coast where many young flatfish are found, and where fishing cannot take place because of the large by-catch.

OPERATION OF THE SANDEEL FISHERY

During July 1996, Jenny Christie was able to sail on a Danish vessel, the *Morthorst* from Esjberg, engaged in the sandeel fishery off the east coast of Great Britain. This exercise was repeated in June 1997, when Ken Coull sailed on the *Peter Marlene*, also from Esjberg.

The Danish sandeel fishery

The Danish fishery for sandeels has been in operation since 1952, and is part of a wider industrial fishery which also utilises sprats, herring, Norway pout and a variety of other species, though the bulk of the catch consists of sandeels. About half the Danish catch is landed in Esbjerg, at the Esbjerg Fiskeindustri a.m.b.a. factory, also known as the '999' fish factory, and the world's largest single producer of industrial fish products. The plant operates 24 hours a day, seven days a week, and is capable of processing 7,000 tonnes of raw material daily. The plant produces a range of fish meals, intended for poultry, pigs, mink, farmed salmon, and ruminants. Fish oils, which are high in health-promoting Ω-3

fatty acids, are sold for blending into animal feeds, and for use in the production of margarine, biscuits and other foodstuffs.

Esbjerg Fiskeindustri a.m.b.a. is a cooperative company involving the owners of about 65 fishing vessels. The company requires that vessels may land their catch only at Esbjerg, and this allows for relatively simple and accurate monitoring of both the landings and distribution of the fishery. Other fish meal factories also process sandeels, in Denmark, Norway, Shetland and Ireland. Typically, the Danish industrial vessels spend four to ten days at sea before unloading at the factory. At the height of the season ships may have to queue in the harbour before unloading. Quality assessment of all landings is carried out at the point of unloading. Freshness is assessed according to the Total Volatile Nitrogen (TVN) scale that ranges from 0 upwards (0 being the freshest and 100 being partially decomposed). This value will vary with the length of time held on board and the degree of icing. On the basis of such analyses, poor quality fish (TVN>40) will incur a financial penalty, while landings with a TVN<40 will result in a bonus for the owner and crew. The TVN required for products for human consumption is generally below 40. Sandeels are relatively low in their oil content compared with mackerel, sprats and herring, but are higher than Norway pout and the other white fish species. There is some mixing of raw materials within the factories to produce fish meals with particular characteristics.

The *Morthorst* is a skipper-owned vessel, purpose built for industrial fishing and operating from Esbjerg. The vessel has a crew of up to five men whose earnings depend partly upon the catch taken, and its quality. During the first part of each year, the *Morthorst* fishes mainly for sandeels in the North Sea. The fishery starts in Norwegian waters around the Inner Shoal, in the first quarter of the year and then moves to the southern part of the Dogger Bank in mid-April (Figure 1). The fleet may then move to banks off the east coast of Scotland and northern England by early summer. As the sandeel season comes to a close, the *Morthorst* pairs up with a second vessel to tow a pair-trawl for sprats, usually off Heligoland. As the year progresses, horse mackerel are targeted in the English Channel. The location of the individual fisheries varies from year to year because of fluctuations in the local stocks of fish, and seasonal changes in abundance. The Danish fleet tends to operate as a unit, and radio contact with the factory and other vessels is maintained to provide updates on the best fishing grounds. Some vessels, but not all, use sonar to detect sandeel concentrations.

The sandeel net of the *Morthorst* weighs approximately two tonnes and is located to the starboard side of the boat. A spare net is usually rigged ready for use in the event of damage to the first. The combination of the weight of the net itself, the otter boards (1,500 kg each, which spread the net) and the towing speed of the vessel (3 to 3.5 knots) allows the net to skim across the seabed while a series of large floats attached to the

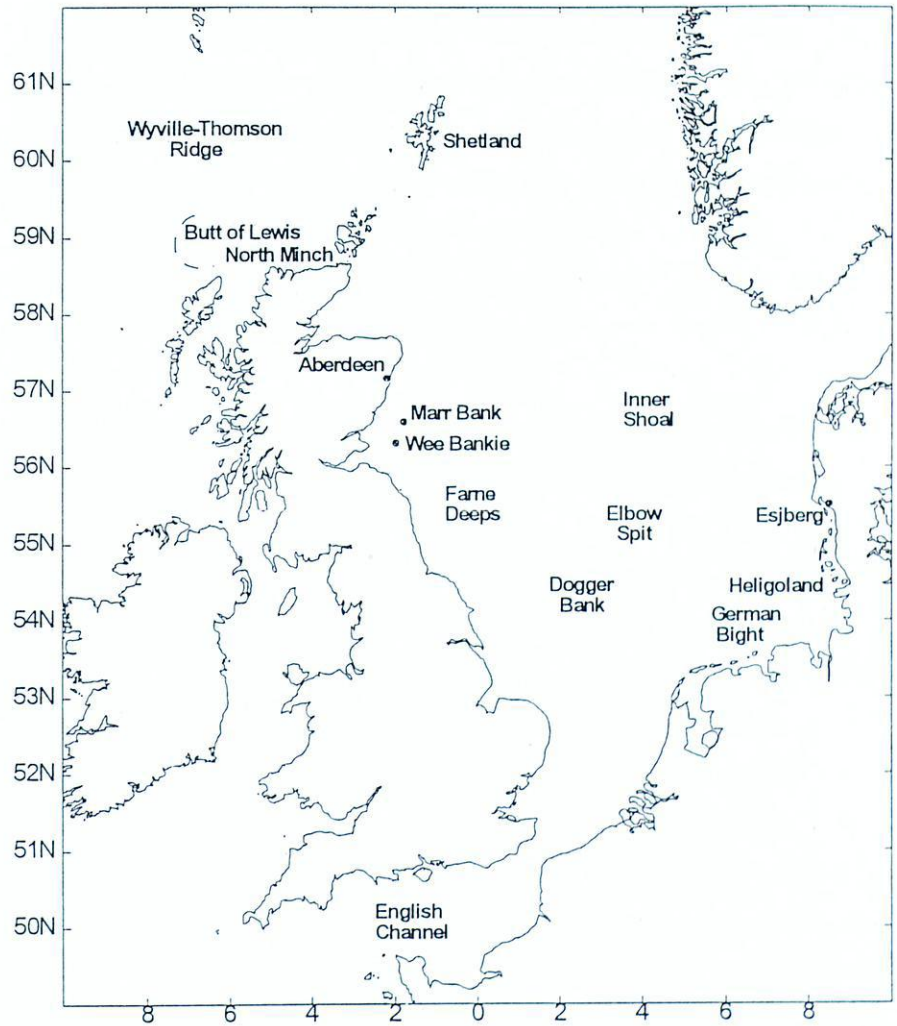

Figure 1. Locations mentioned in the text where sandeel fishing is carried out.

headline provides the buoyancy required to raise the net mouth and keep it open. During trawling the rear end of the net which retains the fish, the cod-end or sec, lies a distance of 350 fathoms (fa.) behind the boat (Figure 2). Sandeel, emerging from the seabed during daylight, rise in the water column on the approach of the net and are captured in the 20 mm mesh cod-end.

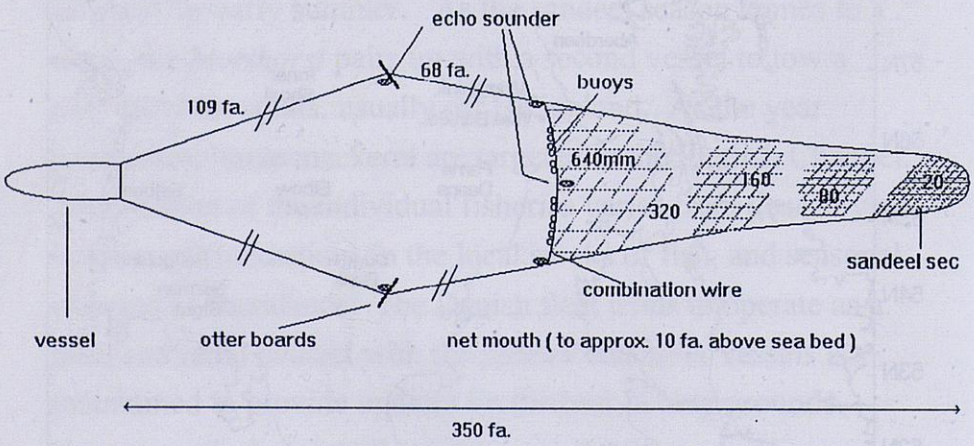

Figure 2. Schematic diagram of a sandeel net, operating at approximate depth of 35 fathoms (not to scale). The numbers superimposed on the net give the mesh size in millimeters.

