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International Council for
the Exploration of the Sea

C.M. 1974/E:8
Fisheries Improvement Committee

Report of the Working Group on Effects on Fisheries of Marine Sand and Gravel Extraction

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CONTENTS

1 INTRODUCTION

1.1 Terms of reference

At its 61st Statutory Meeting in Lisbon the International Council for the Exploration of the Sea passed the following resolution (C.Res.1973/2:9):

"It was decided that a Working Group should be established to

(a) identify the effects (direct or indirect) and international implications of different methods of marine sand and gravel extraction on fisheries, particularly in the North Sea, English Channel and the Baltic;

(b) review techniques for studying these effects;

(c) compare national codes of practice for the control of dredging activities.

The Chairman of the Group should be Mr A. J. Lee and it should hold its first Meeting for three days in February 1974 in London."

The Working Group held its first meeting at the Fisheries Laboratory, Lowestoft on 2-3 April 1974 and this report details the proceedings. Participants were as follows.

1.2 Working Group Members

United Kingdom	
Mr A. J. Lee, Chairman	Fisheries Laboratory, Lowestoft
Dr R. R. Dickson } Rapporteurs	"
Mr R. S. Millner } Rapporteurs	"
Netherlands	
Dr S. J. de Groot	Netherlands Institute for Fishery Investigations, IJmuiden
Ir J. D. Holstein	Ministry of Agriculture and Fisheries, The Hague
Ir P. W. Postema	Directie Noordzee, Rijkswaterstaat, Rijkswijk
Denmark	
Dr O. Bagge	Danmarks Fisker-og Havundersøgelser, Charlottenlund
Germany	
Dr G. Kuhlmorgen-Hille	Institut für Kusten und Binnenfischerei, Kiel
France	
Dr A. Cressard	Centre National pour l'Exploitation des Oceans, Paris
Dr G. Kurc	Institut Scientifique et Technique des Pêches Maritimes, Nantes
Sweden	
Dr B. I. Dybern	Institute of Marine Research, Lysekil

Norway

Mr R. Ljoen	Fiskeridirektoratets Havforskings-institutt, Bergen

Ireland

Mr K. Bhatnagar	Department of Agriculture and Fisheries, Dublin

USA

Dr J. W. Padan	NOAA Pacific Environmental Laboratory, Seattle, Washington

Contributions from the following Working Group members were received by mail:

Belgium

Dr P. Hovart	Station de Recherche pour la Pêche Maritime, Ostende

Finland

Dr P. Tuunainen	Finnish Game and Fisheries Research Institute, Helsinki

and the following participated as observers:

United Kingdom

Mr R. G. Houghton	Fisheries Laboratory, Lowestoft
Dr R. G. J. Shelton	"
Mr R. J. Wood	"
Mr A. C. Burd	"
Mr A. R. Margetts	"
Dr I. C. White	Fisheries Laboratory, Burnham-on-Crouch

2 THE PRESENT AND PROJECTED STATUS OF EUROPEAN OFFSHORE MINING

In most European countries the development of an offshore aggregate industry has been relatively slow, despite the expanding demand for material for concrete, roads and fill in civil engineering works. Until recently land-based resources were sufficient to provide an economical supply of both sand and gravel within a short distance of the major markets. As the pressure on land use for agriculture, housing or other environmental and social needs has become greater, extraction has been forced away from the vicinity of large towns. Rising costs, particularly for transport where an increase in journey length of 15 miles within a town or about 50 miles outside it can double the price of the raw commodity, has increased the demand for alternative sources and provided the impetus for the rapid development which has taken place in marine mining technology.

Initially the dredgers were of small capacity and as late as 1968 the average gross tonnage of British dredgers was 800 tons. However, as Hill (1971) has pointed out, the average size of newly-built British vessels in 1970-71 was 3 500 tons and vessels of up to 10 000 tons are now coming into operation. These ships are capable of working in water depths greater than 35 m and of unloading on a 24-hour cycle so as to make use of cheap tidal docking facilities. A further specialization is the development of onboard methods for screening, separating and washing different size fractions, thus allowing the working of lower grade deposits. Deposits containing gravel and sand in the ratio of 40:60 are considered to be of high quality. Normally, however, a ground with 30 per cent gravel and 70 per cent sand will be dredged, with the result that 2-3 tonnes of sand will be discharged for every tonne of gravel recovered. A misleading picture of the area required to produce a specified amount of gravel may be given unless this fact is recognized.

2.1 The growth of sand and gravel production

The best available estimates of present and future marine aggregate production are listed in Table 1. At present the total European production is from 30 to 35 million m^3/a, of which perhaps one quarter to one third is gravel (6.5 million m^3/a from the UK, 2.5 million m^3/a from Denmark). The distribution of this marine mining activity is shown in Figures 1-3 which include all important European sites licensed for dredging operations up to May 1974.

As Table 1 indicates, our estimates of future marine sand and gravel production are far from certain, yet we may assume that the following tendencies, already evident, will be maintained:

(i) Demand for marine aggregate will increase, and at an increasing rate.

(ii) The continued decrease in availability of farming and building land, together with increasing road congestion, will lead to a disproportionate increase in production from marine sources.

(iii) Despite the increase in the size of dredgers and in their depth of operation, the costs of transporting this low-value commodity will ensure that marine aggregate production will continue to be concentrated in the (relatively) near-shore zone, close to the main metropolitan centres of demand, and will move to more distant deposits only as the near-shore beds become depleted and the market price of aggregate increases.

This increasing pressure on European marine deposits is perhaps best illustrated by comparing two figures from Table 1: the current European production of 30-35 million m^3/a, and the projected Dutch landings of 1 000 million m^3/a in the year 2000. Clearly the extent and intensity of marine aggregate production is about to undergo radical change; equally clearly, this rate of expansion of production is likely to be accompanied by increasing conflicts of interest between the dredging and fishing industries. If these conflicts of interest are to be minimized so as to allow the best yield of both resources (the one a wasting resource, the other sustainable), an effective research programme must be set in train so that, from an early stage, we may be equipped to recognize the serious detrimental effects of dredging on fisheries, and to separate these from effects of minor importance.

Table 1 Current and projected status of marine aggregate production in Europe and in the USA

Country	Annual marine production (million m^3)	Projection (million m^3)	Sand or gravel?	Usual duration of production licence (years)
United Kingdom	9.8	At least 200 million m^3 by year 2000(1)	2/3 gravel, 1/3 sand	20
Netherlands	7.0	40 million m^3 by year 2000(2)	Sand	1
Denmark	6.2	"Great increase"(3)	See footnote (4)	5
Germany	2.7	"Great increase"	Sand	1(5)
France	2.0	40 million m^3 by 1985	Sand, gravel	No set duration. Depends on circumstances
Sweden	0.55	"Doubling several times in next few years"	Sand (perhaps some gravel in future)	2-3
Finland	> 0.40	No information	Sand	Unknown
Norway	"Very small"	Increase expected	-	-
Belgium	0	Increase(6)	Sand	Unknown but "temporary"
Ireland	0(7)	Increase expected	-	-
USA	0.1	Increase dependent on environmental considerations	Variable(8)	10 (proposed)

(1) Projection of total land and sea demand by year 2000 = twentyfold increase (Sand and Gravel Association). Even if the marine share relative to the land does not increase it will amount to 200 million m^3.

(2) Dutch total <u>from all parts</u> of the European shelf is estimated at 1 000 million m^3/a by year 2000.

(3) Total land- and sea-based production in Denmark is now 24 million m^3. Even with <u>no</u> increase in demand, pressure on land means a shift to marine production, mainly in Belts, Sound and Baltic.

(4) Danish breakdown: sand 3.0, moulding sand and gravel 1.0, pebbles 2.0, stones 0.2 million m^3/a at present.

(5) Major exceptions are (a) Ems estuary where one licence is for 6 years in an area where continuous dredging is necessary for navigation;
(b) Baltic: several short-term projects with licences from 2-14 months.

(6) Dredging of 5 million m^3 of sand was authorized in 1974. Extraction will take place over 4 years or more depending on demand for motorways.

(7) No sand and gravel extraction at present but (a) one prospecting licence (temporary) issued to UK company;
(b) <u>Lithothamnion</u> permit for Galway Bay.

(8) No sand and gravel extraction at present. If it does occur there is likely to be a different demand (quantity/type) in each of the five main market areas (Los Angeles, San Francisco, Boston, New York, Washington DC).

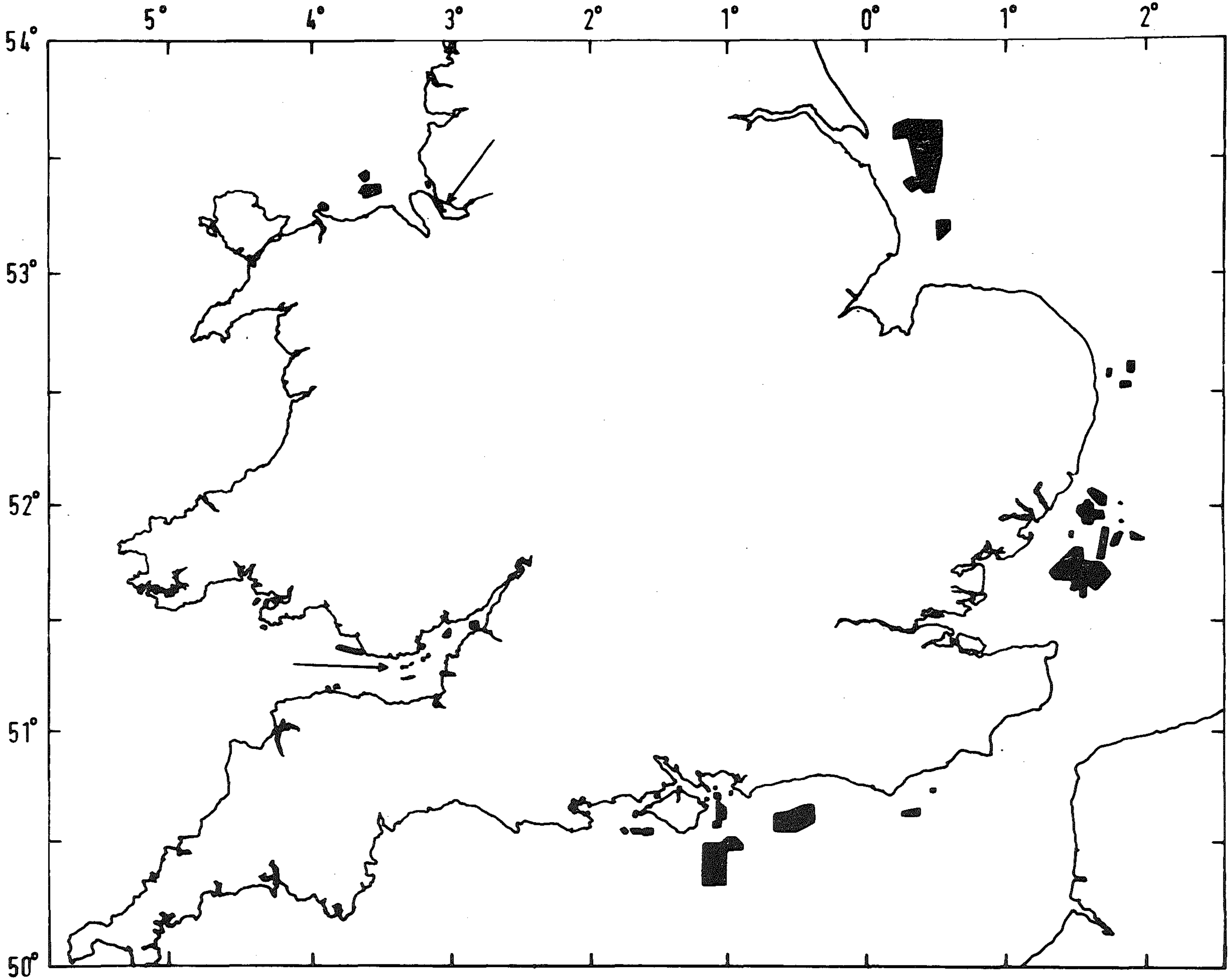


Figure 1 Location of dredging concession areas off the coasts of England and Wales.

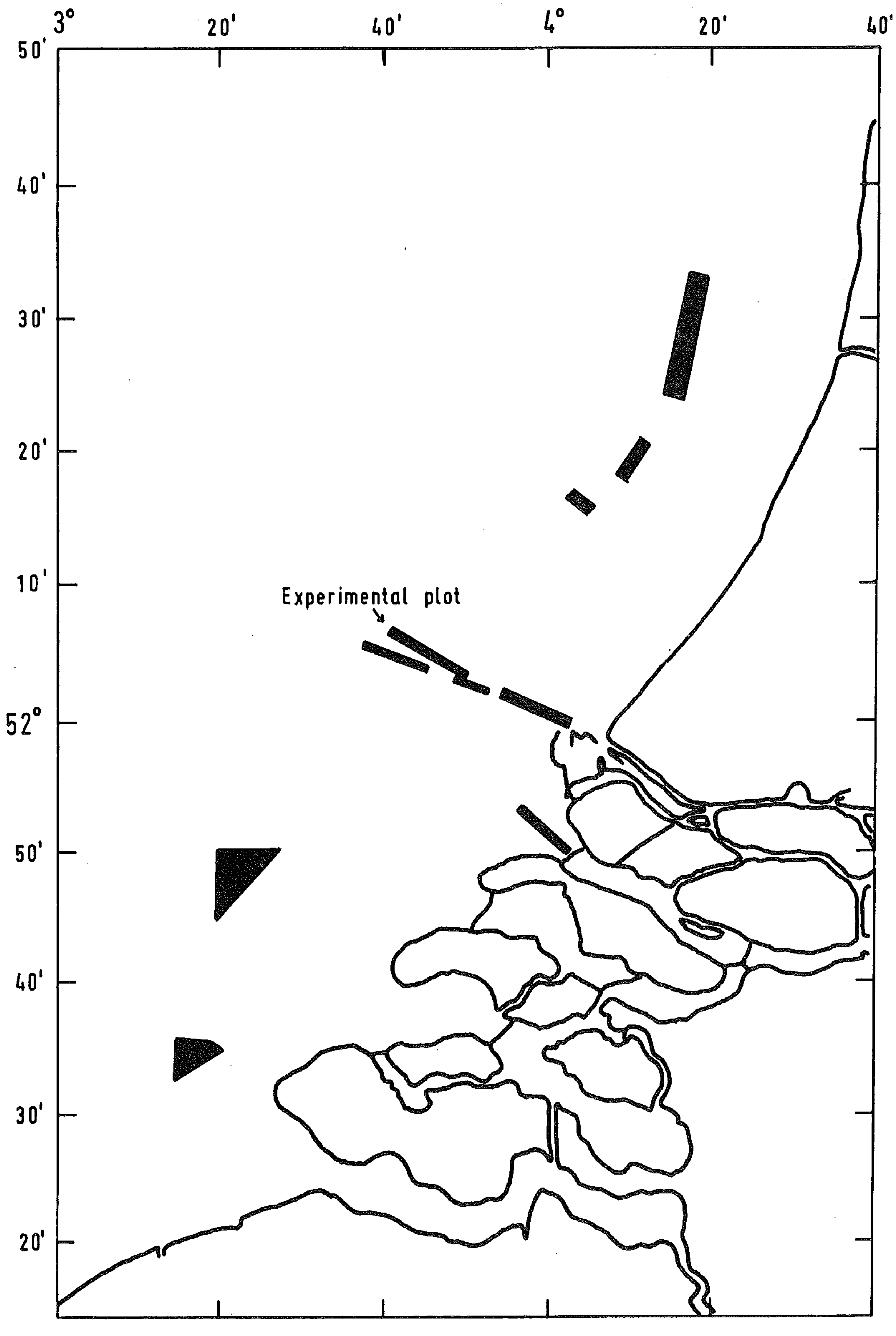


Figure 2 Areas of sand dredging off the Dutch coast.

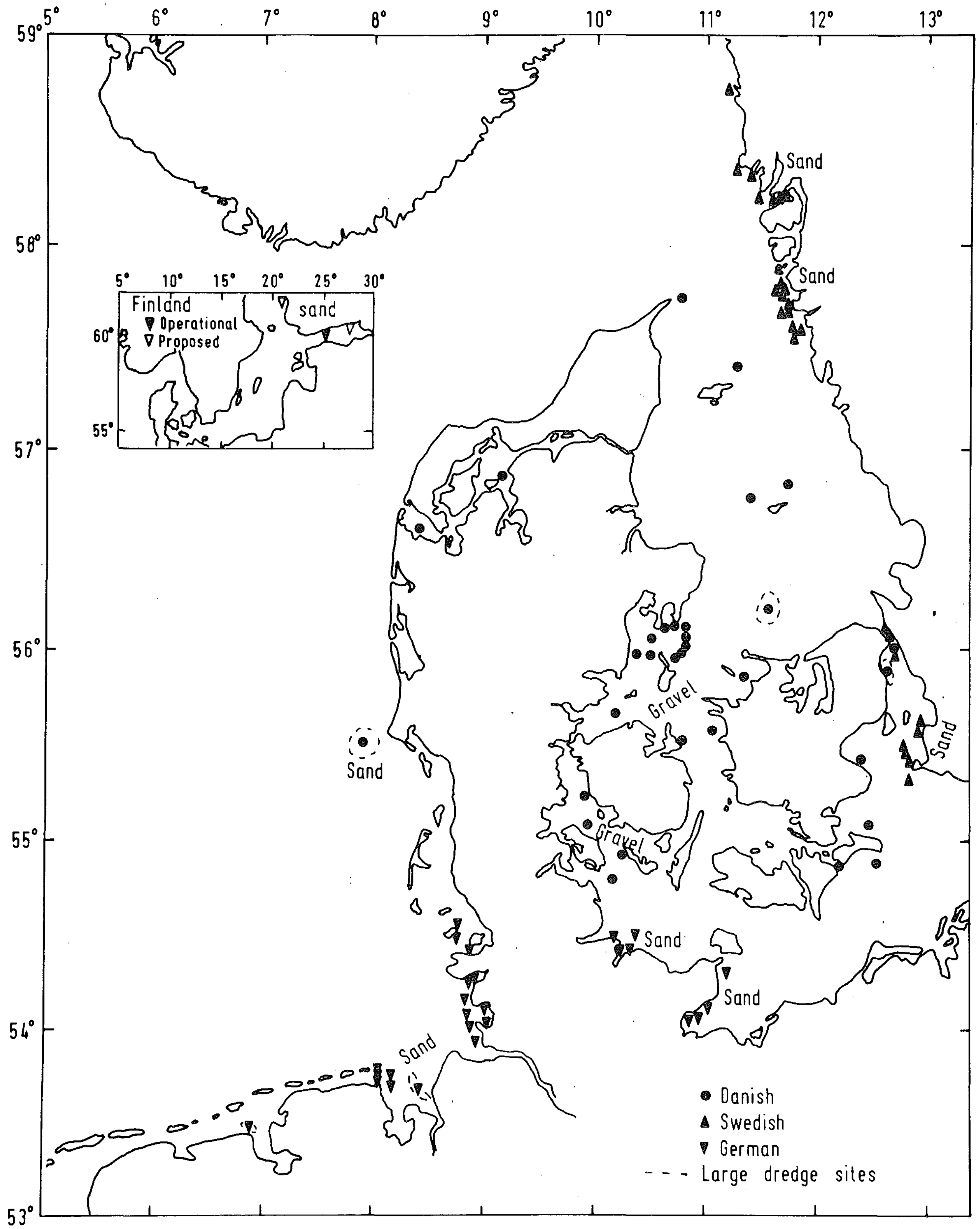


Figure 3 Sites of sand and gravel dredging off Germany, Denmark and Sweden (for Finland see inset).

2.2 Calcareous deposits

Apart from the sand and gravel deposits which form the main object of offshore mining in Europe, there is some demand for calcareous marine deposits in certain localities for use in the production of fertilizer and cement. The *Lithothamnion* beds of the south-west part of the European shelf form the main calcareous deposit under exploitation and the present situation is as follows:

(a) United Kingdom: No *Lithothamnion* mining at present, but a large demand is expected shortly, using the Cornish and Channel Islands beds.

(b) France: *Lithothamnion* is currently produced at a rate of 0.3 million m^3/a. Further expansion is unlikely since the beds are already heavily exploited and are becoming exhausted. Instead the industry is expected to diversify into calcareous sands, and extraction of this material is expected to increase rapidly to some 1-2 million m^3/a.

(c) Ireland: Production of *Lithothamnion* is just beginning. Two licences for a total production of 100 000 tons have been granted for the south coast, Galway and Mayo.

Because of its restricted distribution no other country mines *Lithothamnion* (though some small-scale "calcareous" production from shell beds is found in Germany and the Netherlands). No research has yet been carried out into the effect of *Lithothamnion* mining on the benthos, and indeed in the case of France the need for such research has been made obsolete by the working-out of deposits. The *Lithothamnion* beds of the United Kingdom and Ireland, however, may shortly be expected to come under heavy commercial pressure and research is urgently required. This type of research programme is beginning at the Fisheries Laboratory, Burnham-on-Crouch, with possible supporting studies from the Marine Biological Association, Plymouth.

3 POSSIBLE GROUNDS FOR FISHERIES CONCERN

This section and the following section of the report attempt to identify, from the many *possible* effects of dredging on the fisheries, the most important grounds for concern, to review current research into these problems, and to suggest how future research might best be organized to fill the main gaps in our knowledge. This approach is based on the realization that although dredging in any part of the shelf will have some effect on some aspect of the environment, nevertheless dredging must inevitably be permitted, and therefore in some locations these effects must be accepted. In this light, it becomes important to distinguish all serious grounds for concern from those of relatively minor importance, so that the best yield from both fisheries and offshore mining may be achieved with the minimum conflict of interest.

The following effects of dredging on the fisheries have been suggested in the literature.

3.1 Direct damage to fishing gear

The loss of long-lines due to dredging has been reported in several regions off the British coast, and damage to stake net fishing has occurred in Denmark.

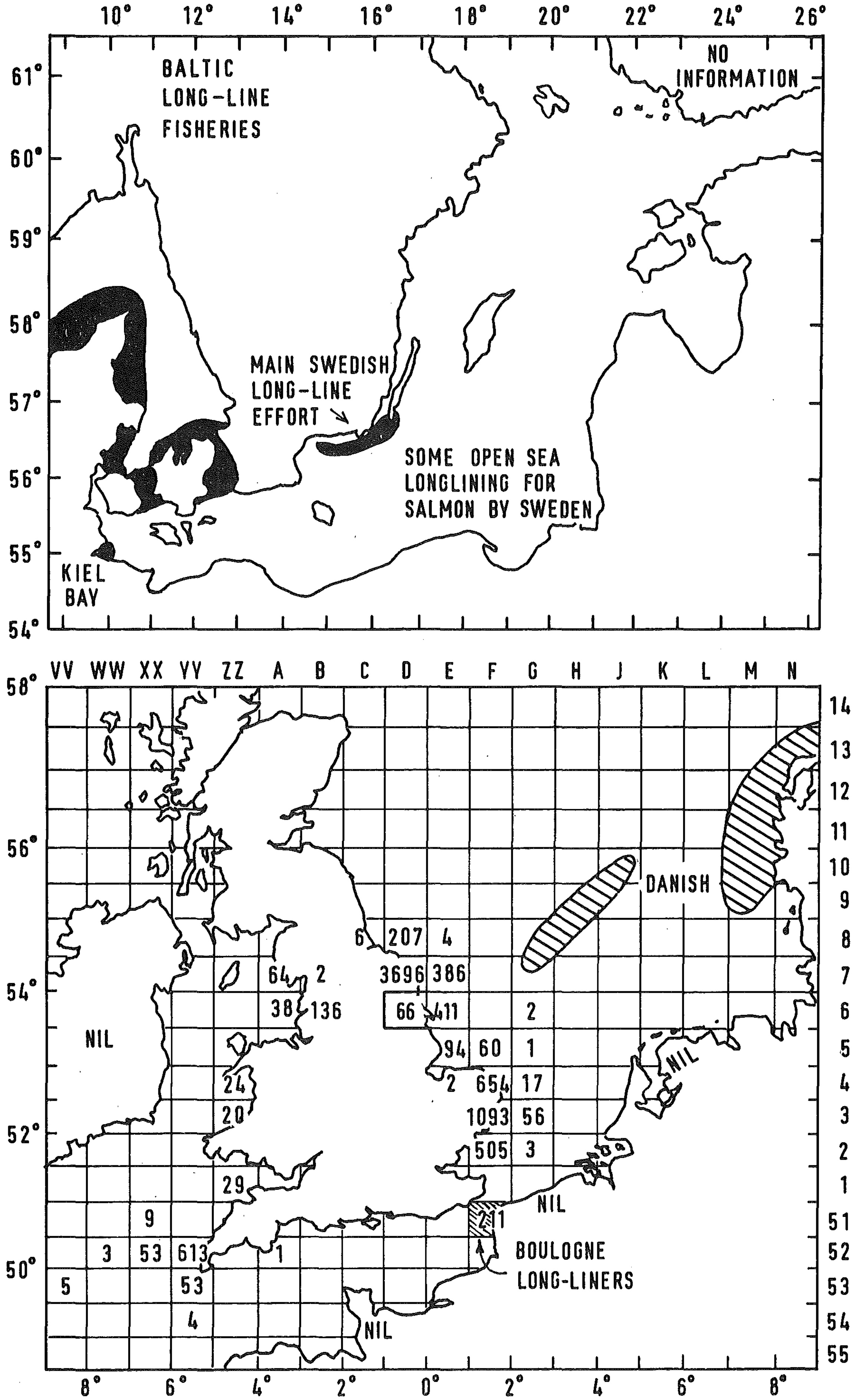


Figure 4 Distribution of long-line fisheries on the European shelf. UK figures represent "days absence" of long liners in 1973.

Furthermore, fishermen will not risk losing their gear in or near an area where they know dredgers have been operating and this fear effectively sterilizes these grounds so far as fishing is concerned. This type of damage may also be expected to affect fisheries based on the use of pots, and other types of set nets (i.e. trammel, tangle and hoop nets). Figures 4 and 5 show the distributions of long-lines and set nets on the European shelf.

3.2 Indirect damage, affecting the efficiency of fishing gear

Figure 6 illustrates the two types of suction dredger responsible for the majority of European offshore aggregate production. One type anchors and dredges large pits (say, 30 m diameter, 4 m deep) through a forward-facing pipe. The second type, trailer dredgers, dredge through one or two rear-facing suction pipes while under way, producing shallow linear furrows on the sea bed (say, 0.5-1.0 m diameter by 0.2-0.5 m deep). Efficient and intensive trailer dredging will not greatly affect the action of bottom trawls or seines, but intensive anchor dredging leaves a heavily-cratered sea bed which may completely destroy the efficiency of this type of gear. Further, in the case of pits dredged in gravel, this effect is likely to persist, since tidal current velocities strong enough to move gravel are rather rare on the European shelf. It has also been reported that the hauling of long lines and scallop dredges has been impeded (presumably through snagging) in areas of intensive anchor dredging.

3.3 Direct effects on fish stocks (i.e. at the dredge-head)

The removal of surface sediments has been suggested to have four main direct effects on the well-being of fish stocks:

(1) by destroying spawning grounds of those species which lay their eggs on the bottom (e.g. herring);

(2) by destroying the substrate in which fish such as sandeels live and feed;

(3) by destroying or altering the benthos which forms the main source of food for many demersal fish species;

(4) by exposing anoxic sediment layers (e.g. in the Øresund).

3.4 Indirect effects on fish stocks (i.e. remote from the dredge-head)

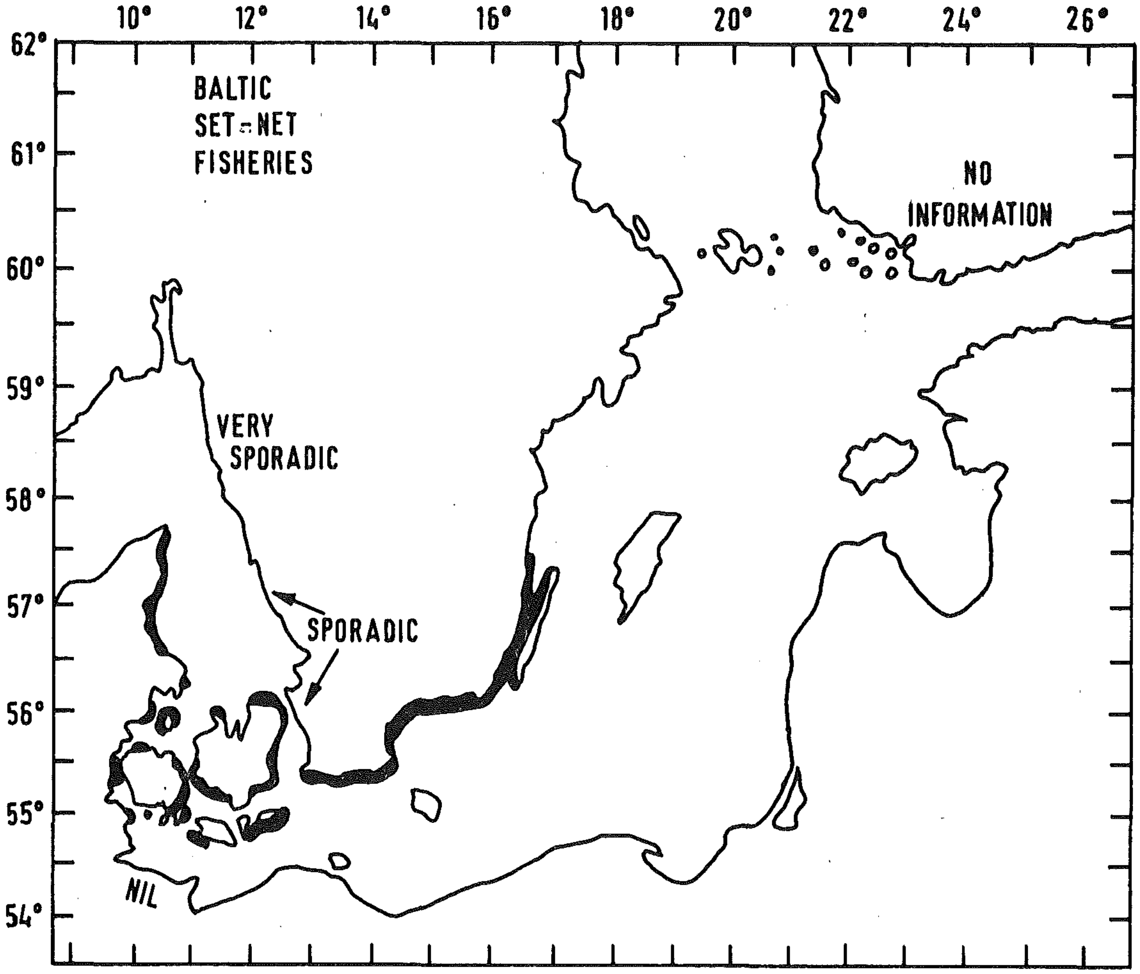
It has been suggested that where dredged aggregate is washed to remove fine sediments the outwash fines:

(1) increase turbidity locally, irritating or clogging fish gills, interfering with visual feeding and inhibiting photosynthesis;

(2) increase siltation and so blanket shellfish, alter the character of the sediment on spawning grounds, and interfere with egg development;

(3) reintroduce toxic compounds into the water column from the sediment.