The net is usually first shot in the early morning and trawl duration may last from one to 12 hours depending on catch success. On average, during the high season for sandeels, boats will usually shoot their nets twice a day. They tend to trawl repeatedly along the sand banks, manoeuvring by lifting one of the otter boards above the sea surface. In some locations the areas of suitable substrate form long corridors and several vessels may fish the same sand bank in line behind one another. Then, as catch rates fall, the vessels will move on to another sandbank and repeat the process.

The *Morthorst*, like other vessels is equipped with a device to detect the fullness of the net, by monitoring the strain across the cod-end. An echo sounder, attached to the headline, is used through the duration of the trawl haul to indicate the passage of fish into the net and the decision to haul the gear is ultimately left to the skipper's discretion. Once the otterboards have been secured, the net is brought along the starboard side of the vessel and winched on board (Plates 1 and 2). The more advanced vessels employ a fish pump to empty the catch from the net, which may have given rise to the idea that the ships 'hoover' up their catch. It is more typical for the cod-end to be emptied manually, a section at a time. As the catch may be many tonnes (the winch has a 25 tonne capacity) this emptying process may take 90 minutes for larger catches.

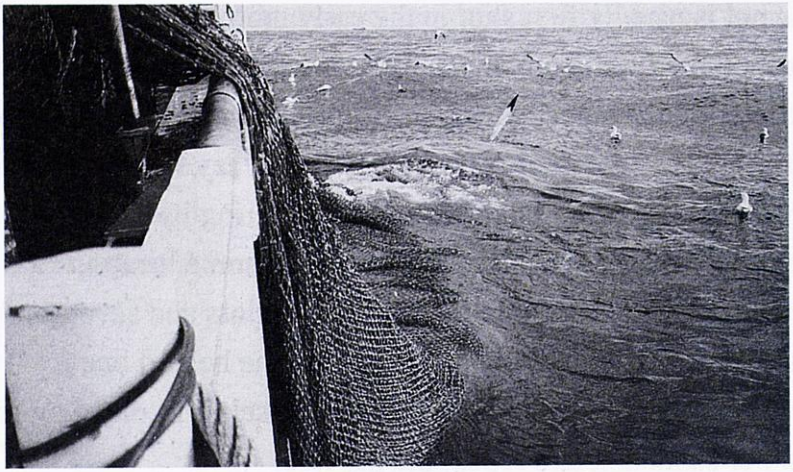

Plate 1. Bringing the fishing net on board the sandeel vessel.

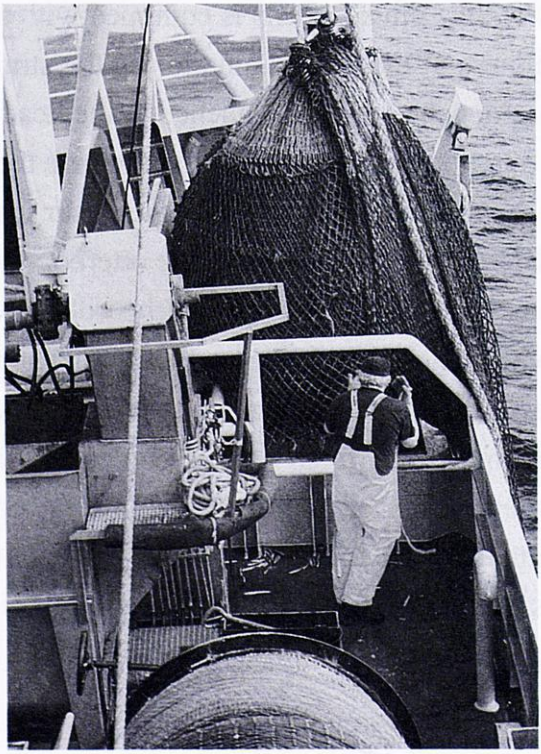

Plate 2. The sec of the sandeel net is on board, prior to being opened to release the catch

On emptying the cod-end, fish pass through a grating, dropping below the main deck. At this point many industrial vessels employ a sorting device, where fish above a given size are separated out. However, as the *Morthorst* seasonally participates in the horse mackerel fishery, the only grading device employed is a series of bars approx. 20 cm apart, over which the net is emptied (Plate 3). The sandeels are then conveyed upwards at an angle of 45° and then mixed with ice. The ice and sandeels then enter a vertical chute (approximately 30 ft high) onto which two extendable pipes are affixed (Plate 4). These pipes feed directly into storage areas and may be rotated manually to feed the fish into the different holds.

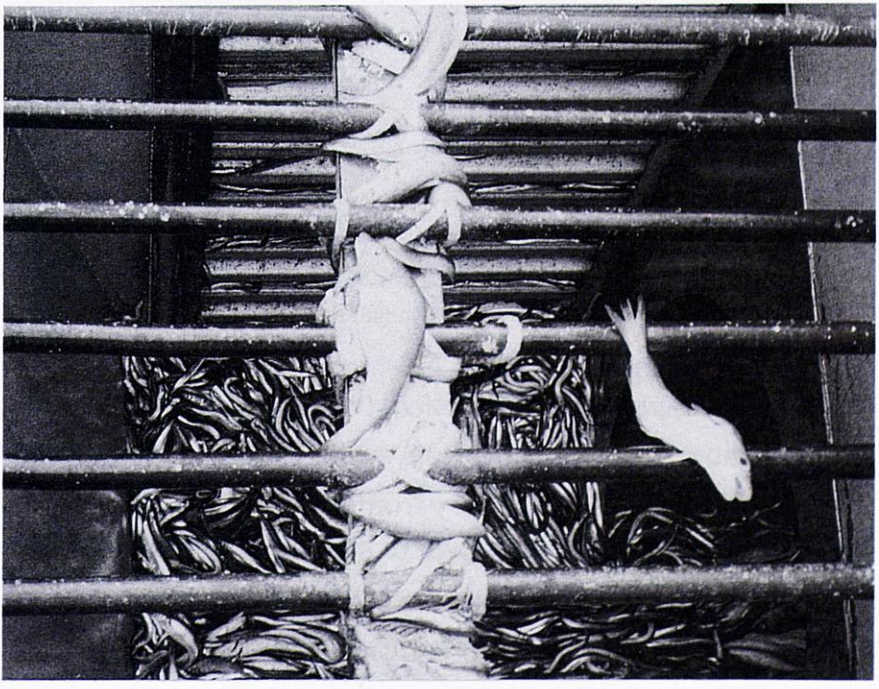

Plate 3. Grading device, consisting of a series of bars to retain larger by-catch species.

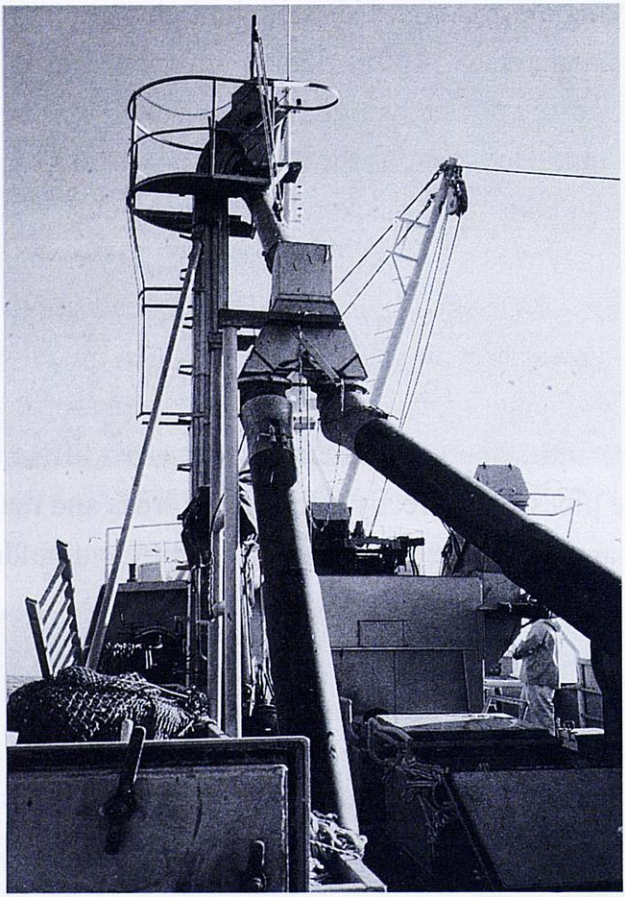

Plate 4. Pipes for directing fish into the different holds.

While the cod-end is being emptied, two men work in the storage spaces, one works on deck, while the other operates the winch and other deck machinery from the bridge.

There are two storage decks on the *Morthorst*. On each deck, the fish rooms are sub-divided into smaller areas allowing sections to be isolated, an important feature in providing greater stability in bad weather. Excess water is allowed to

drain from the fish and pumped from the storage spaces. In general the spaces are left partially filled to allow fish to settle before being topped up by subsequent hauls and then finally secured. In accordance with factory recommendations the crew receive a financial reward if they regularly record storage temperatures in the hold.