The above represent the principal effects of dredging on fisheries which have been suggested in the literature. At present the lack of adequate research information has meant that many of these suggestions have been made intuitively. The



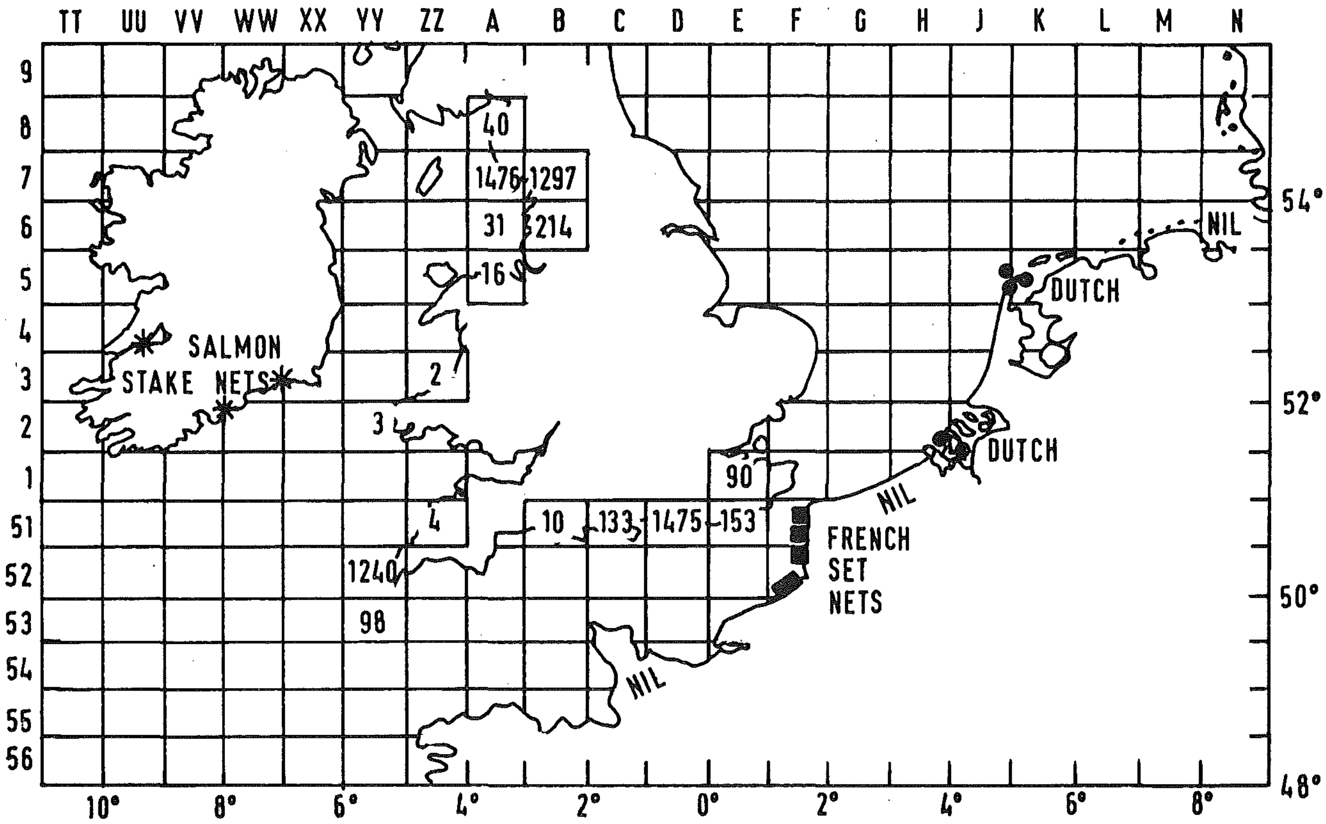


Figure 5 Distribution of set-net fisheries on the European shelf. UK figures represent "days absence" in 1973.

statistical rectangles by which fishery returns are made are large compared with the scale of dredging activity (see Figures 14 and 15) and this in itself has posed considerable problems in the validation of these suggestions. Nevertheless, the onus is at present on the fisheries research agencies to show that damage will occur through dredging, rather than on dredging firms to prove that it will not, and, in many cases, a firmer research base is needed before this can be done. The following section attempts to identify the principal effects on fisheries in the light of what is known and to describe the principal lines of research which are required.

4 THE ORGANIZATION OF RESEARCH

The principal research objectives described below are grouped under the same headings as in the previous chapter (e.g. Section 3.1 (page 8): "Direct damage to fishing gear"). An additional section (4.5) has been included which will describe the planning behind a number of large-scale comprehensive research programmes.

4.1 Direct damage to fishing gear

Research is unnecessary.

4.2 Indirect effects of dredging on the efficiency of fishing gear

To a large extent, the research requirement under this heading concerns our need to estimate the extent and permanence of damage to the sea bed which might arise through dredging. With the exception of the special situation posed by the tideless conditions in the Baltic, current velocities on the open European shelf are generally sufficiently strong to ensure that a sandy sea bed will recover fairly quickly after dredging. The possibility of extended damage to the sea bed arises when dredging is carried out in gravel since current velocities capable of moving gravel are rare, and since the influence of wave action on the sea bed is generally weak in depths greater than c. 15 m (Anon. 1972). Again, of the two main types of suction dredger currently in operation (see Figure 6) the pits dredged in gravel by anchor dredgers are clearly more damaging to the efficiency of trawls (for example) than are the relatively shallow furrows caused by trailer dredging.

There are two ways of assessing the recovery-time of a dredged gravel bed. Firstly, we may treat each application to dredge this type of sea bed as a separate study, and estimate the extent of sediment movement from measurements of the shear stress acting on the bed during the strongest tides. Ideally these observations should be supplemented by measurements of the suspended sediment transport into the area, and some allowance should also be made for the sediment movement due to wave action if the area is sufficiently shallow for wave action to reach the sea bed during storms. One such exercise, carried out in the English Channel off Hastings by the Lowestoft laboratory, is described in a recent report by Dickson and Lee (1973a, b).

While this type of exercise will certainly give a very clear indication of seabed recovery rate the research involved is extremely time-consuming and it is difficult to apply the results obtained to other areas of different water depth, sediment-type, tidal stream velocity, storm frequency, wind fetch, etc. Thus a

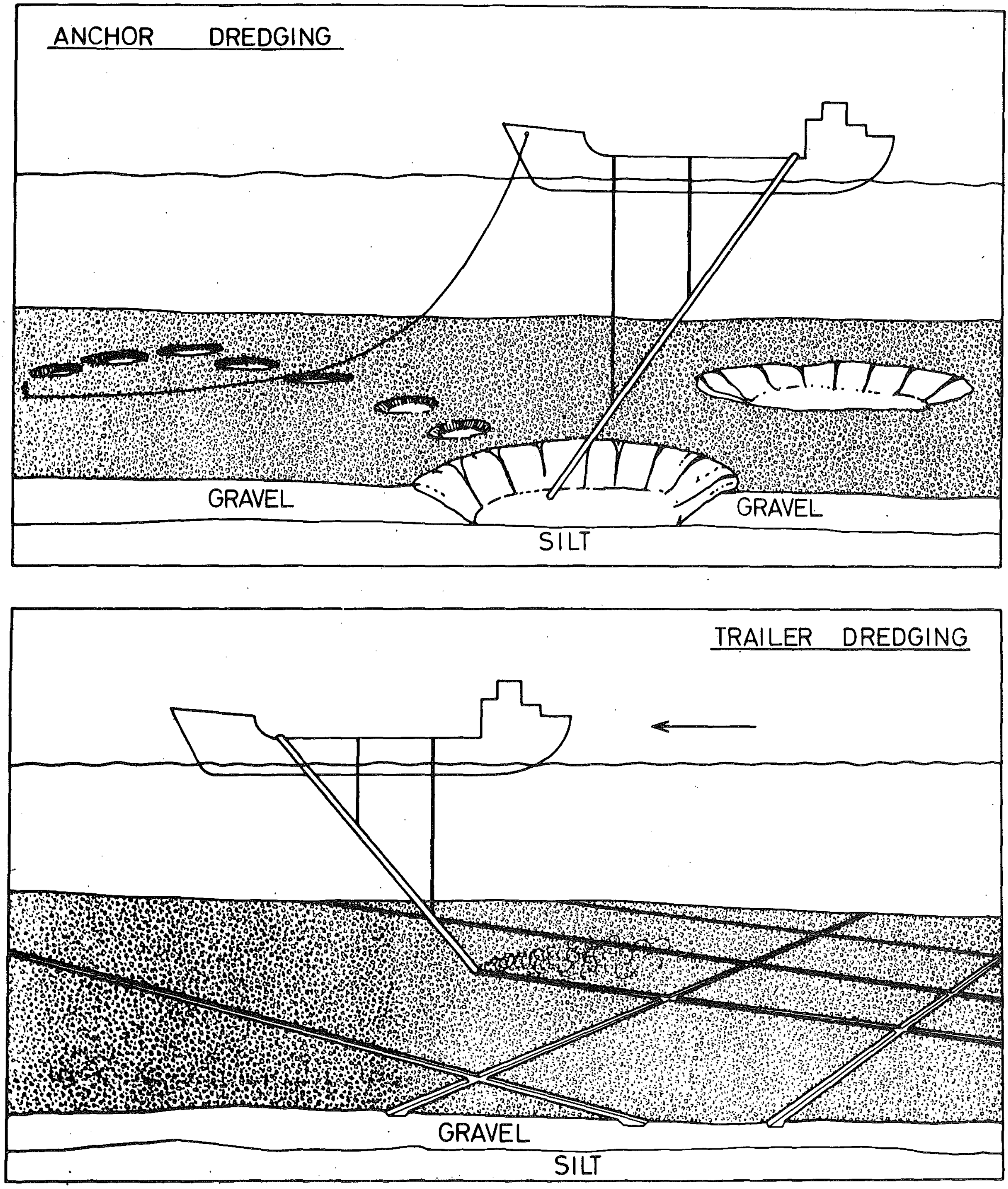


Figure 6 Schematic representation of the two main types of suction dredger in operation on the European shelf.

second parallel line of research must also be pursued which aims at an understanding of the empirical relationships between these parameters. This too will be a slow operation requiring cooperative planning of research and pooling of results in view of the many parameters involved; however, once such relationships are established it should be possible to make an approximate but rapid estimate as to whether any significant sediment movement is likely to occur in any particular area, and in most cases where relatively coarse sediment is concerned this approximate estimate will be sufficiently accurate for our purpose. To give one example, the detailed measurements obtained during the Hastings study showed that at spring tides the maximum seabed shear stress observed in the test area (2.95 N/m^2) was capable of moving sediment up to a diameter of c. 3 mm; since a shear stress of 18x this value would have been required to move the local bed material it is clear that even an approximate estimate would have shown quite adequately that no sediment movement was likely to occur.

In order to establish the necessary relationships between the parameters important for sediment transport, our principal research requirement is for the following type of data set, from as many locations as possible:

(i) Detailed measurements of the velocity profile in the near-bottom boundary layer, conducted at half-hourly intervals over at least one tidal cycle at spring tide. (These observations should be made using an array of current sensors exponentially spaced and set within 1.5 m of the bed.)

(ii) Observations of near-surface current velocity and windspeed over the same period.

(iii) A sediment sample representative of the surrounding sea bed.

(iv) Water depth and mean density (preferably close to the bed).

(v) Position.

Since in the majority of cases gravel beds on the European shelf will have a long recovery time, the likelihood arises that trailer dredging should be specified when offshore mining is planned for these areas*. In order that the entire layer of gravel is not removed the rate and period of removal should also be specified. In this connection a second important research objective lies in testing the contention of the dredging industry that intensive trailer dredging is capable of "planing" a pre-determined thickness of gravel from a gravel bank, leaving a sufficient thickness of gravel to maintain the sea bed in its pre-dredged condition. This research would involve a pre-dredge "boomer" survey to establish the original thickness of the deposit, followed by repeat surveys to monitor the state of the bed as dredging proceeds.

A third research programme is required to take account of the special conditions in the Øresund and Baltic. Specifically this programme should estimate

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*In fact, as rich deposits of sand and gravel in relatively shallow water have diminished there has been a tendency for the industry to replace anchor dredgers with trailer dredgers. This has enabled grounds to be exploited which were formerly not considered economic.

Figure 7 The Eagle Bank herring spawning ground exposed at spring tides.

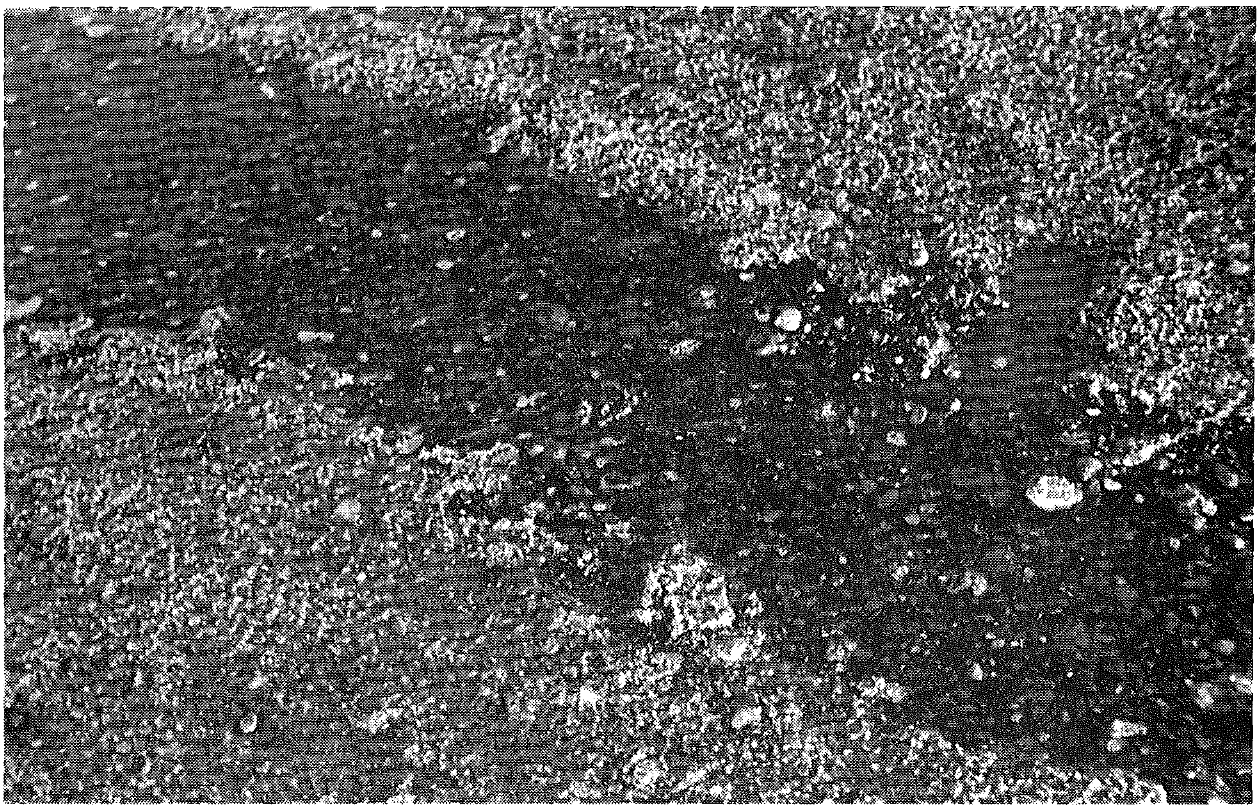

Figure 8 Close-up view of the egg mat on the Eagle Bank spawning ground.

the permanence of dredged seabed features (in sand as well as gravel), and the influence of dredged pits on the generation or maintenance of anoxic conditions when dredged above, at or below the primary pyknocline.

4.3 Direct effects on fish stocks

(1) Herring spawning grounds In areas where offshore mining is concentrated on gravel deposits, there is a clear possibility that important spawning grounds will be destroyed. Herring spawn in a range of depths on the European shelf (between c. 18 fm on Sandettié to 40 fm off Buchan) but almost always on clean gravel. The eggs are attached to the gravel in the form of a sticky "mat" and Figures 7 and 8 show one such spawning bed exposed on Eagle Bank (Blackwater Estuary, south-east England) during spring tides. Certainly not all areas of gravel are used in this way but in general there is a good correspondence between the distribution of gravel and the distribution of herring spawning grounds. Figure 9 is a composite chart, based largely on Dutch data, showing the locations where spawning herring or newly-hatched larvae were caught during the period 1955-73, and this distribution shows a great similarity to the distribution of gravel in the southern North Sea (e.g. Veenstra 1971) and English Channel (e.g. Boillot, Bouysse and Lamboy 1971). Figure 10 shows the known and suspected herring spawning grounds around the Irish coast; again they are based on gravel beds and many of the south coast grounds are already the object of dredging applications. Figures 11-13 illustrate the largely coastal distributions of spawning off Norway, in the Skagerak and Kattegat, and in the Baltic. In these cases the spawning often takes place on stony bottoms, or even coarse sand in addition to gravel.

Although these maps give the most detailed available picture of spawning grounds throughout the European shelf, the distributions shown are certainly over-generalized, and would be of little value in establishing prohibited zones for offshore mining. On the one hand we are aware that within these generalized spawning patterns the herring spawn preferentially on a number of relatively restricted areas of sea bed and they presumably distinguish between suitable and unsuitable areas of gravel according to rather minor characteristics of the bottom; the detailed pattern of bottom currents, the precise character of the substrate, and other unknown criteria. On the other hand, the locations of these small spawning grounds are extremely difficult to map in adequate detail; for unknown reasons attempts to locate eggs by grab-sampling have proven unsuccessful in almost every case, and surveys using underwater television are likely to fail owing to the high natural turbidity of the near-bottom layer. Unable to locate spawning grounds directly we are forced to use indirect indications of spawning, the presence of ripe adults, or young larvae for example, yet these inevitably provide less precise distributions than those of the eggs themselves. Until we can describe the precise locations of the egg-patches, we are unable to recognize the specific characteristics of the sea bed which make an area attractive as a spawning ground, and in this situation it is impossible to assess the importance of any environmental change which dredging activity might make. (For example, would an increased deposition of outwash fines alter the character of the gravel bed to the extent of making it unsuitable for spawning?) Thus at present we are unable to delimit those local areas of gravel which are apparently unsuitable as spawning grounds (and which might therefore be dredged) or to recommend

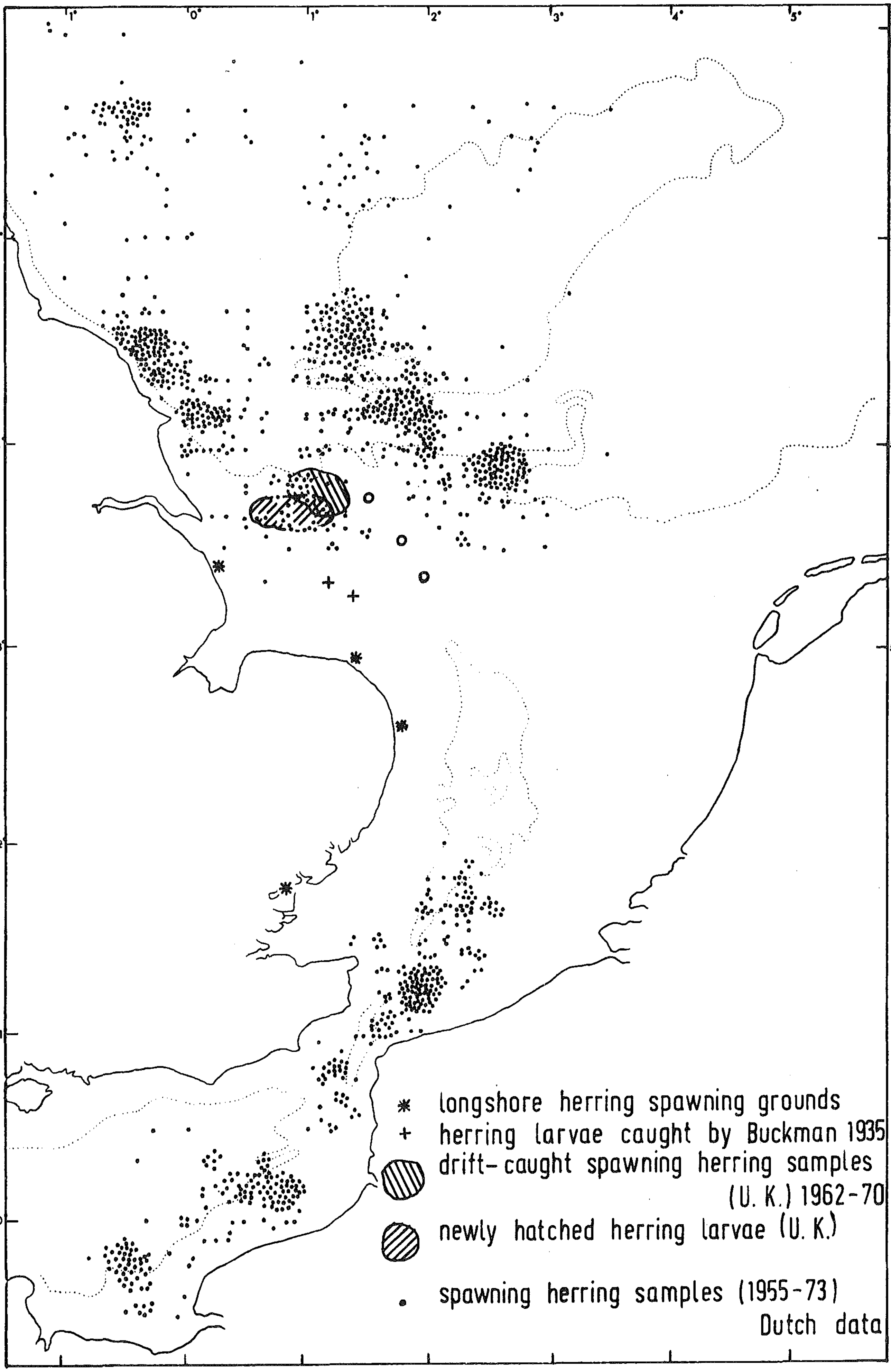

Figure 9 Indirect indications as to the location of herring spawning grounds.

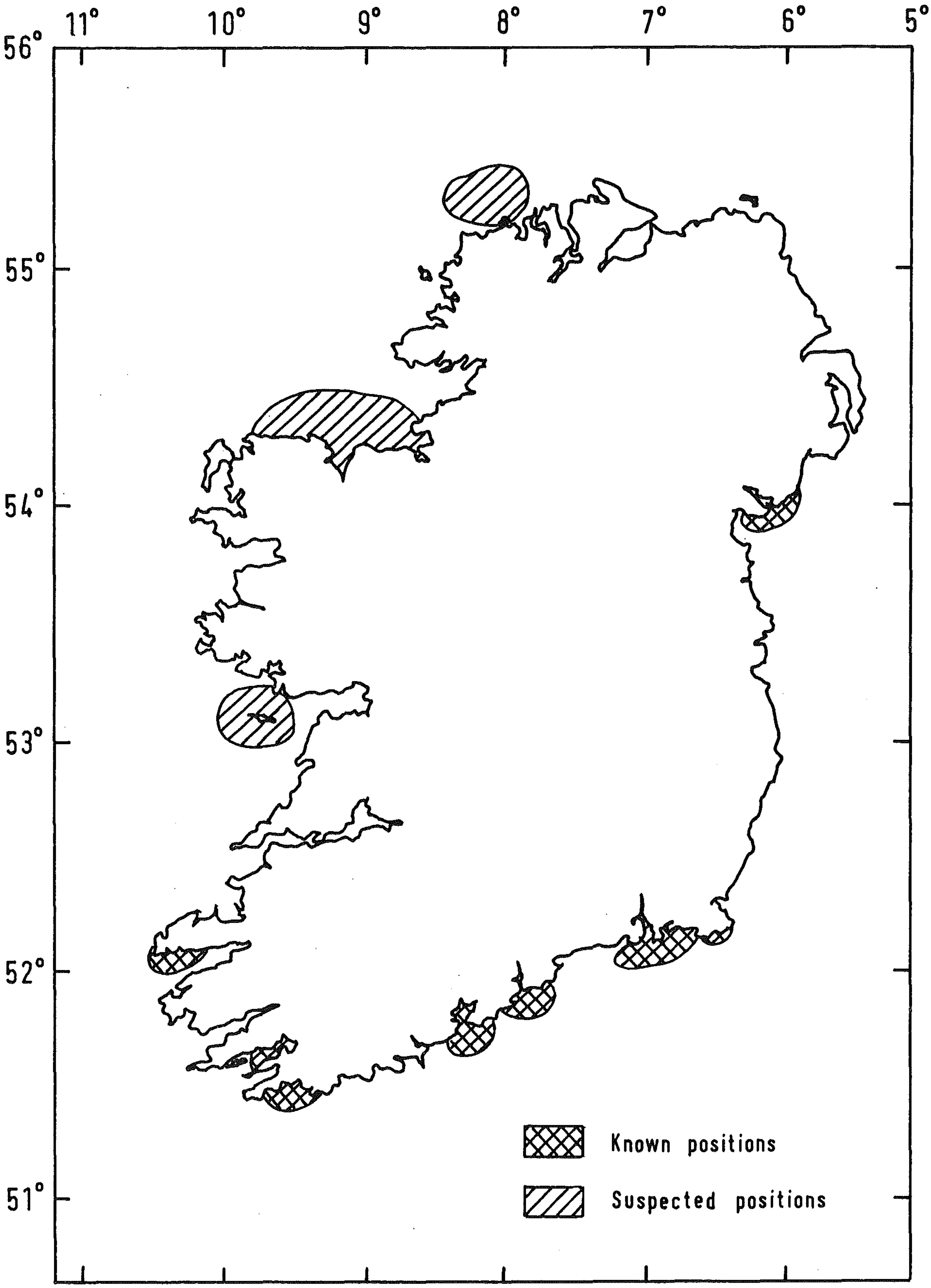

Figure 10 Distribution of known and suspected herring spawning grounds around the Irish coast.

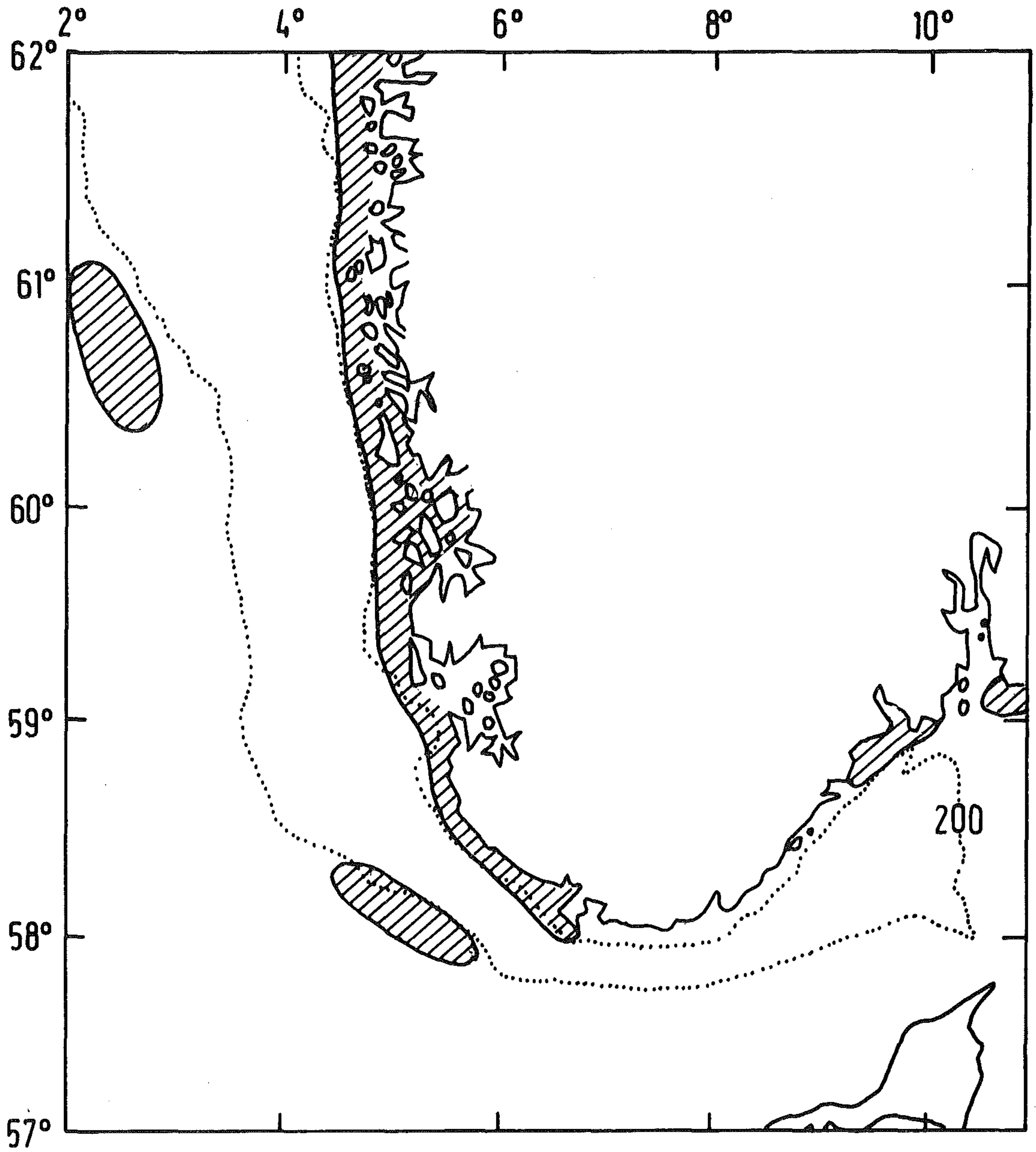

Figure 11 Distribution of herring spawning grounds off Norway. (Exact locations are listed below)

Fredrikstad/Hvaler	Røvaer	Solsvik
Telemark-coast	Mølstervåg	Heggholmen
Lista	Bømmelfjorden	Blomvåg
Siragrunnen	Espevær	Fedje
Åna Sira	Ålfjord	Sognesjøen
Løsgrunnen	Hisken	Bulandet
Egersundbanken	Beiningsundet	Hellefjorden
Feisteinen	Brandasund	Stavfjorden
Bokn	Selbjørnsfjorden	Florø
Loddersøy	Stolmen	Bareksteren
Karmsundet	Reksteren	Batalden
Vespestadvågen	Siggervåg	Hovden
Ferkingstad	Vinnesvågen	Frøysjøen
Utsira	Korsfjorden	Olderveggen
Urter	Glesvær	Egersund-banken/revet
		Vikingbanken