On return to port the fish are removed from the hold by a pump which directs the catch immediately into the processing plant. This ensures rapid and environmentally safe unloading. Representative samples are drawn from various sections of the hold and undergo analysis at the on-site laboratory. The results, and therefore gradings, may vary between holds within an individual boat depending on storage time and facilities. Though tests involve bacterial counts and analyses of water and fat content, they are mainly used to assess the freshness of the raw product which ultimately determines the TVN values.

Sampling the catch

Jenny Christie and Ken Coull sailed on two Danish vessels, the *Morthorst* and the *Peter Marlene* respectively, to collect information on the fishery itself, to measure the length and age of the sandeels caught, and to investigate the by-catch from the fishery. Information was also recorded on the timing and location of each haul, and on the size of the total catch.

Several baskets (approximately 40 kg) of fish were taken randomly from each haul, at various stages of the catch being pumped on board. The sample baskets were then sorted and the length, distribution and weight of each species determined. The length of all non-target species was measured to the nearest cm. A sample of about 4.5 kg of sandeels was then taken, and the length recorded to the nearest 0.5 cm. From each major area fished, five pairs of otoliths (ear bones) were removed from a sample of fish at each 0.5 cm length increment, and the age determined from the annual rings.

Fishing activity by the *Morthorst* took place between the 5th and 13th of July 1996 and was concentrated at two locations, firstly on the Farne Deeps (hauls 1-8) and then farther south (hauls 9-10). A total of ten hauls was made during the eight day trip at depths of between 32 and 38 fathoms. The tonnage per haul ranged from 20 to 100 tonnes. The duration of the hauls ranged from 55 minutes to eleven hours 39 minutes. The first haul of the day was shot between 06.04 at 10.08h and the last haul was brought up at 21.32h. The total catch was 550 tonnes, taken over a trawl time of 58 hours 55 minutes, giving an average catch rate of 9.34 tonnes per hour.

From the 550 tonne total catch, 569 kg of fish were sampled of which 565 kg (99.3%) were sandeels. Raitt's sandeel, *Ammodytes marinus* was the only sandeel species caught. A summary of the catch sampling is given in Table 1.

Haul no.	Total Catch (tonnes)	Sample Weight (kg) (all species)	Sample Weight (kg) (sandeels)	Subsample Weight (kg) (Sandeels)	No.Sandeels Measured	Subsample wt as % of haul wt.
1	45	25	25	4.4	249	9.78×10^{-3}
2	80	35	35	4.6	180	5.75×10^{-3}
3	25	36	36	4.6	152	0.0184
4	60	69	65	4.6	168	7.67×10^{-3}
5	100	63.5	63.5	4.8	194	4.8×10^{-3}
6	40	63	63	4.6	251	0.0115
7	50	65	65	4.8	346	9.6×10^{-3}
8	20	57	57	4.8	639	0.024
9	50	79	79	4.9	336	9.8×10^{-3}
10	80	76.5	76.5	4.8	322	6.0×10^{-3}
Total	550	569	565	46.9	2837	

Table 1. Summary of sandeel sample and subsample measurements for 10 hauls by the *Morthorst*.

The length of the sandeels varied from 4.5 to 23.5 cm (Figure 3), and there were two strong peaks, at about 9 cm and 17 cm in the overall length/frequency distribution. There were small differences in the length/frequency distribution of fish from different areas. The ages of the sandeels ranged from 0 to 8 years (Table 2), though 0, 1 and 2 year old fish dominated the catch

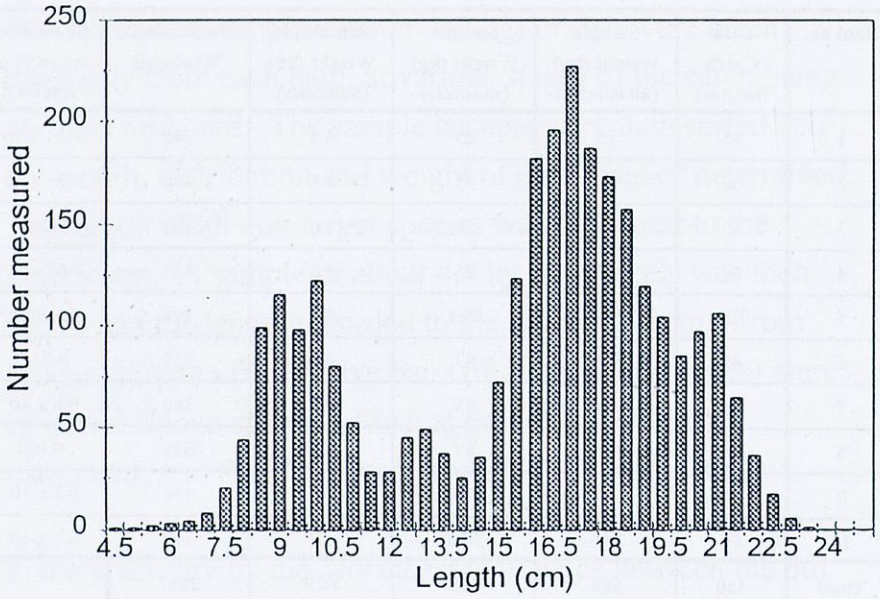

Figure 3. Combined length frequency distribution of Raitt's sandeel sampled on the *Morthorst* (July 1996).

On industrial vessels there is a restriction on the use of automated grading machines which might be used to remove and reject by-catch species. The by-catch is brought on board and examined, and there is a requirement to close the fishery if the by-catch is too large. During the voyage of the *Morthorst* six non-target fish species were identified,

whiting *Merlangius merlangus*
haddock *Melanogrammus aeglefinus*
mackerel *Scomber scombrus*
herring *Clupea harengus*
common dab *Limanda limanda*
sprat *Sprattus sprattus*

The most abundant non-target species was the whiting, ranging in size from 16-30 cm. Haddock was the second most abundant. During the trip it was estimated that about 63,000 fish belonging to non-target species were landed. This compares with about 30 million sandeels. No salmon smolt was encountered. By-catches of whiting and haddock are said to be higher earlier in the morning. A grey seal *Halichoerus grypus* was caught during the voyage, which had been tagged in the Farne Islands in 1993.

Four hauls were examined from the *Peter Marlene* though five hauls were made during the five day trip. The vessel commenced fishing at a ground known as the Elbow Spit, but the small catch of 0.5 to 1.0 tonnes was released at the surface as it was considered too small to bring on board. The vessel recommenced fishing at 0500 hours on 5th June on the southwest side of the Dogger Bank. The tonnage per haul ranged from 135 to 200 tonnes, and the vessel eventually broke off from fishing on the morning of 6th June and returned to Esjberg with 700 tonnes of fish on board.

From the total catch of 700 tonnes, 1,108 kg of fish were sampled, of which 1,104.8 kg (99.7%) were sandeels. Raitt's sandeel *Ammodytes marinus* was the main species of sandeel caught, accounting for 1103.3kg (99.6% of the total sample). Small numbers of greater sandeels *Hyperoplus lanceolatus* were also taken. The length of the Raitt's sandeels caught varied from 9.5 to 18.0 cm (Figure 4). Though there were

small differences in the length frequency distribution in different hauls, the median length was about 14 cms. Their ages ranged from 1 to 4 years (Table 3), though 1 and 2 year old fish dominated the catch. Length frequency compositions for the greater sandeels are shown in Figure 5.

Of the total catch, 2,385 kg of by-catch was estimated to have been caught. Seven non-target species were identified, in the following order of abundance:

whiting *Merlangius merlangus*
haddock *Melanogrammus aeglefinus*
grey gurnard *Eutrigla gurnardus*
lesser weever *Echiichthys vipera*
cod *Gadus morhua*
mackerel *Scomber scombrus*
sprat *Sprattus sprattus*

The raised length frequencies of the whiting which were caught are shown in Figure 6. No salmon smolt was encountered.