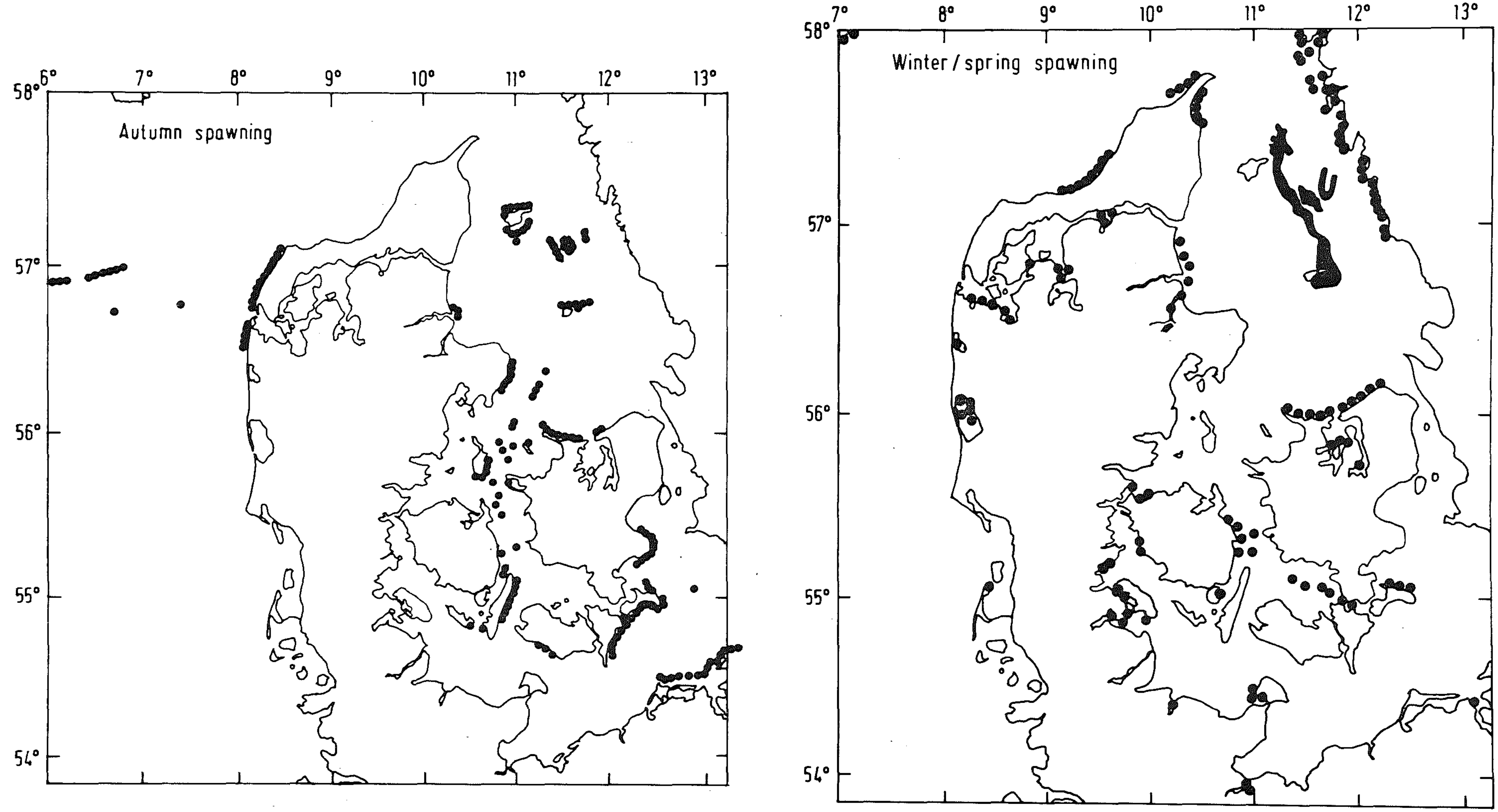

Figure 12 Spawning grounds of autumn and winter/spring herring around the Danish coast.

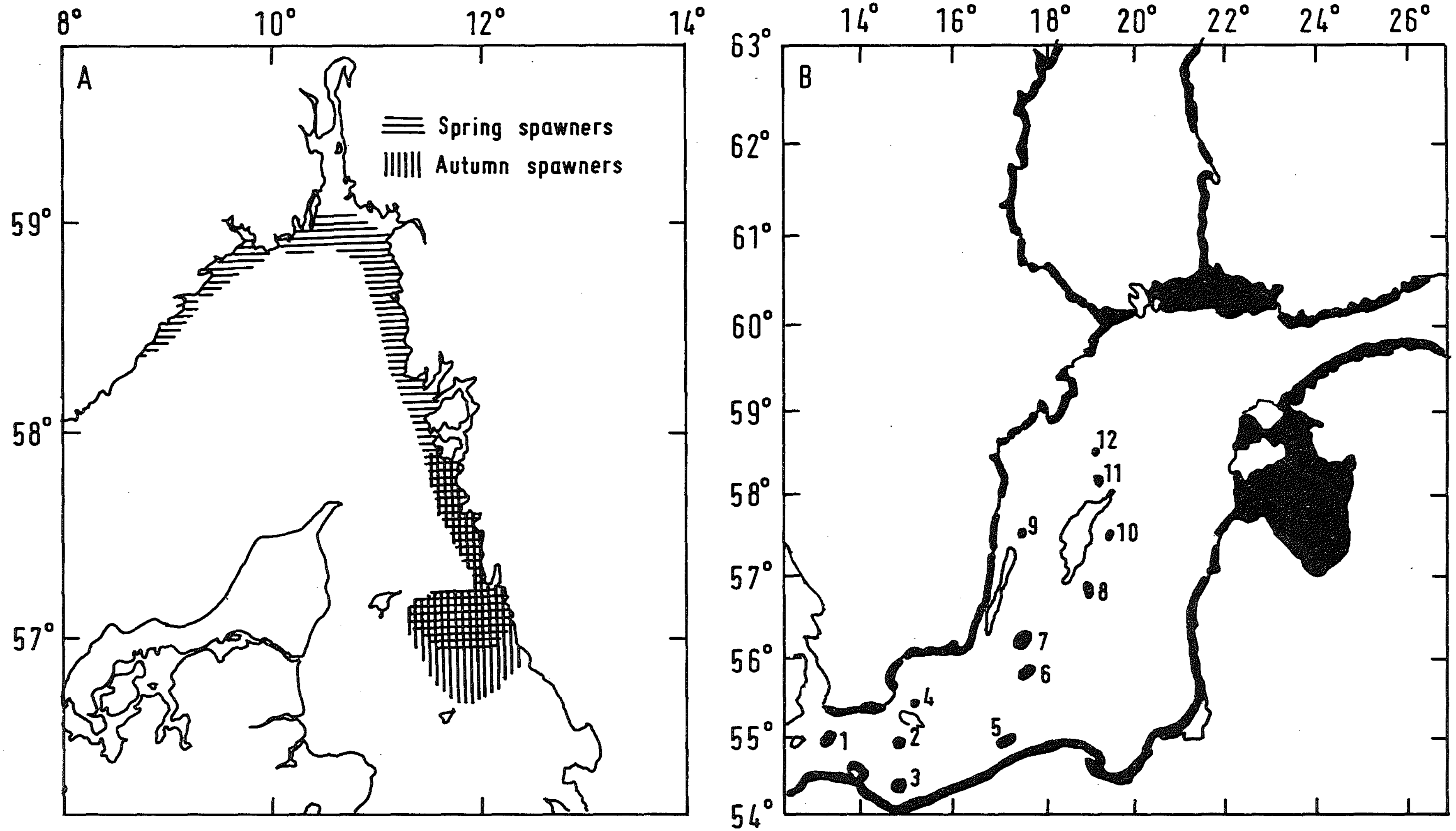

Figure 13 Distribution of herring spawning grounds in (a) the Skagerak-Kattegat (Hoglund 1969), (b) the Baltic. (Exact locations for Baltic offshore grounds are listed below):

1	Kriegers Flak	5	Stolpe Bank	9	Knolls Grund
2	Röhne Bank	6	N. Midsjöbank	10	Klint's Bank
3	Oder Bank	7	S. Midsjöbank	11	Gotland-Gotska Sandön
4	David's Bank	8	Hoburgs Bank	12	Kopparstenarna

"close season" dredging of a spawning ground, since this might well alter the sea bed in some slight but significant way.

Accordingly, the main threat posed by dredging lies in the alteration of the sea bed, either grossly by removing the entire gravel bed, or more subtly by altering the suitability of the ground for spawning. The main research requirement lies in the establishment of better methods of delimiting spawning grounds. In this connection the Working Group noted that some useful information may already be available. The yolk sac stages of herring larvae are known to hug the sea bed, so that their distribution must reflect the spawning pattern rather closely. However, because of this behaviour they are thought to be unquantitatively sampled by the normal larvae survey methods and are usually not included in the results of such surveys. For this reason it is suggested that members of the ICES Working Group on North Sea Herring Larval Surveys should re-examine past records in an attempt to establish the detailed distribution of yolk sac stages, and that the occurrence of these stages should be given some greater attention in future (see Recommendations).

However, if we are to identify the precise characteristics which make a localized area of sea bed attractive as a spawning ground, the most likely solution appears to lie in the use of submersibles to make near-bottom observations of water quality, sediment type, general topography and detailed egg distribution. A preliminary grab survey would be required to locate the spawning ground (see Iles and Caddy 1972).

(2) Sandeel grounds Sandeels appear to be non-migratory so that the spawning areas may be inferred from the distribution of the commercial fishery. As with the herring however, the statistical rectangles by which landings are reported are too large to be of value in delimiting specific sandeel grounds (see Figure 14). Even splitting the catch into statistical sub-squares provides too generalized a picture (Figure 15)*, since it is known that individual sandeel stocklets show a marked preference for certain very specific areas of sea bed, presumably those with certain preferred conditions. Since it is impracticable for fishery returns to be made at scales larger than the statistical sub-square, the compilation of more detailed maps of sandeel distributions relies on reports of fishing experience by individual skippers or in the results of scientific surveys specifically designed to show the required detail. Figure 16 represents the former type of chart for an area of the southern North Sea and is approaching the detail required for delimiting sandeel grounds from possible dredging areas. However, this aim is not fully achieved until each stock is mapped individually, inevitably involving considerable research effort. To date only one ground (the Outer Dowsing Shoal) has been mapped in this way but this is occupied by one of the most economically important stocks in the North Sea. Figure 17 shows the narrowly-defined boundary of this stocklet as defined by the limit of commercially-viable catches during four research cruises of FV "Matanuska" in June/July 1969 (from Macer and Burd 1970). Despite the small area involved (i.e. approximately 12 naut. miles in length by

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*The vast majority of the total sandeel fishing effort on the European shelf is shown in Figures 14 and 15. Aside from the Danish, UK and Norwegian landings shown, only Ireland (with c. 220 tonnes from Kish Bank in 1973) and Germany (with 50 tonnes from the East Friesians in 1973) have any fishery.

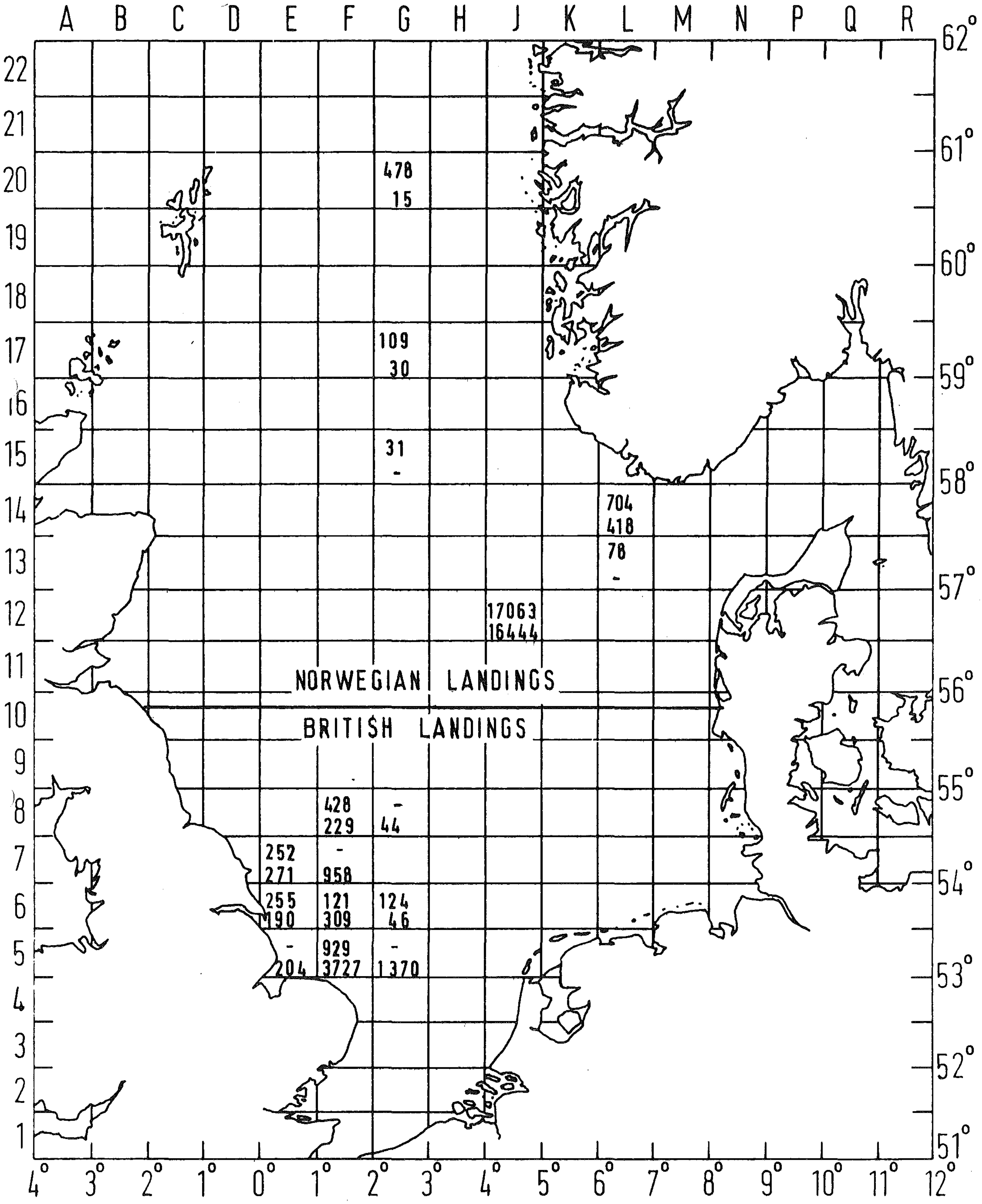


Figure 14 Landings of sandeels (tonnes) by Norwegian and UK vessels in 1972 (upper figures) and 1971 (lower figures).