Area: 39E9 Hauls: 1 to 8

Length	Age (years)				
7	0	0	0	0	0
7.5	0	0	0	0	0
8	0	0	0	0	0
8.5	0	0	0	0	0
9	0	0	0	0	0
9.5	0	0	0	0	0
10	0	0	0	0	0
10.5	0	0	0	0	0
11	1	0	0	0	0
11.5	1	1	1	0	0
12	1	1	1	1	1
12.5	1	1	1	1	1
13	1	1	1	1	1
13.5	1	1	1	2	1
14	2	1	2	2	1
14.5	2	2	1	2	
15	1	2	2	2	2
15.5	2	2	2	2	2
16	2	2	2	2	2
16.5	2	2	2	2	2
17	2	2	2	2	3
17.5	2	2	2	2	2
18	4	2	2	2	2
18.5	2	2	2	2	2
19	2	2	2	2	2
19.5	6	2	2	6	2
20	7	5	3	3	5
20.5	2	5	5	5	7
21	6	4	5	5	5
21.5	6	5	5	5	5
22	4	5	5	5	
22.5	6	5	5	7	5
23	5	5	5	8	5
23.5	6				

Area: 39E8 Hauls: 9&10

Length	Age (years)				
7					
7.5					
8					
8.5	0				
9	0	0			
9.5					
10	0	1	0		
10.5	0				
11	1	1	1	1	1
11.5	1	1	1	1	1
12	1	1	1	1	1
12.5	1	1	2	1	1
13	1	1	1	1	1
13.5	1	1	1	1	1
14	2	2	1	1	2
14.5	2	2	2	1	2
15	2	2	2	2	2
15.5	2	2	2	2	2
16	2	2	2	2	2
16.5	2	2	2	2	2
17	2	2	2	2	2
17.5	2	2	2	2	2
18	2	2	3	4	2
18.5	2	2	2	2	2
19	2	2	2	2	2
19.5	2	6	2	2	2
20	2	2	6	7	5
20.5	2				
21	5				
21.5	4	5	3	5	
22					
22.5					
23					
23.5					

Table 2. Ages of Raitt's sandeel sampled during the trip on the *Morthorst* (July 1996).

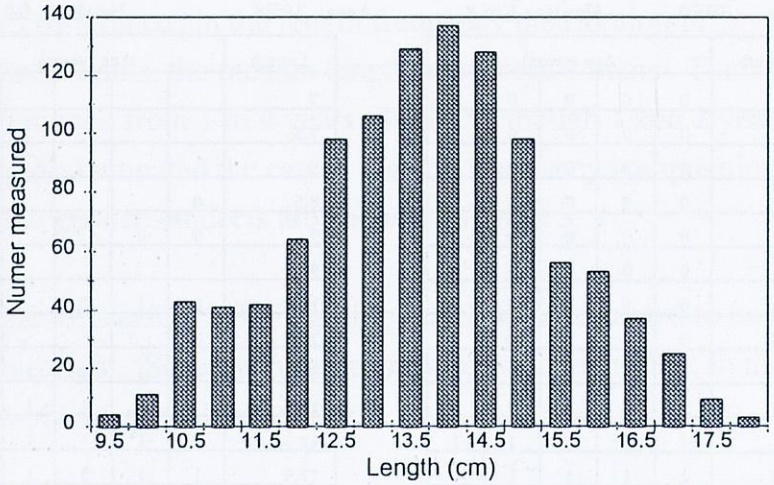

Figure 4. Combined length frequency distribution of Raitt's sandeel sampled on the *Peter Marlene* (June 1997).

Area: 38F1 Hauls 1 to 5

Length	Age (years)				
10	1	1	1	1	1
10.5	1	1	1	1	1
11	1	1	1	1	1
11.5	1	1	1	1	1
12	1	1	1	1	1
12.5	1	1	1	1	1
13	1	1	2	1	1
13.5	1	1	1	1	1
14	1	1	1	1	
14.5	1	1	1	1	1
15	2	1	1	1	1
15.5	2	1	1	1	1
16	1	1	1		
16.5	1	1	2		
17	1	1			
17.5					
18	4				

Table 3. Ages of Raitt's sandeel sampled during the trip on the *Peter Marlene* (June 1997).

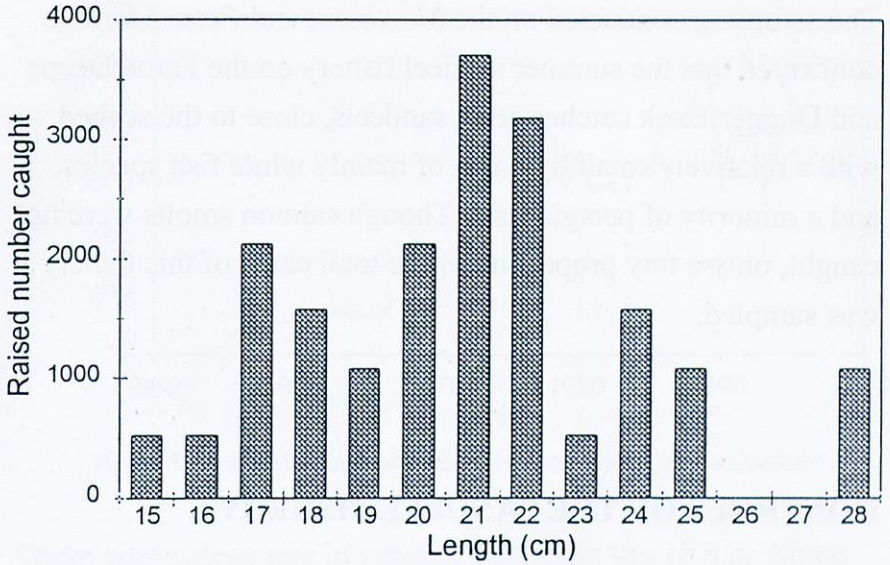

Figure 5. Combined length frequency distribution of greater sandeel sampled on the *Peter Marlene* (June 1997).

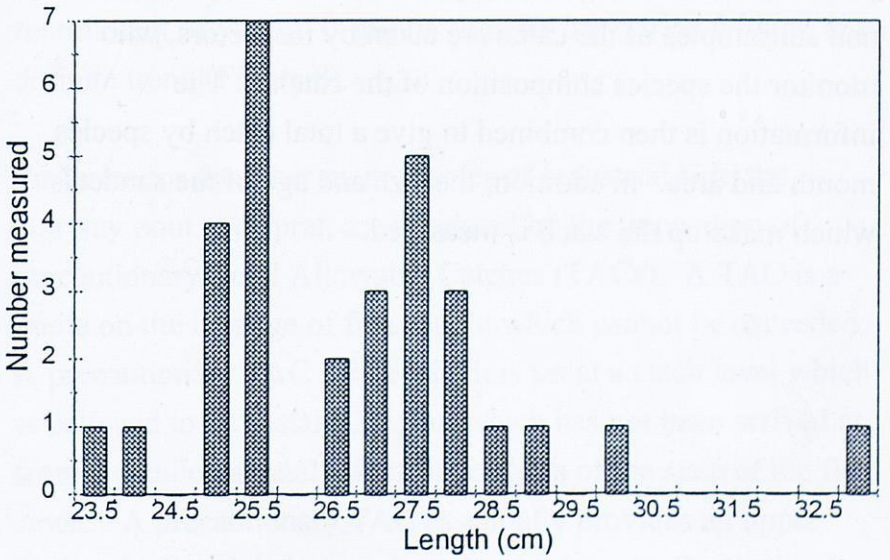

Figure 6. Raised length frequency distribution of whiting caught on the *Peter Marlene* (June 1997).

The sampling conducted on the *Morthorst* and *Peter Marlene* confirmed that the summer sandeel fishery on the Farne Deeps and Dogger Bank catches adult sandeels, close to the seabed, with a relatively small by-catch of mainly white fish species, and a minority of pelagic fish. Though salmon smolts were not caught, only a tiny proportion of the total catch of this fishery was sampled.

CONTROLS ON THE SANDEEL FISHERY

Sandeel vessels are obliged to keep a log-book recording the date, position, and composition of their catch. The fish meal plants then have to report the quantities landed by each vessel, and subsamples of the catch are taken by inspectors, who monitor the species composition of the catches. The information is then combined to give a total catch by species, month and area. In addition, the size and age of the sandeels which make up the catch is measured.

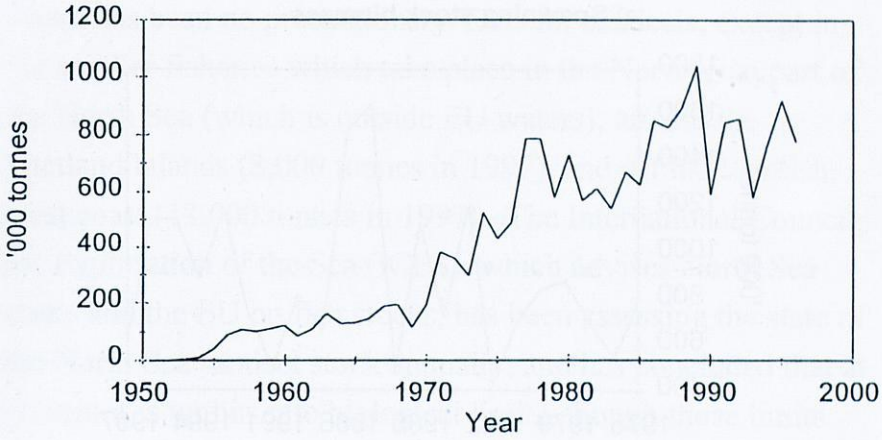

Figure 7. Annual landings of sandeel from the North Sea, 1952-1996

There was a steep rise in sandeel catches in the 1970s. Since 1977, annual catches of sandeels from the North Sea have fluctuated between 0.5 and 1 million tonnes (Figure 7). Spawning stock biomass varies greatly from year to year. The recruitment of young '0' group sandeels has varied without any definite trend (Figure 8).

Fisheries for the other main species of industrial fish, the Norway pout and sprat, are regulated by the imposition of precautionary Total Allowable Catches (TACs). A TAC is a quota on the tonnage of fish caught which cannot be exceeded. A precautionary TAC is one which is set at a catch level which is believed to be sustainable, but which has not been arrived at from a detailed annual scientific analysis of the state of the fish stock. A precautionary TAC essentially provides an upper limit, which may help to reduce the year to year fluctuation in catch, and prevent the catch suddenly rising to too high a level.

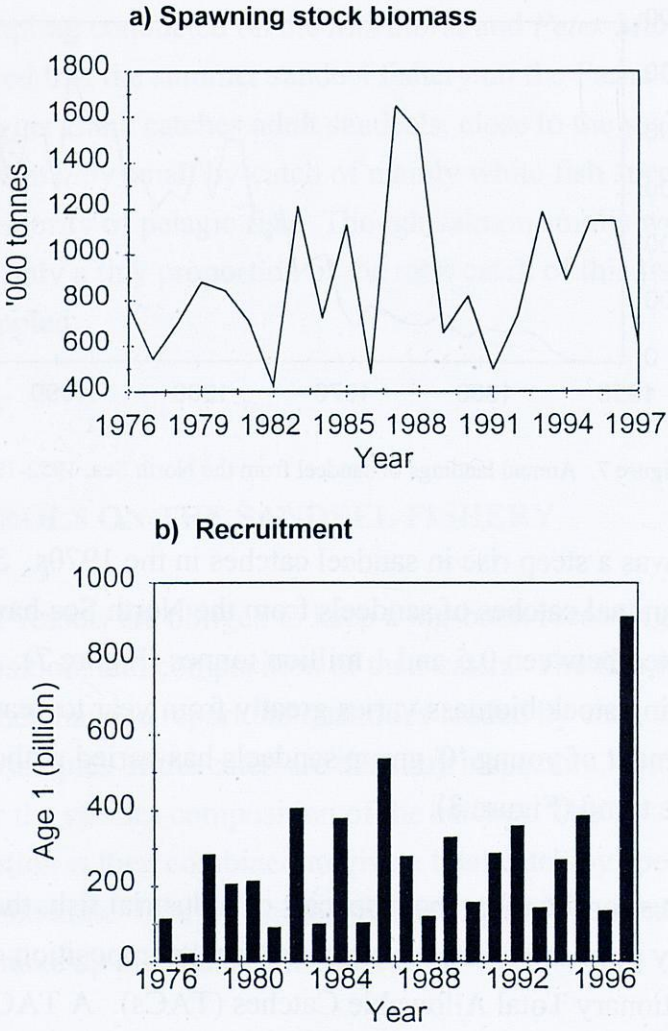

Figure 8. a) Spawning stock biomass and b) recruitment of North Sea Sandeel. Estimates from Anon (1998) Report of the Working Group on the assessment of Demersal Stocks in the North Sea and Skagerrak. ICES CM 1998 Assess:7.

There has been no precautionary TAC for sandeels, except in the smaller fisheries which take place in the Norwegian part of the North Sea (which is outside EU waters), around the Shetland Islands (3,000 tonnes in 1997), and off the Scottish west coast (12,000 tonnes in 1997). The International Council for Exploration of the Sea (ICES), which advises North Sea states and the EU on fish stocks, has been assessing the state of the North Sea sandeel stock annually, and has concluded that at present it is within safe biological limits, though those limits have not been explicitly stated.

The concept of safe biological limits was introduced to identify those stocks that are at levels at which their productive capacity is impaired, or which may become so at current levels of fishing. For some fish stocks, especially those which have been very heavily fished in the past and where signs of a reduction in the recruitment of young fish has been observed, it has been possible to define a minimum biologically acceptable level of spawning stock size. This level can then serve as an indicator of serious damage to the stock. If spawning stock size falls below this figure, future sustainability of the stock may be threatened. No estimate of a lower safe biological limit of spawning stock is available for the sandeel.

The strength of recruitment to the sandeel stock has varied from year to year (Figure 8), but there has been no clear indication of a trend towards reduction in recruitment, or in the size of the spawning stock. Indeed, the sandeel spawning stock

size, though variable, has remained high. The level of fishing mortality (the proportion of fish removed through fishing) is also relatively low for North Sea sandeel stocks, certainly much lower than for many of the fish stocks harvested for human consumption. On the basis of these criteria, it has been agreed by ICES that there is little justification for the imposition of restrictive TACs. At the end of 1997, however, the European Commission came forward with proposals for a precautionary TAC for North Sea. A TAC of 970,000 was agreed early in 1998 by the EU Council of Ministers, which is just above the current level of catches.

However, it is not appropriate to manage the sandeel fisheries in isolation, since it affects other resources. All the industrial fisheries are taking other fish which are important for human consumption, and which also form the food of predators, such as sea mammals, seabirds and a variety of fish. These factors must be considered in managing the sandeel fisheries.

The first of these problems—the capture of other commercial species—many of which are protected, is controlled by restrictions on the by-catch of protected species (those for which a minimum landing size is in force). In the fisheries for sandeels and sprats, the by-catch is not allowed to exceed 10% of the total catch. In the fishery for Norway pout, which takes a larger proportion of protected species, a 15% by-catch limit is in force. Concern over the low size of the herring spawning stock has resulted in the imposition of a by-catch TAC for

herring in all industrial fisheries since 1996. There is also currently a ban on the direct capture of herring for industrial purposes. To ensure that the by-catch is not exceeded and that quotas are observed, fishing vessels may be subject to random inspections at sea, and at points of unloading. Log books may be inspected, and entries compared with actual catches including the by-catch.

Concern over high levels of by-catch has prompted the closure of certain areas to industrial fishing at some times of the year. The closure of grounds in the German Bight and off the Jutland coast to protect juvenile plaice and cod has already been mentioned. In addition, a Norway pout box has been established in the north western North Sea, close to the Scottish coast, where fishing with small mesh trawls for Norway pout is forbidden in order to protect haddock and whiting stocks. There is also a Danish sprat box along the Danish west coast where fishing for sprats is forbidden between July and October.

LOCAL SANDEEL FISHERIES

Some local fishing for sandeels takes place close to the Scottish coast.

In the 1970s a fishery for sandeels began at Shetland. By 1982 the catch had risen to 52,600 tonnes. At the end of the 1980s, however, the annual recruitment of young fish to Shetland waters had fallen to a very low level and catches sharply

declined. Concurrently, a fall in the breeding success of some seabird species was observed along the nearby coast. The sandeel fishery was blamed for both the decline in sandeel recruitment and the fall in breeding success of birds. The fishery was closed in 1991.

Research subsequently revealed that Shetland sandeels do not constitute a completely discrete stock. In most years, the majority of '0' group sandeels settling upon the seabed at Shetland come from areas to the south and west of the Islands and the numbers recruiting depend upon the strength and direction of ocean currents. The decline in recruitment at Shetland could not be blamed upon the Shetland fishery. Rather, fluctuations in the currents carrying the larvae to Shetland were responsible (Wright, 1996). Poor transport of larvae, resulting in a low availability of sandeels at Shetland, gave rise both to the poor breeding success of seabirds and the poor fishery. After the closure of the fishery there were several more years of poor recruitment at Shetland, which again affected the breeding success of sea birds. However, in 1995, following several years of strong sandeel recruitment, and an improvement in seabird breeding success, the fishery was re-opened. The Shetland fishery has since been regulated by a TAC, initially set at 3,000 tonnes, and by a restriction of the fishery to named, licensed vessels of no more than 20 metres. The fishery has been closed at the end of June. During 1995 and 1996 the TAC was not reached. In April 1998 new arrangements were introduced following consultation. The

TAC was increased to 7,000 tonnes, but the fishery will be closed during the main seabird breeding season in June and July. The 20 m vessel restriction may be raised if it appears that the TAC is unlikely to be taken. Management of the fishery will be delegated to the Shetland Fish Producers' Organisation.

There is also a small sandeel fishery on the west coast of Scotland, which started in the 1980s. The localised grounds are found in the North Minch off the Butt of Lewis and around the island of North Rona. The catch peaked at 25,000 tonnes in 1986, but with the closure of the local fish meal plant catches fell to less than 5,000 tonnes in 1992. Since then, landings have increased slightly. A precautionary TAC of 12,000 tonnes has been set since 1995, and access to the fishery is limited to vessels with a track record. The fishery closes at the end of July. Vessels are required to land their catch at Lerwick unless they give 24 hours notice of their intention to land elsewhere.