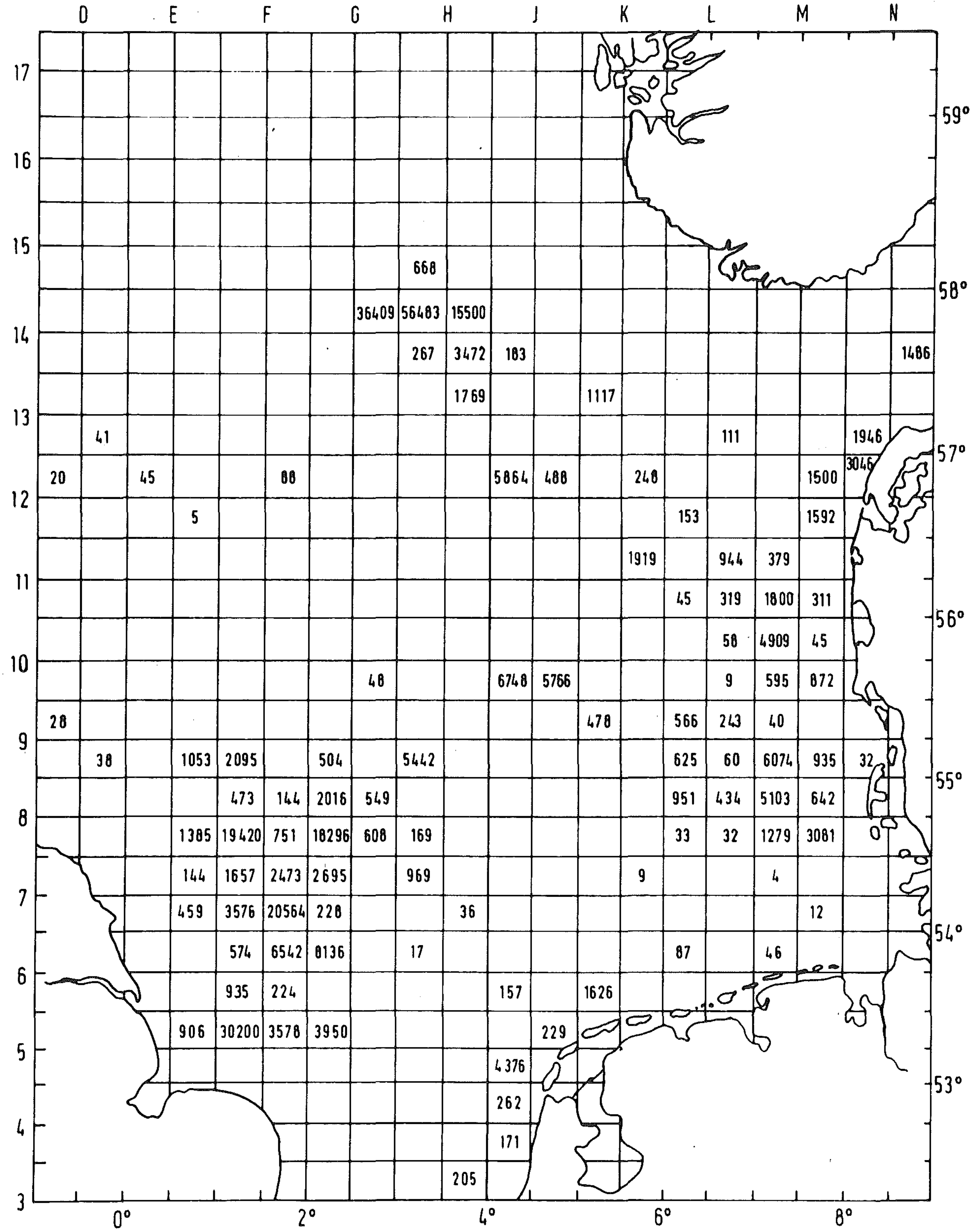


Figure 15 Danish catches of sandeels (tonnes) by statistical sub-squares (15 x 15 naut. miles), 1972.

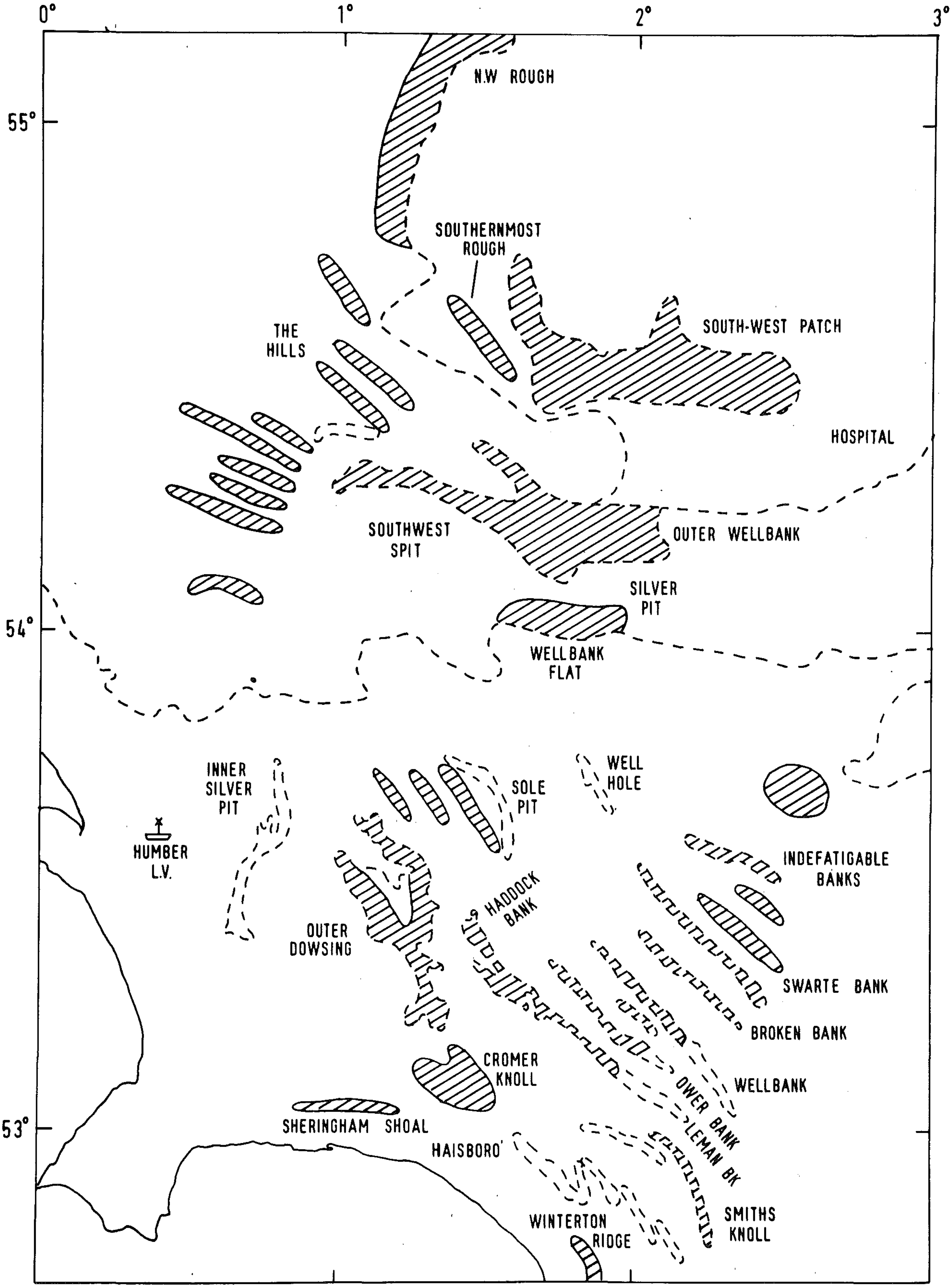


Figure 16 Detailed distribution of sandeel fishing grounds in the south-western North Sea. From information supplied by fishermen, 1974.

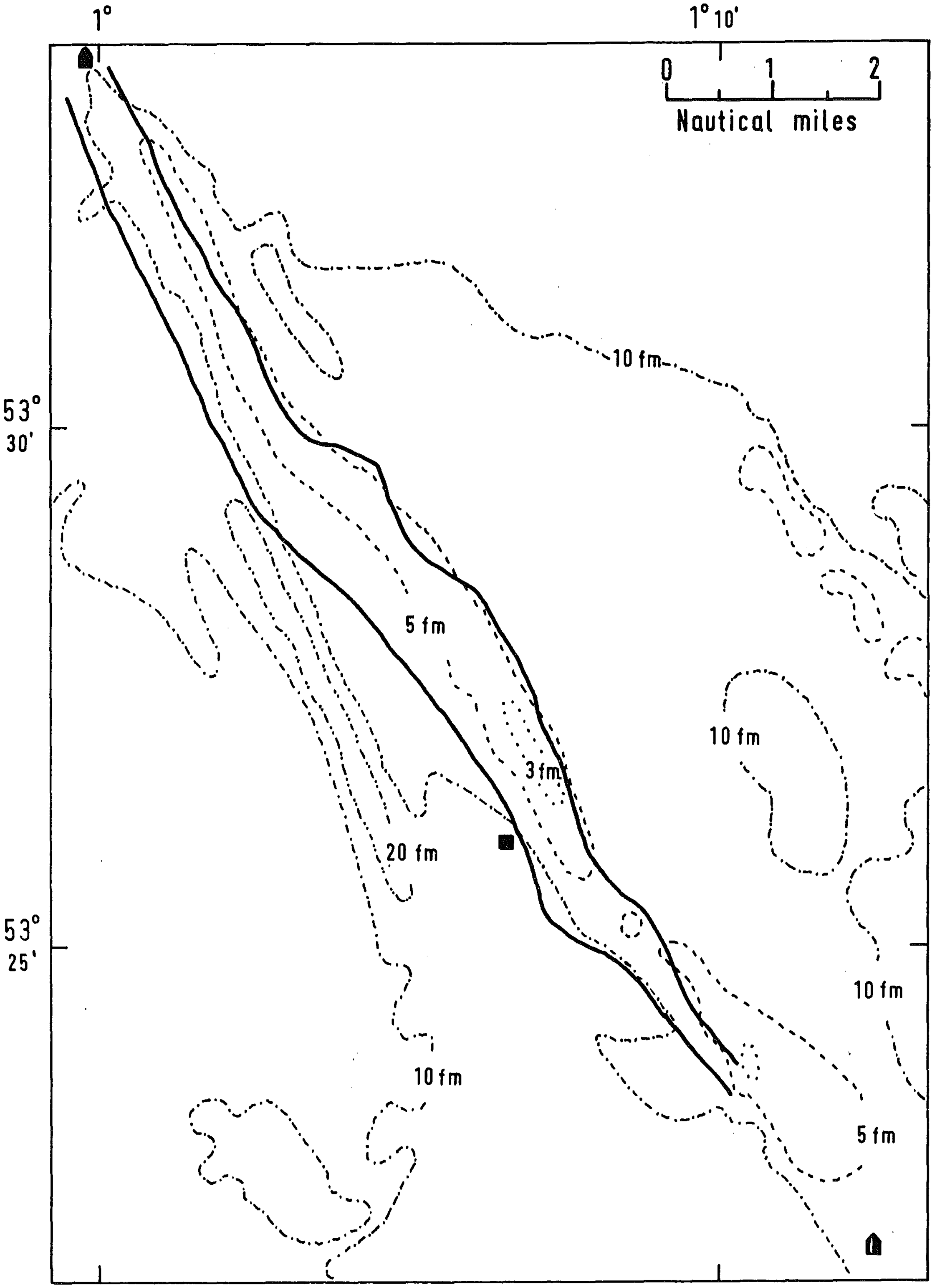


Figure 17 Area occupied by the sandeel stocklet on the Outer Dowsing Shoal in June/July 1969 (limits of commercially-viable catches by FV "Matanuska" - Macer and Burd 1970).

0.5-1.0 naut. miles in width) this stocklet is held to provide the vast majority of the total sandeel catch from the Outer Dowsing Shoal (see Table 2).

Table 2 International catch of sandeels from the Outer Dowsing Shoal, 1971-73

	Danish		UK		Total	
	Weight ('000 tonnes)	£ ('000)	Weight ('000 tonnes)	£ ('000)	Weight ('000 tonnes)	£ ('000)
1971	20.0	600.0	3.7	103.6	23.7	703.6
1972	31.6	948.0	0.9	25.2	32.5	973.2
1973	10.1	303.0	1.0	28.0	11.1	331.0

Notes: (a) 1971 Danish catch estimated from data for Esbjerg (the most important port).
(b) Values (£) based on 1973 prices for raw material, which was £28 per tonne on the Humber and £30 per tonne at Esbjerg.

Dredging clearly poses a threat in this type of situation where a major industrial fishery is based on a few restricted areas of sea bed, where certain special conditions must obtain. With little knowledge as to what these conditions might be, we do not know how sensitive the fish might be to relatively minor changes in their environment. For example, we know that sandeel eggs are laid in the sand and that sand grains of a certain size adhere to them (see Figure 18); we also know from Danish investigations that the development of sandeel eggs is arrested when they are covered with a thin layer of fine material. Thus the size of the sand grains may well be critical for successful hatching, and this may be upset by the deposition of outwash fines during dredging. Equally it has been suggested that a change in the character of the sediment might affect the burrowing behaviour of adults or the settlement of newly-metamorphosed fish, and other grosser effects can be envisaged (for example by making the bottom unsuitable for trawling).

Thus, apart from improving our survey techniques to obtain better maps of sandeel territories, our principal research requirements appear to be the following:

(a) The study of a small area of a proven sandeel ground in the spawning seasons of successive years, with dredging taking place in the intervening period (i.e. surveys in January, dredging from April onwards after the eggs have hatched). This would allow any changes in the general state of the sea bed, sediment size range, the density of adults and the density of sandeel spawn to be assessed. An adjacent but undredged area should be studied as a control to permit the monitoring of any natural change in stock density.

(b) Laboratory studies into the effect of a change in sediment size on the sandeel's burrowing behaviour.

If these studies show that minor changes in sediment type may have important effects on a sandeel population, then the effect of remote dredging activity

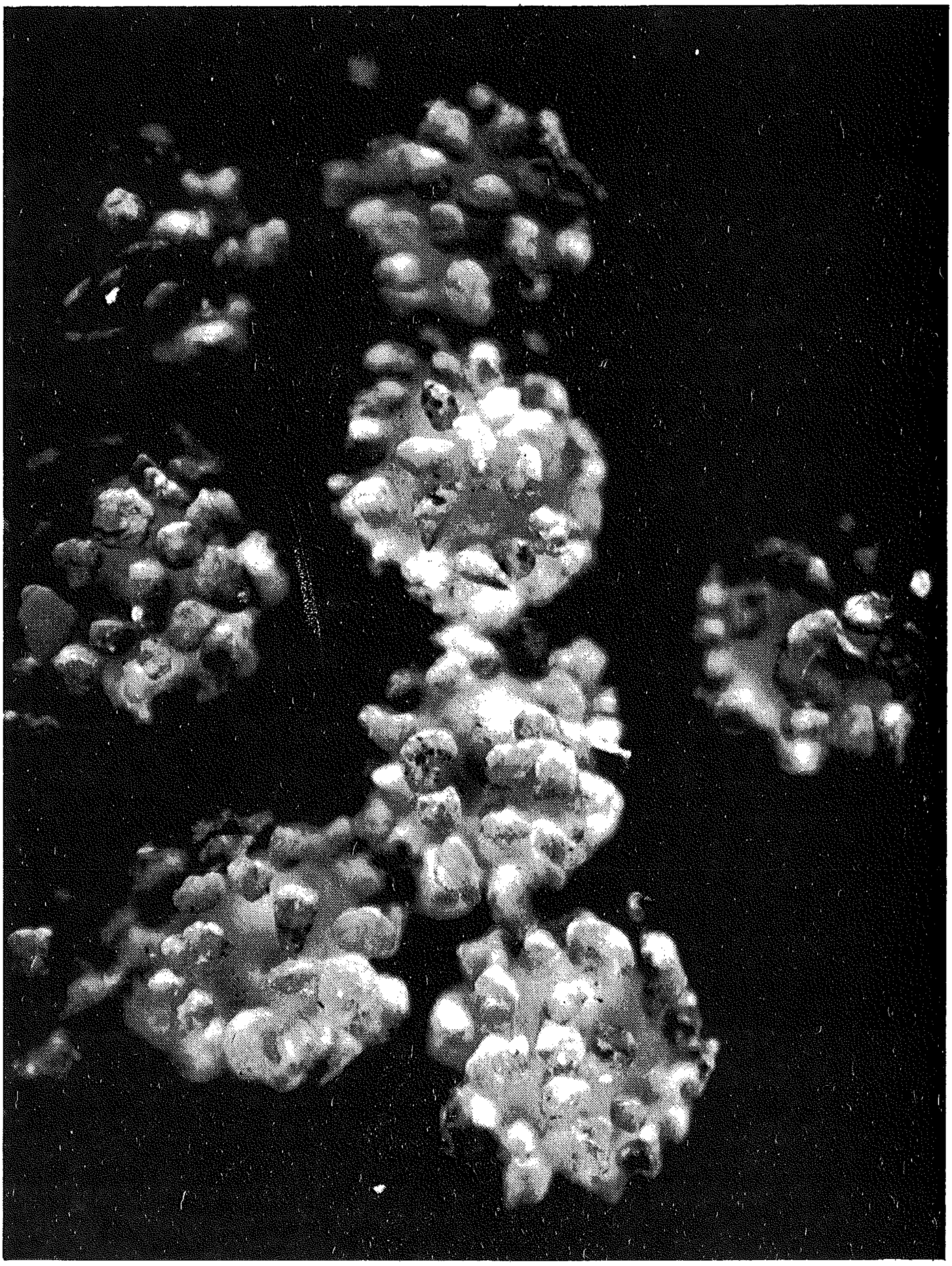


Figure 18 Sandeel eggs showing covering of sand grains.

must also be examined:

(c) Field studies of the dispersion of outwash fines in areas adjacent to the sandeel ground.