By far the largest sandeel fisheries taking place off the Scottish coast are those based on a number of banks to the east of the Firth of Forth, including the Marr Bank and the Wee Bankie. Unlike the Shetland and west coast grounds, these are in waters outside UK territorial limits which are subject to the rules of the Common Fisheries Policy. In recent years, Danish vessels have targeted these banks towards the end of their annual period of sandeel fishing in the North Sea. In 1993, when these

banks were especially heavily fished, around 115,000 tonnes of sandeels were taken from the Wee Bankie alone. These areas support local fisheries for cod and haddock based on the small Fife ports. They also form feeding areas for some species of birds from the Bass Rock, the Isle of May, and the Firth of Forth, and of course they are close to the salmon producing rivers of the Tay and Forth.

INTERACTIONS WITH OTHER FISHERIES AND WITH PREDATORS

The North Sea industrial fishery has been controversial from the beginning. It has often been argued that, by catching large quantities of small fish, at the base of the food chain, the food supplies for human consumption species like the cod and haddock are being removed. Moreover, it is said that other predators such as seabirds, salmon, seals and cetacea are also being deprived of their food supply. In the case of salmon, fears have been expressed that when the fishery is pursued close to the Scottish east coast, it may inadvertently take salmon smolts as a by-catch.

Effects on other fisheries

The industrial species of fish are not in fact at the bottom of the food pyramid, they lie somewhere in the middle. Sandeels, Norway pout and sprats eat mainly zooplankton, the small animals which graze upon the green phytoplankton which lie at the very bottom of the pyramid. In turn, the small industrial fish, the larger crustaceans and other predators of the zooplankton are eaten by cod, haddock, mackerel and salmon. These in turn are eaten by Man and the larger predators. There is a loss of biomass to about one tenth in moving up from one level to another in this food pyramid. The greatest biomass is in the phytoplankton, then the zooplankton, then the smaller fish like sandeels, and then the larger commercial species. A very small proportion of the total biomass sits at the apex of the pyramid, with the top predators.

There is no doubt that the sandeel is an important prey for many fish species. A stomach sampling programme carried out by ICES has confirmed the importance of sandeels to the five main predatory fish which inhabit the North Sea. About 8% of the food of cod and haddock, 5% of the food of saithe, 19% of the food of North Sea mackerel, and 25% of the food of whiting consists of sandeels. Indeed, collectively these five predators consume annually about 900,000 tonnes of sandeels, a figure comparable to the total landings from the sandeel fishery (Gislason and Kirkegaard, 1996). A number of other predatory fish, including the herring, plaice, grey gurnard, sea

trout and salmon also feed upon sandeels or the predators of sandeels.

The question of whether to fish for sandeels, as oppposed to cod or haddock, is mainly an economic one. The lower down the food pyramid the greater the quantities of fish are available. The sandeel fishery is capable of supplying a great bulk of fish, and fulfilling the strong demand for fish oils and meal, but the sale price per unit weight is lower than that for the prime roundfish like cod and haddock.

One question which has to be asked, however, is whether the removal of large quantities of sandeels is likely to cause particular damage to other parts of the ecosystem. Is the sandeel a keystone species within the North Sea or is its ecological role taken over by other species if it is removed? Where keystone species exist, their exploitation can cause major changes in ecosystem structure. Often, such species are predators, controlling the numbers of other species (often, for example, grazing species). Removal of the keystone predator can cause the prey species to multiply, with undesirable consequences (for example, very heavy grazing pressure). As yet, there is no evidence that the sandeel is such a keystone species, and that its removal will affect the whole ecosystem adversely. What evidence we have points to a great deal of functional redundancy in North Sea ecosystems, where the removal of a particular species results in other species

assuming a similar role. This is an area where more research is required.

There is of course a risk that, if sandeel stocks are very heavily exploited, the larger whitefish which eat them will be deprived of food, affecting their growth and survival. At the moment, the stocks of several whitefish, and especially the cod, are in a poor state. However, this can be attributed directly to the very high level of fishing effort directed at them by the human consumption fisheries, aggravated by over-quota landings and the discarding of immature fish. There is no evidence that the white fish are suffering from a shortage of food; rather, the decline in their stocks is reducing the level of predation on sandeels, releasing fish which may be taken as food by other predators. Indeed, there is a strong contrast between the fisheries for white fish, and those for the sandeel in terms of their vulnerability to fishing. Whereas the human consumption fisheries are removing about 80% of the annual production of cod and haddock, the industrial fisheries take less than 25% of the annual production of industrial species.

Effects on predators

Do the industrial fisheries adversely affect the top predators? Overall, across the North Sea, a proportion of the production of sandeels is consumed by predators other than fish. These predators include many charismatic creatures, like the porpoises, dolphins, seals, and a great variety of seabirds.

Indeed, sandeels, along with sprats and herring, are the most important source of food for seabirds in the North Sea, especially during the breeding season. Is it possible that the industrial fisheries are competing directly with the seabirds and sea mammals for the smaller fish species?

In general, many marine predator populations around the North Sea are in a healthy state. Populations of some seabirds, including the herring gull, fulmar, gannet, and cormorant are at unprecedentedly high levels. Breeding numbers of these birds on North Sea coasts have increased at least tenfold since the beginning of the century. Grey seals too have increased steadily in numbers, though common seals have not. Killer whales are on the increase. However, some specific predators are declining. The harbour porpoise appears to be less abundant than it once was, though in this case a major contributory factor may be the incidental capture of porpoises in set-nets fished along the coasts of Germany and Denmark. Some species of seabird, like the puffin, the kittiwake and the arctic tern have undoubtedly shown poor breeding success in some years, at Shetland, and elsewhere. These shallow water feeding seabirds are very dependent on prey species found close to the sea surface, like sprats, herring and very young recruiting '0' group sandeels. Moreover, their foraging range is limited during the breeding season, and they are therefore especially dependent on the availability of small fish at or near the surface, close to the coast. The sandeel grounds at Shetland, and areas like the Wee Bankie, off the Firth of Forth,

undoubtedly provide important feeding opportunities for such seabirds. It is known that local sandeel populations can be very variable, due to the short life span of the species and variable and patchy recruitment.

Overall, across the North Sea, the actual proportion of sandeels taken by the industrial fishery is quite small, about one quarter of what is there. The catch of 1 million tonnes is about the same or rather less than the quantity taken by predators. The five main species of predatory fish are estimated to consume 900,000 tonnes of sandeels (Gislason and Kirkegaard, 1996), while seabirds are estimated to consume a further 200,000 tonnes. Seals and dolphins take additional quantities. So far, despite the heavy catch from industrial fisheries and the heavy level of preparation, there is no evidence of a downward trend in either the size of the spawning stock of sandeels, or recruitment to the stocks (Figure 8).

However, if the sand banks off the Scottish coast have their own, discrete, sandeel populations, and if the heavy concentration of industrial fishing on these banks continues, then local spawning stocks could be greatly reduced, recruitment to them could be seriously affected, food supplies for predatory fish in those areas could be reduced, and the availability of '0' group sandeels as food for surface foraging seabirds and other predators operating close to the coast could diminish. Preliminary studies have indicated that there are few genetic differences between sandeels taken from different parts

of the North Sea (Donaghy *et al*, 1995) which would indicate free exchange between the separate banks, which should act against any local depletion. However, further study of the degree of separation of the stocks is needed.

SANDEELS AND SALMON

Salmon spend part of their lives in the sea. Salmon smolts leave Scottish rivers every year to begin their migrations through the north Atlantic Ocean. They may remain in the sea for a year or more before they return to the coast, enter their home rivers and spawn in the rivers and streams where they were born.

Salmon smolts have rarely been caught along the coast or in the open sea, and their migrations remain largely a mystery. In their first few days in the sea such small fish cannot hope to stem the strong coastal currents, and almost certainly their movements are dominated by local water movements. Recent studies of acoustically tagged smolts have shown that even within sheltered parts of the coast they tend to be moved back and forth by local tidal currents. The small fish stay close to the surface, at least during the initial phase of their migration. Nevertheless, the fish do make progress. Salmon smolts leaving the western coasts of the British Isles are found four to six weeks later in surface waters to the northwest of Britain. They are especially numerous in the vicinity of the Wyville

Thompson ridge, associated with the northward flowing shelf edge current. Fish from the east coast rivers have not yet been recaptured off the UK coast and their movements are less well known. The prevailing currents along the Scottish east coast are moving predominantly to the south and east, and it would be difficult for young fish to stem them. In order to move north, it is possible that the smolts may move slowly eastwards across the North Sea before being carried northward in the Norwegian coastal current. Whatever their route, the post smolts are later to be found in the highly productive frontal areas of the north Atlantic, where they evidently grow very rapidly.