(3) Direct effects on benthos Following the removal of the benthos after suction-dredging activity the principal questions to be answered are as follows. Firstly, if the same sediment type remains after dredging it is reasonable to assume that the dredged ground will eventually be recolonized by the same type of benthic community that obtained before dredging; what will be the rate of recovery to its original abundance and species diversity? Secondly, if a different sediment type is left after dredging, what changes will take place in the species composition of the benthos?

In comparison with the literature on the effects of high suspended sediment loads on animals, the direct destruction of the benthos by suction dredging has been little studied, and most reviews deal with estuarine or inshore areas which are of little relevance to the marine benthos (e.g. Mackin 1961, Boyd et al. 1972, Sherk 1972; see also Anon. 1971). A variety of relevant points from the literature are reviewed below, but there remains a requirement for extended studies in different types of benthic community to establish the natural (seasonal and interannual) changes in the recruitment of the benthos, for comparison with studies of the recovery rate after the benthos is removed.

From the literature it is clear that the structure of benthic communities is closely related to the nature of the substrate. Since, in addition to removing all burrowing and attached organisms, marine mining is likely to alter the mechanical and chemical properties of the sediment, this may be of considerable importance to recolonization, influencing the rate of recolonization and the species involved. The majority of shallow-shelf bottom invertebrates possess pelagic larval stages so that the repopulation of a dredged ground will be determined by the number of larvae in the water column passing over the area and by the suitability of the sediment for settlement. Numerous studies indicate the ability of larvae to select very specific conditions for settlement and larvae may delay metamorphosis until these conditions are found (see review by Crisp 1965). The presence of algal or bacterial films, individuals of the same species and other chemosensory stimuli all seem to be important and these conditions may well be destroyed by dredging (though quantitative investigations in this field have yet to be completed). Harrison (1967), Cronin (1970), Cronin et al. (1971) and Flemer et al. (1968) found that repopulation of dredged grounds occurred rapidly. Successful recovery appeared to take place within 18 months of dredging and some species re-established themselves soon after dredging, except in the regularly dredged channels. Godcharles (1971), studying hydraulic clam dredging in shallow water, did not observe any differences between dredged and undisturbed grounds except where the sea grasses *Thalassia testudinum* and *Syringodium filiforme* had been uprooted; the recolonization by the grasses had still not occurred after one year. Under somewhat similar conditions, Bybee (1969) recorded that the fauna had completely recovered after some 6 months. Of greater relevance perhaps to the marine environment, Shelton and Rolfe (1972) found only a slight faunal recovery after one year in the case of dredged pits in the English Channel off Hastings. The initial colonizers in samples of sand and shell were species of polychaetes and bivalves. In other samples containing varying amounts of gravel and sand both gravel-dwelling and typically sand-dwelling organisms were obtained. A number of additional studies have indicated that fauna is reduced within dredged channels compared with undisturbed grounds (Brehmer et al. 1967, Taylor and Saloman 1968, Leatham et al. 1973, Kaplan et al. 1974) and in the special cases of the New Jersey estuaries and the Baltic the development of anoxic conditions in the dredged pits was found to be an important factor in delaying recolonization (Murawski 1969, Ackefors and Fonselius 1969).

As regards the second question raised above, the importance of any change in the species composition of the benthos lies chiefly in the relative values of the pre-dredge and post-dredge fauna as fish-food. Organically-rich muddy sand typically provides rich feeding grounds where dense populations of invertebrates occur (e.g. the Abra alba communities in the English Channel and North Sea). The importance of these areas lies not only in their abundant food supply but also in the fact that the concentration of fish on these grounds will improve the catch-rate. Many other productive and distinctive areas are the result of the activities of the organisms themselves (Rhoads 1967, Ginsberg and Lowenstam 1958, Lund 1957, Mills 1969). Reworking of the sediment by deposit feeders results in a faecal-rich sediment layer which provides a basis for bacterial and algal culture which in turn increases the capacity of the ground to support high populations of deposit feeders. Although such communities, characterized by a diverse fauna, are basically stable, continuous interference by dredging may lead to the development of an ecosystem characterized by one or two resistant organisms which is inherently unstable, and even a slight alteration of the habitat may lead to the elimination of desirable fish-food species.

(4) The exposure of anoxic sediment layers Offshore mining may affect the oxygen climate in two ways. Firstly, increased siltation due to outwash may reduce oxygen exchange in sediments and reduce the oxygen supply to eggs which are laid on or in the sediment (see Sub-section 4.4(1)). However, in certain circumstances dredging may have a direct effect on the establishment and maintenance of anoxic conditions at the sea bed.

In sediments with a high organic carbon content the subsurface layers rapidly become anaerobic as the oxygen diffusing through is used in biological and chemical processes. The reducing conditions resulting from the bacterial breakdown of organic matter can lead to the formation of metallic sulphides and H_2S. Disturbance of these deep layers by dredging and outwash of anoxic sediments may result in depletion of oxygen and H_2S formation in the water column, though these conditions will normally develop only where water movements and mixing are insufficient to replenish the local oxygen supply.

In the Øresund and Baltic the intense pyknocline prevents the transfer of oxygen into the near-bottom layers. In a study of a dredging ground at the mouth of the Baltic, Vallin (1948) noted that the dredged pits represented sites of intense local stagnation. At the base of deep pits no oxygen was found and H_2S had evolved. Ackefors and Fonselius (1969) reported that in the vicinity of a sand dredger in the Øresund there was a strong smell of H_2S and samples of spill water were found to contain high concentrations of the gas and depleted oxygen levels. Several hours after dredging conditions had returned to normal at the surface but in deep pits where water circulation was sluggish very slight stagnation occurred. Similar stagnant conditions have been observed on dredge sites in Danish waters (Bagge, personal communication). Murawski (1969), in a study of 38 dredged holes in New Jersey estuaries, found that 60 per cent developed low levels of oxygen or H_2S. In the same general location, Brown and Clark (1968) measured dissolved oxygen levels during a dredging operation in a narrow channel and found that the concentration was reduced by up to 83 per cent of normal values. Taylor and Saloman (1968) report one occasion during summer when oxygen levels on a dredging ground in Boca Ciega Bay, Florida were greatly reduced (to 2.1 ml/l). Similar cases of oxygen depletion have been observed in the carbon-rich sediments of New York Harbour and Los Angeles-Long Beach (O'Neal and Sceva 1971, Reish 1971). Theede et al. (1969) have described a number of similar environments where the oxygen is naturally depleted.

In many of the cases described above the presence of anoxic conditions is partly due to the weakness of local water movements. Thus, not only will dredged pits become stagnant, but the infill-rate of the pits will be slow so that stagnant conditions will tend to be maintained.

4.4 Indirect effects on fish stocks (i.e. remote from the dredge-head)

(1) Influence of turbidity on fish gills, visual feeding and photosynthesis Information on these subjects is still largely at the stage of conjecture. Basically it is a problem of assessing locally whether the outwash of fine material is capable of causing a noticeable increase in turbidity (bearing in mind that turbidity levels are generally high on the European shelf) and if so whether this increase is significant from the point of view of the fishery. In the case of the sandeel grounds discussed earlier, the expected increase in sediment deposition through dredging would probably be all important; in the context of this subsection the effects of the dredge plume on fish gills, visual feeding and photosynthesis will probably be negligible. However, the literature is of little assistance in confirming whether or not this is the case. Most of the published work on the effects of high suspended-sediment loads on animals has been conducted on freshwater fish (reviewed by Cordone and Kelley 1961, Anon. 1964, Alabaster 1972). These reports indicate that adult fish are able to withstand considerably higher concentrations of sediment than larvae, particularly those of salmonids which are extremely sensitive to silting, but it is unknown whether this result also applies to marine species. Conflicting reports exist on the avoidance of turbid water by fish. Radtke and Turner (1967) found that suspended sediment concentrations of 350 parts/10^6 prevented the upstream spawning migration of striped bass, but other studies (Anon. 1964) show that salmonid migrations were not adversely affected up to concentrations of several thousand parts/10^6. Whitebait and sprats have been seen to avoid an advancing cloud of china-clay waste (Shelton 1973), though other species were caught within the plume and were presumably less affected by it. As regards the effect of increased turbidity on phytoplankton it is thought that although the dredge plume may have some effect on the depth of the euphotic layer this effect would be local and insignificant compared with the major changes in suspended sediment load due to tidal resuspension and mixing (see Joseph 1957).

(2) Effect of increased siltation on shellfish, spawning-bed characteristics and egg development As regards shellfish, most marine field and laboratory studies have concerned the effects of suspended solids on oysters. Lunz (1938) found no increase in mortality of oysters in the immediate vicinity

of dredge operations and 94 per cent survival even when suspended in spill water from the dredge. At the same time no apparent effect on spat survival was observed. Wilson (1950) in a study of shell dredging indicated that oysters only died if completely smothered in silt. A similar result was obtained by Rose (1973) in an examination of beds of the oyster Crassostrea virginica in the vicinity of a dredging operation. In general, the results of various workers indicate that oysters are remarkably tolerant of high suspended solid levels and are able to survive unless buried (Butler 1949, Ingle 1952, Mackin 1961). Before death occurs, however, a marked reduction in feeding and "condition" would be expected. In laboratory experiments, significant reductions in pumping rates of adult oysters and clams occurred at 100 mg/l of silt. In stronger concentrations oysters ceased pumping altogether and prolonged exposure led to death (Loosanoff 1961). Davis (1960) and Davis and Hidu (1969) tested the effect of clay, fuller's earth, chalk and silt on eggs and larvae of oysters and clams and although eggs were able to develop at concentrations of up to 4 000 mg/l, no growth of larvae was found at greater than 250-500 mg/l.

Observations on other groups are less complete. Benthos in normally turbid environments are probably able to survive smothering unless the rate of deposition is excessively high, but less tolerant species may be excluded. Saila et al. (1972) conducted surveys of Rhode Island Sound during a spoil disposal operation. Most mollusc species were able to re-surface after shallow burial but Mercenaria mercenaria were killed by burial near the dump centre. In contrast, Shelton (1973) reported that long-term dumping of colliery waste and flyash off the north-east coast of England resulted in impoverished fauna inshore where it blocked rock crevices and smothered surfaces. Offshore no animals were collected up to 1.6 km from a large beach dump, and a second survey 10 years later produced only a few polychaetes. A marked decline in lobster and crab fisheries was also observed. In a study of china-clay waste-deposition off Cornwall, Howell and Shelton (1970) identified a sterile region where deposition was highest but an increase in biomass offshore where the rate of settlement was lower.

In addition to directly smothering the benthos, silting may have more subtle effects by altering the characteristics of sand and gravel sediments. Webb (1969) examined the importance to certain organisms of irrigation and drainage in sediments. Blockage of the pore spaces by silt prevents the movement of water through the substrate and leads to the formation of deoxygenated sediment layers. Many organisms characteristic of free draining sands and gravels are unable to tolerate the anaerobic conditions produced.

The irrigation and oxygenation of sediments is equally important to the survival and development of eggs laid on the sea bed. Cordone and Kelley (1961) reviewed numerous early papers on the effect of siltation on spawning in salmon and trout and concluded that even moderate siltation was detrimental and probably one of the most important factors limiting reproduction. Stuart (1953) demonstrated that brown trout were able to recognize areas where, though the surface layer of gravel was clean, the lower layers of sediment were blocked and poorly irrigated. These areas were avoided during spawning.

Although these results apply to freshwater fish, it is possible that a similar situation is true for the herring. As described earlier, one of the factors in the choice of spawning ground is thought to be the presence of a clean unsilted gravel substrate. General field observations by Parrish et al. (1959) and Bowers (1969) showed that the lower layer of eggs in the egg mat showed slower development and increased mortality compared with the surface egg layer, and more specifically Winslade (1971) found that the period taken to hatch increased for herring eggs held in dissolved oxygen concentrations between 2.1 and 7.4 parts/10^6, while no hatching took place below 0.2 parts/10^6. Embryos of eggs held at 2.4 and 4.0 parts/10^6 were retarded and smaller than control embryos after 15 days. Similarly Braum (1973) noted in experiments with Baltic herring that no hatching was recorded below 20 per cent oxygen saturation, and above this concentration the size of newly-hatched larvae was shown to be influenced by the prevailing oxygen tension.

Clearly, any factor which tends to reduce gaseous exchange between the egg and surrounding water will affect development; deposition of silt on the egg mass or around individual eggs will consequently be detrimental.

The possible influence of siltation on sandeel eggs was mentioned earlier (Sub-section 4.3(2)).

In addition to on-going research into the effects of outwash fines on spawning grounds and on other aspects of the fishery, there is a clear need for physical research into the dispersion of fines in relation to tidal current regimes and particle size. This research is necessary in order to establish how close dredging may be permitted to approach a ground where the deposition of fines would be undesirable from a fisheries point of view. While, strictly speaking, the dispersion of fines will depend on local tidal conditions and on the size distribution of the local outwash material, it should nevertheless be possible to distinguish from "local" studies some more general guidelines for predicting outwash dispersal.

A number of observations are already available. Cronin (1970) found an increase in turbidity over an area of 2 square miles as a result of spoil disposal. Tidal currents carried the plume a maximum distance of 3 miles but the plume disappeared within two hours of pumping being stopped. Ingle (1952), studying shell dredging, found that most of the suspended material settled out within 100 yards and total disturbance did not extend beyond 400 yards. In the weak tidal regime of Louisiana Bay Mackin (1961) reported that the maximum dispersal of fines was about 1 300 feet. He calculated that not more than 1 per cent of dredged material actually drifted away from the dispersal area. A considerably more detailed investigation has recently been conducted in Massachusetts Bay.

In May and June 1973 a detailed examination of water mass movement and sediment dispersion was carried out as part of the USA's Project NOMES (New England Offshore Mining Environmental Study). The aim was to develop a dredge plume dispersion model one year prior to dredging, which would permit the prediction of the thickness and distribution of outwash deposition. The outwash fines were simulated using 2 000 lb of small glass beads ($5\ \mu m < d < 50\ \mu m$) and 1 000 lb of small ZnS crystals ($0.5\ \mu m < d < 20\ \mu m$) which were dumped on 11 June. These were then tracked until 22 June using water sampling (by boat and helicopter) and seabed sampling (using divers, together with a variable deployment of sediment traps). Tide gauges, drogues, two profiling current meters and an array of 28 standard current meters were used to monitor water movements. The information obtained is currently being analysed.

(3) Reintroduction of toxic compounds from the sediment The presence of toxic materials in sediments close to large towns is the result of discharge of sewage and industrial wastes into the surrounding body of water. Further offshore the deposits may also become contaminated by the dumping of sewage and redge spoil, usually in set dumping grounds. The build-up of pollutants in sediments has been recorded at numerous dump-sites, including New York Bight (Gross 1972) and Liverpool Bay (Winter and Barrett 1972).