In the initial part of their migrations, smolts have a varied diet of crustaceans, fish larvae, young fish and terrestrial insects. Later, as they grow bigger they consume larger crustaceans, and fish like the sandeel, blue whiting, capelin, and myctophids. Fisheries for capelin, a small arctic species of fish, take place around Iceland, Greenland, and in the northern part of the Norwegian Sea, where feeding salmon are to be found. The Barents Sea stock of capelin is currently in a state of severe decline, and the fishery has been closed. The capelin stock in the Iceland-East Greenland-Jan Mayen area is currently in a healthy state, though it is subject to high variability. It is simply not known whether these capelin fisheries, or other pelagic fisheries which take place in non-EU waters, or international waters beyond UK jurisdiction, have

an effect upon salmon stocks, either through depriving salmon of food, or removing salmon as a by-catch.

The smolts emigrating from Scottish rivers consume, alongside their other prey, sandeel larvae, including the small '0' group fish found in surface waters. These younger stages of the sandeel are found right across the North Sea and to the north of the British Isles (Figure 9). At the present time, there is no evidence that such larvae are in short supply overall, though there are undoubtedly shortages in abundance in some areas in some years - for example at Shetland.

It is not clear whether salmon smolts ever take the '0' group sandeels once they have settled on the seabed. If they did, the smolts would be vulnerable to being caught in the sandeel fisheries operating off the coasts of Scotland. At the moment, all the evidence points towards salmon smolts remaining in surface waters as they migrate northwards, taking the more widely distributed younger stages of sandeel and other species as food. Certainly the small sandeels found in the stomachs of post smolts are almost all the larval pelagic stages (Plate 5). Moreover, sampling of sandeel catches has not so far revealed any by-catch of salmon smolts, and in over 40 years of sandeel sampling the Danish Institute for Fisheries and Marine Research has yet to observe a smolt.

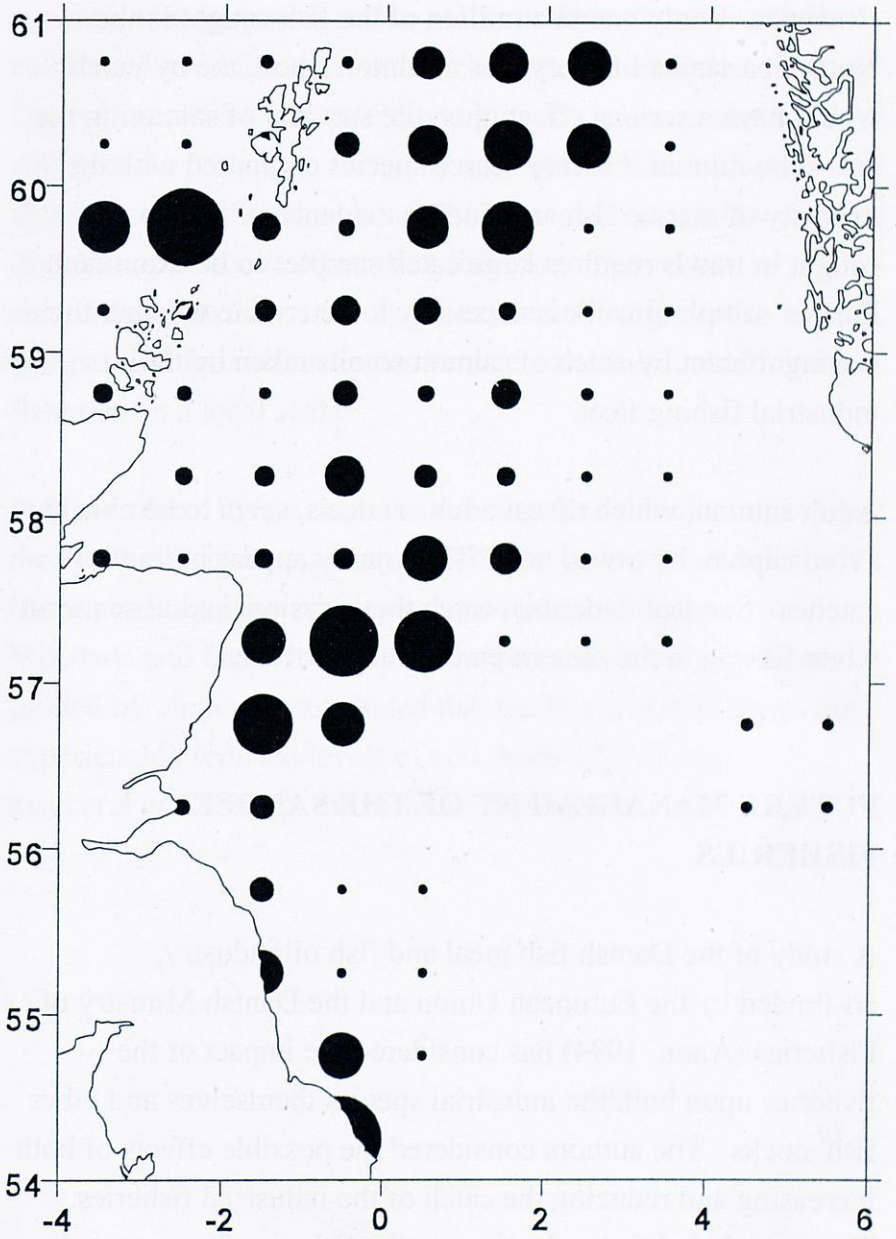

Figure 9. Distribution of 0-group sandeels in the North Sea (June 1997).

However, if only one in a million of the fish caught in the North Sea sandeel fishery was a salmon smolt, the by-catch would have a serious effect upon the survival of salmon in the sea. The salmon is a very scarce species compared with the majority of marine fish and finding evidence of their being caught in trawls requires large catch samples to be examined. Further sampling work is necessary to determine whether there is a significant by-catch of salmon smolts taken by the industrial fishing fleet.

Adult salmon, which do eat adult sandeels, seem to be able to avoid capture by towed nets. They rarely appear in trawl catches. Sandeel fishermen catch the occasional adult sea trout when fishing in the eastern part of the North Sea.

FUTURE MANAGEMENT OF THE SANDEEL FISHERIES

A study of the Danish fish meal and fish oil industry, co-funded by the European Union and the Danish Ministry of Fisheries (Anon, 1994) has considered the impact of the fisheries upon both the industrial species themselves and other fish stocks. The authors considered the possible effects of both increasing and reducing the catch of the industrial fisheries. They concluded that reductions in the fisheries for sprat and/or juvenile herring in the Kattegat and Skagerrak would lead to substantial increases in the catches of herring for human

consumption purposes, and to more moderate increases in the catches of whitefish. However, changes in the sandeel and Norway pout fisheries would result in much less pronounced changes. In particular, the analyses indicated that reductions or closures in the Danish sandeel fishery would not greatly improve opportunities for other fisheries. The review concluded, however, that there may be indications of a competition for fish resources between seabirds and industrial fisheries on a local scale.

In November 1996, a report examining the ecological effects of the North Sea industrial fishing industry on the availability of human consumption species was published (Robertson, McGlade and Leaver, 1996). The report, commissioned and funded by Unilever, concluded that the North Sea fisheries are experiencing reduced levels of cod, haddock, whiting, mackerel and herring, the main human consumption species.

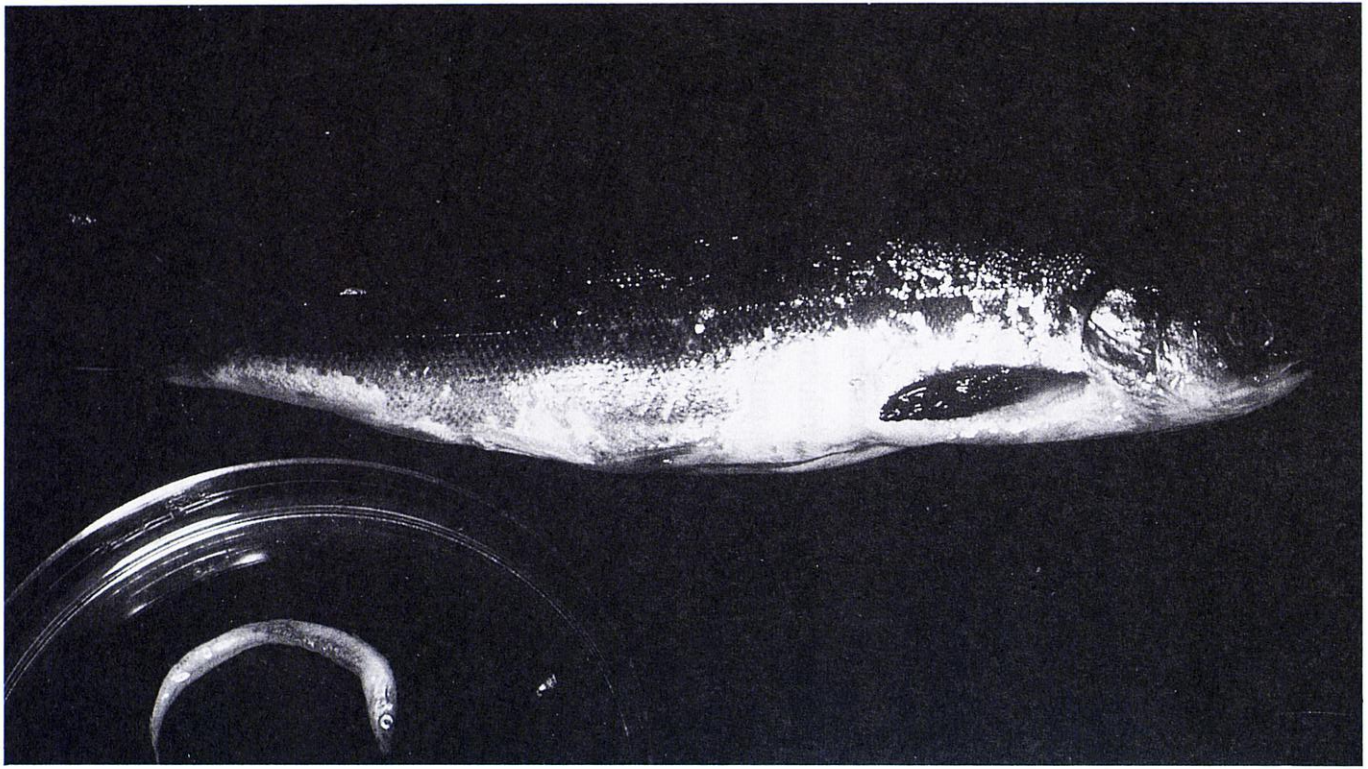

Plate 5. Post smolt Atlantic salmon shown alongside an '0' group sandeel taken from its stomach. This young salmon was caught close to the sea surface off the shelf edge near the eastern end of the Wyville-Thomson Ridge (see Figure 1). Photograph courtesy of Dr. Richard Shelton.

Sandeels and Norway pout are the two most important food items for these species in the North Sea, but the authors believed that in recent years the food preferences and requirements of these fish has altered. They suggest that a reduction in the industrial fisheries would result in some improvement to human consumption fish stocks, though various factors could mitigate (they may have meant militate) against the full effects being observed. The authors argued that the food needs of birds and mammals should no longer be ignored within the North Sea system. A reduction in the industrial sandeel fishery would allow more food to become available to predators. The report recommended that studies should be carried out into the ecological changes taking place in the North Sea, and into the impact of over-quota landings. It suggested that the sandeel stock assessment required greater accuracy. Because of the importance of the western side of the North Sea to human consumption fish stocks, the report recommended that reductions in sandeel extraction should take place to the west of the 4 E line of longitude.

At the request of the Danish Government, ICES subsequently produced a commentary on the report by Robertson, McGlade and Leaver (1996). The ICES Advisory Committee on Fishery Management (ACFM) in commenting on the report's content considered that some of the analyses were inappropriate; several of the conclusions were well known while others were not supported by any analysis and there were a number of errors of detail. ACFM agreed that many of the North Sea fish

stocks are at reduced levels. However, the committee pointed out that many of the human consumption fish of the North Sea are opportunistic predators which are not heavily reliant on any single prey type; there is no reason to suppose that food preferences and requirements have changed in recent years. ACFM accepted that a reduction in sandeel fishing would make more fish available as prey to other predators, and agreed that more ecosystem orientated fisheries models were needed. The suggestion that there should be a 4° E median line to the west of which sandeel fisheries should be reduced was rejected as arbitrary, although ACFM agreed that there may be reasons to consider certain areas as potential regions for restricting industrial fishing.

In 1996 a Greenpeace vessel attempted to interfere with sandeel fisheries close to the Scottish east coast. Following this episode, Greenpeace published a report on industrial 'hoover' fishing (Aikman, 1997). This strongly criticised current management of the industrial fisheries in the North Sea, and recommended the full closure of all North Sea sandeel fisheries in areas sensitive to wildlife, including areas where sandeel fisheries extended onto critical wildlife feeding grounds, such as those foraged by seabirds. It also recommended full closure of sandeel fisheries which extended into spawning, nursery grounds and important feeding grounds for human consumption fish, and recommended that elsewhere catch limits should be regulated according to a strictly precautionary approach.

Danish scientists have recently commented on the industrial fishery and the North Sea sandeel stock in the context of the precautionary approach to fisheries management (Gislason and Kirkegaard, 1996). They have concluded that the present management of the sandeel fishery is far from being precautionary. A management plan has not been elaborated and there is no limit on access to the fishery, no stated agreed objectives and no target reference points available. Early warning signs have not been identified and pre-agreed management measures have not been established. On the positive side, the necessary data to monitor the fishery are being collected, and perhaps because no TAC regulation is in force, and by-catches are small, data on total landings and effort are of a better quality than for many other North Sea fisheries. Gislason and Kirkegaard concluded that given the low level of fish mortality experienced by the sandeel stock and the fact that the fishery has been at the same level for the last 20 years, the need for reductions in overall fishing effort to safeguard the spawning stock does not seem compelling. The sandeel fishery seems to be sustainable with regard to its effect on the overall North Sea sandeel population. They agreed, however, that the indirect effects of the sandeel fishery, and in particular the effect on seabird breeding, could be important. They suggested that a management plan for the fishery should be elaborated in which an upper limit on the total fishing effort and other reference points were specified in relation to factors like spawning stock size and impact on seabirds. They ended by recommending that it would seem precautionary to close

areas in the vicinity of seabird colonies to fishing until more is known about the sandeel stock structure and the interactions between sandeels and seabirds.

The Ministers responsible respectively for the protection of the environment of the North Sea and for fisheries met in Bergen in March 1997. The Ministers recognised the concern about the adverse effects of fisheries on North Sea ecosystems. They also recognised the desirability of an ecosystem approach, to ensure that the characteristic structure and biological diversity of ecosystems was maintained and species and their habitats protected. They agreed to apply a precautionary approach to the management of living marine resources, and invited the competent authorities to establish target reference points and limit reference points for fish stocks, and to establish criteria by which stocks shall be judged to be within or outside safe biological limits. They also agreed to impose restrictions on fishing in any area where the competent authorities judge that the ecosystem of that area requires protection against the impact of fishing.

The North Sea and the seas around the British Isles provide one of the world's most important and productive fishing grounds. It is, however, a complex area both in terms of its hydrography, the inter-relations between the different biological resources, and the management of those resources. The North Sea is bordered by 8 countries, 7 belonging to the EU, all of them with an interest in the fisheries. Political difficulties in

implementing cuts in fishing effort, particularly for the human consumption species, have resulted in very high levels of exploitation. The yield from some of the whitefish stocks might be appreciably greater in the longer term if the fish were less heavily exploited. Moreover, some stocks and most notably cod may be below safe biological limits. In this context, the presence of large industrial fisheries for species of fish which form the food of human consumption species and also support seabirds and sea mammals should be viewed with some concern.

There will be greater pressure in the future to integrate fisheries and environmental policies, and to consider the interactions between different species in managing the various North Sea fisheries. There will undoubtably be closer scrutiny of the sandeel and other industrial fisheries, which may ultimately bring about their closer regulation or even the local closure of fisheries which can be shown to be causing significant damage to the ecology of the North Sea.

Currently, the only sandeel fisheries close to the UK coast where control measures are in place are those on the west coast of Scotland and at Shetland. There is a strong case for looking more closely at the effects of the sandeel fisheries on other grounds, most notably those off the Scottish east coast at the Marr Bank and Wee Bankie. A project funded by the European Union (ELIFONTS) is now underway to assess the exploitation of sandeels on these east coast fishing grounds, not

only by the industrial fishery but also by the main predators, including seabirds, common and grey seals, and the most abundant predatory fish. The project aims to determine the extent of any competition between the fishery and the top predators in these areas. Such ecological studies, which look at the interactions between different marine species, will become increasingly important for the proper management of marine fisheries in the future.

For salmon, there is a continuing need to monitor sandeel catches, particularly those taken near the coast, for the presence of smolts. There is no *prima facie* case for concluding that smolts, which are believed to swim near the surface, are caught in sandeel nets operating at the seabed. However, the level of fishing effort in these areas is so high that if only a tiny proportion of the catch is composed of salmon it could nevertheless result in severe damage to local salmon stocks. A greater degree of management of the sandeel fishery, and particularly the closure of sandeel fisheries on sand banks close to salmon rivers to protect local fisheries and wildlife which preys on sandeels would provide additional safeguards for salmon. Finally, the decision by the EU Council of Ministers to impose precautionary TACs upon the sandeel fisheries is an important step. The development of a management plan for these fisheries, which takes into account not only the health of the sandeel stocks but also the impact of the fishery upon other predators - including salmon - must receive a high priority.

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