Clearly, the outwash of fine material during dredging operations may result in the release of toxic compounds previously buried in the sediment but the severity of this problem will depend so specifically on the area involved that general research programmes are likely to be of limited value. Studies of the uptake of pollutants by fish and shellfish are already in train; where dredging is proposed in areas which have potentially high levels of pollutants in the sediments, it is important that detailed pollutant surveys specific to each area are undertaken and the effects on the fishery assessed before dredging concessions are granted.

4.5 Major research projects

(1) The New England Offshore Mining Environmental Study (NOMES) The NOMES project was designed to assess the whole complex of environmental effects which would result from dredging the glacial outwash gravels off the New England coast. The project was an ambitious one covering a five-year period at an estimated cost of c. $4.5 million, and though the project has now been cancelled the work-programme is of interest here.

Stage 1 would attempt the detailed "baseline" characterization of an experimental dredge-site 16 km east of Boston. These initial experiments may be described under the following headings:

Geological	• Close bathymetric mapping • Sub-bottom profiling, grab sampling • Side scan sonar mapping
Chemical	• Core and grab samples to be analysed for organic toxins pesticides, iron, copper, zinc, lead, cadmium, arsenic, mercury, antimony, inorganic and organic nutrients, chemical oxygen demand • Laboratory studies of the mobility or breakdown of contaminants within sediment phases
Physical	• Particle size distribution (for sediment dispersion calculations • Soil compactness, bulk density, specific gravity and water content (for estimation of sediment settling-rates) • Underwater photo-reconnaissance of the substrate • Water movements, using current meters, drogues and dye (to predict dispersal of the dredge plume) • Water quality (temperature, salinity, dissolved oxygen, phosphate, nitrate, silicate)

Biological
- Abundance and seasonal fluctuation of principal organisms
- Selection of key species for study based on commercial importance, importance to food chain, representation of different taxonomic groups, suitability for laboratory experimentation.

These background studies were due to begin well before the experimental dredging operation to be used in the detailed design of the subsequent laboratory and field experiments. They would continue for at least two years after dredging.

The principal experiments of Stage 2 were to be as follows:

- Distribution of suspended sediment: Mathematical model using water sampling and seabed sampling to provide verification.
- Physicochemical and biochemical interactions between sediments and water: Release of nutrients and toxic substances to the water, effect of suspended particles on the scattering and absorption of light.
- Energetic relationships in organisms stressed by the presence of sediments: Physical and/or chemical effects on respiration, photosynthesis, assimilation, feeding rates, and reproductive potential in adults, juveniles and larvae of key species (including benthic invertebrates, benthic algae, zooplankton, phytoplankton, demersal and pelagic fish.

While it was designed to investigate a specific area of the American shelf, the scope and complexity of this programme would have had great value in illuminating a number of the more general problems that have arisen in connection with dredging on the European shelf. (Indeed, as described on page 33, a number of the initial NOMES studies have already proved of value in this connection.)

(2) The Baie de Seine Project A major experiment currently under way in France concerns the experimental dredging of a site (1 000 x 400 m to a depth of 5 m) in the Baie de Seine, 17 km to the west of Le Havre. The following ancillary studies are planned before, during and after the dredging operation:

- Initial detailed benthos study over a wide area of the eastern channel (obtaining benthos "reference levels" summer and winter).
- Systematic repeat trawling of the area.
- Study of the relation between the benthos and commercial fish species (stomach contents of sole, plaice, whiting, cod and other gadoids).
- Water quality (temperature, salinity, oxygen and nutrients).
- Mapping of the main herring spawning grounds in the eastern Channel (during November-December 1974, using underwater TV and bottom sampling).
- Determination of the date of larval settlement.
- Mapping coastal nursery grounds for commercial fish.
- Development of a mathematical model for the ecological system.

Studies to be conducted more specifically within the dredge site include:

- Detailed benthic survey along legs radiating from the dredge site.
- Influence of fines on plankton, beaches and oyster culture.
- Field study of dredge plume dispersion using radioactive tracers.
- A mathematical model of dredge plume dispersion.
- Estimate of seabed recovery rate (sidescan sonar survey, current meters).
- Effect of dredging on recolonization by benthos (by dredging pits in the contrasting Abra and Ophiotrix facies).

(3) The Southwold-Thorpeness Project In addition to a number of relatively short-term studies around the British coast, the Fisheries Laboratories at Lowestoft and Burnham-on-Crouch are planning a longer-term project at a test site some 5-12 km off the Suffolk coast. Detailed grab surveys have shown that this area (which is scheduled for commercial dredging) is characterized by a wide range of sediment types from coarse gravel to mud. It is therefore ideally suited to the study of the direct and indirect effects of dredging on a variety of different benthic communities and this is the primary aim of the project. Thus the main aspects of the work programme will be as follows:

- Detailed topographic mapping of the sea bed using sector scanning sonar (now complete).
- Repeated benthic surveys before dredging to establish the normal seasonal changes in the benthos.
- Monthly studies of suspended sediment load in the water column before dredging to assess the natural sediment regime.
- Repeat benthic surveys after trailer dredging to assess the recolonization rate and recovery of species diversity in the dredged area, and to identify any change in the benthos of the surrounding sea bed.
- Measurements of the velocity shear in the near-bottom boundary layer at spring tide in areas of different sediment type and water depth.
- Research vessel, and commercial fishing vessel surveys (using long lines) of the catch-rate and stomach contents of commercial fish species.

5 THE CURRENT AND PROJECTED STATUS OF REGULATORY LEGISLATION

At present there is no common legislation for the regulation of marine mining in the different national sectors of the European shelf. Instead, as might be expected, the amount of regulation is roughly proportional to the amount of dredging activity. In the face of the expected increase in marine mining activity in all parts of the shelf, many nations are currently framing more rigorous legislation, but even so this legislation is not being designed to any common set of standards.

Ireland

The licensing authority inside the 3 mile limit is the Department of Transport and Power (under Foreshore Act of 1933 (Section 6)); outside the 3 mile limit it is the Department of Industry and Commerce (under Continental Shelf Act of 1968). Advice on the quality and quantity of gravel deposits is given by the National Geological Survey Office which is attached to the Department of Industry and Commerce. There is no obligation for the relevant Government Department to consult other groups but this is normally done. Fisheries objections at the prospecting stage may lead to the withdrawal of a licence.

Norway

For the time being there are no statistics showing the amount of sand and gravel extracted from Norwegian coastal waters, but as far as is known the amount is very small, and mostly for private purposes.

As in Sweden and Finland there is no regulation within the inshore limit (the 2 m contour) where the grounds are mostly privately owned. Outside this limit there is no properly constituted licensing authority at this moment apart from the general principle that any agency seeking to conduct activities which might affect the fishery are obliged to consult and inform the fishery authority informally for permission to do so. However, Norway envisages an increased demand for marine sand and gravel (some for rig platforms) and therefore a law dealing with the utilization of minerals (including sand and gravel) on the continental shelf is being formulated and this law will possibly be effective by the end of this year (1974). The aggregate deposits fringing the fjords are narrow and the law seeks to regulate activity not only for fishery protection but also to prevent the possibility of coastal erosion.

Finland

The licensing authority is not known. The privately-owned grounds on which most of the dredging takes place are not subject to regulation. Finnish water law only gives general guidelines on extraction.

Sweden

(a) Inshore of the 6 m contour the land is private and no permission is required for aggregate extraction. (b) The licensing authority outside the 6 m contour is the Statens Industriwerk (Board of Industry). Applications are sent by the Statens Industriwerk to interested groups such as the Fishery Board and the Environmental Protection Board for consideration. If there is no serious objection a licence is issued for 2-3 years only, for a specified amount of material. The licence comes into force after approval by the local Water Court. Enforcement is based on the Swedish Law of the Continental Shelf (1966) but further legislation is envisaged to cover the areas within the 6 m contour. A charge of 2.75 crowns/m^3 is levied for extraction in "public waters".

France (from 3-12 miles from the coast)

At present the only conditions on extraction are that the ships transporting the aggregate (not the dredgers) should carry the French flag, and that the dredgers must have an automatic Decca plot system. Companies need only ask permission, and at that stage a number of agencies may give advice. However, a new law is now in the course of construction which will be much more comprehensive and precise. This law will be incorporated into the Code Minier.

Germany

The licensing authority inside the 3 mile limit is the regional Wasserund Schiffahrtsamt (Water and Navigation Office). There are 15 of these around the German coasts. The licensing authority outside the 3 mile limit is the German Hydrographical Institute and the Mining Office (Oberbergamt). In addition, the Wasserund Schiffahrtsamt has to ensure that applicants follow navigation and safety regulations and do not endanger shipping. Within the 3 mile limit the Wasserund Schiffahrtsamt has to pass the applications on to the Provincial Fishery Office to ask for objections, unless only small amounts of material are involved. Scientists are not involved. Outside the 3 mile limit the German Hydrographical Institute must by regulation ask both the Federal Research Board for Fisheries and the Provincial Fishery Office for objections. Wherever possible dredging of sand in the Ems, Weser and Elbe estuaries is directed to areas where dredging is also required in the interests of navigation. This minimizes the fishery and environmental effects.

Belgium

A Royal Decree is now being prepared according to the Law of 13 June 1969. This will require a permit before any exploration or exploitation of the Belgian continental shelf can begin. Permits will be issued by the Ministry of Economic Affairs and requests for permits will have to be accompanied by a note stating the measures which will be taken to conserve fish, prevent destruction of eggs and larvae and maintain the environment. The final decision regarding the issuing of a permit will be taken by the Ministerial Committee for Economic and Social Coordination. Certain navigation areas, and areas of fisheries importance (nominated by the Ministry of Agriculture) have been designated as forbidden areas for dredging. Their limits are:

(a) The area between the coastline and a line joining the following coordinates:

51°11'50"N	02°29'00"E
51°14'35"N	02°38'25"E
51°21'10"N	02°42'40"E
51°24'00"N	02°42'40"E
51°31'10"N	03°05'50"E

(b) The Belgian shelf north-west of the line joining:

51°34'30"N	02°58'00"E
51°21'30"N	02°24'30"E

In future the latter area could be made available for exploitation (in whole or in part) but this will depend on the results of scientific investigation.

Denmark

The Ministry of Public Works (MPW) acts as the licensing authority both inside and outside the 3 mile limit. (Not valid for Faroes and Greenland.)

(a) Inside 3 miles: The MPW may at any time make restrictions regarding the quantity and type of material dredged, can stop the dredging activity and can restrict the depth of sediment removed. Licence applicants must inform the Ministry as to the type and amount of material to be extracted.

(b) Outside 3 miles: Rules for extraction of sand and gravel in the Danish sector are outlined in Law No. 285 of 7 June 1972.

Netherlands

Within 20 km of the coast marine dredging is not allowed. Studies are now being carried out in order to investigate the possibilities of shortening the 20 km zone, bearing in mind the problems of inshore and beach protection.

Licences for sand extraction on the continental shelf are at present issued under the Mijnwet (Mining Act) by the Domeinbestuur (Public Property Board of the Finance Department) for a royalty, and the Directie Noordzee (North Sea Directorate of the Ministry of Transport and Public Works) in consultation with the Ministry of Economic Affairs (Geological Service Department).

Within a few months, however, exploitation will be governed by the Wet Bodenmaterialen (Bill of Soil Materials), in order to direct and protect sand dredging entirely. Before licences are issued the Ministry of Agriculture and Fisheries and the Netherlands Institute for Fishery Research are notified. Licence areas are restricted in size (5 x 2 km lots) and duration (one year).

United Kingdom

The licensing authority, both within the 3 mile limit and for territorial waters outside the limit, is the Crown Estate Commissioners Office.

(a) Prospecting licences: Fisheries interests are informed about prospecting licences but objections are not normally raised until an application for a production licence is made. An area of up to 1 000 square miles can be leased for a period of two years, during which time no more than 1 000 tons of exploratory samples may usually be removed. The results of prospecting operations must be notified to the Commissioners who make the information available to the Institute of Geological Sciences in a scrambled form.

(b) Production licences: Before proceeding with an application the Crown Estate Commissioners obtain advice from the Hydraulics Research Station, Wallingford on possible coastal erosion or siltation problems. If there is no objection from this source the Commissioners forward the application to the Department of the Environment for a coordinated Government view, and interested parties are then invited to submit their opinions. The Ministry of Agriculture, Fisheries and Food is consulted at this stage and it obtains the views of local river authorities and local fisheries groups. At the same time the Department of Trade and Industry is consulted about hazards to navigation or pipelines.

If there is a serious objection the application may be amended or finally rejected but, once a favourable Government view has been expressed, the Commissioners will issue a production licence stipulating the annual rate of gravel removal. This is usually sufficient to allow the deposit to be worked for 15-20 years. A scale fee is charged dependent on the annual removal rate and a royalty fee has to be paid on each ton dredged. More than one operator can apply to survey or work on the same grounds.

Although this review has described no more than the basic outlines of national practice in dredging legislation, the diversity of approach is clear. A further aspect of this diversity may be found in Table 1, where it is shown that in different parts of the shelf the normal duration of a production licence may vary from 1 year to 20 years. Nevertheless it is likely that, as the European offshore mining industry expands, these diverse national codes of practice will be required to deal increasingly with international problems of regulation. Individual nations are already, directly or indirectly, seeking to exploit deposits of aggregate in other sectors of the shelf than their own, and many of the fisheries liable to be affected by dredging are subject to international exploitation or show patterns of fish migration which do not recognize national boundaries. For these reasons, the Working Group takes the view that some common code of practice should be established for the regulation of dredging (see Recommendations, page 48).

To this end the Netherlands have submitted the following suggestion for a common code of practice based on the forthcoming Dutch law. It is relevant to add that when adopted the new Dutch laws will represent the most comprehensive body of legislation in Europe in this field, designed to provide tight control on all aspects of the Netherlands offshore mining industry. It should be noted that this code of practice is included here merely as a basis for discussion and as a guideline from which some more common "European" code might be established (some minor amendments have already been made by the Working Group):

Recommendations for a code of practice

A We should distinguish the following types of extraction:

1 Gravel
2 Sand
3 Gravel in combination with sand
4 Calcium carbonate

B Aggregate dredging in general

1 Licences should only be given when based on the results of geological and bio-ecological surveys carried out by the Government and/or its Commissioners.

2 The cost of this must (partly) be paid by the licence-holder.

3 Based on this research, licences should be given for the extraction of (1) gravel, (2) sand, (3) gravel and sand, (4) calcium carbonate.

4 In these licences conditions protecting the interests of others should be incorporated. For fisheries these are:

(a) the exact boundaries of the extraction area

(b) the instrumentation to be used for accurate position fixing

(c) the thickness of the layer allowed to be dredged away

(d) the condition of the sea bed after the dredging operations have been finished

(e) the amount of gravel to be left on the sea bed to enable herring to spawn, etc.

(f) the period in which dredging is not allowed for some reason

(g) the total type and quantity of material to be removed.

5 The proposed method of extraction should be specified:

(a) Drags

(b) Anchored suction dredgers (deep extraction in a restricted area)

(c) Trailing hopper dredgers (shallow extraction in a large area)

(d) Cutter dredgers.

6 The separation of sand and gravel at sea should be avoided.

7 If possible the licence forms should be the same for each of the member countries.

C <u>Gravel dredging</u>

The licences should be given only for areas with a high concentration of gravel and so concentration maps are required and the gravel percentage should exceed 60 per cent. Trailer hoppers are preferred to anchor dredgers.

D <u>Sand dredging</u>

Extraction should be allowed only in areas relatively unimportant for fisheries and with a low amount of fine sand and mud.

The sand fraction should be more than 100 μm.

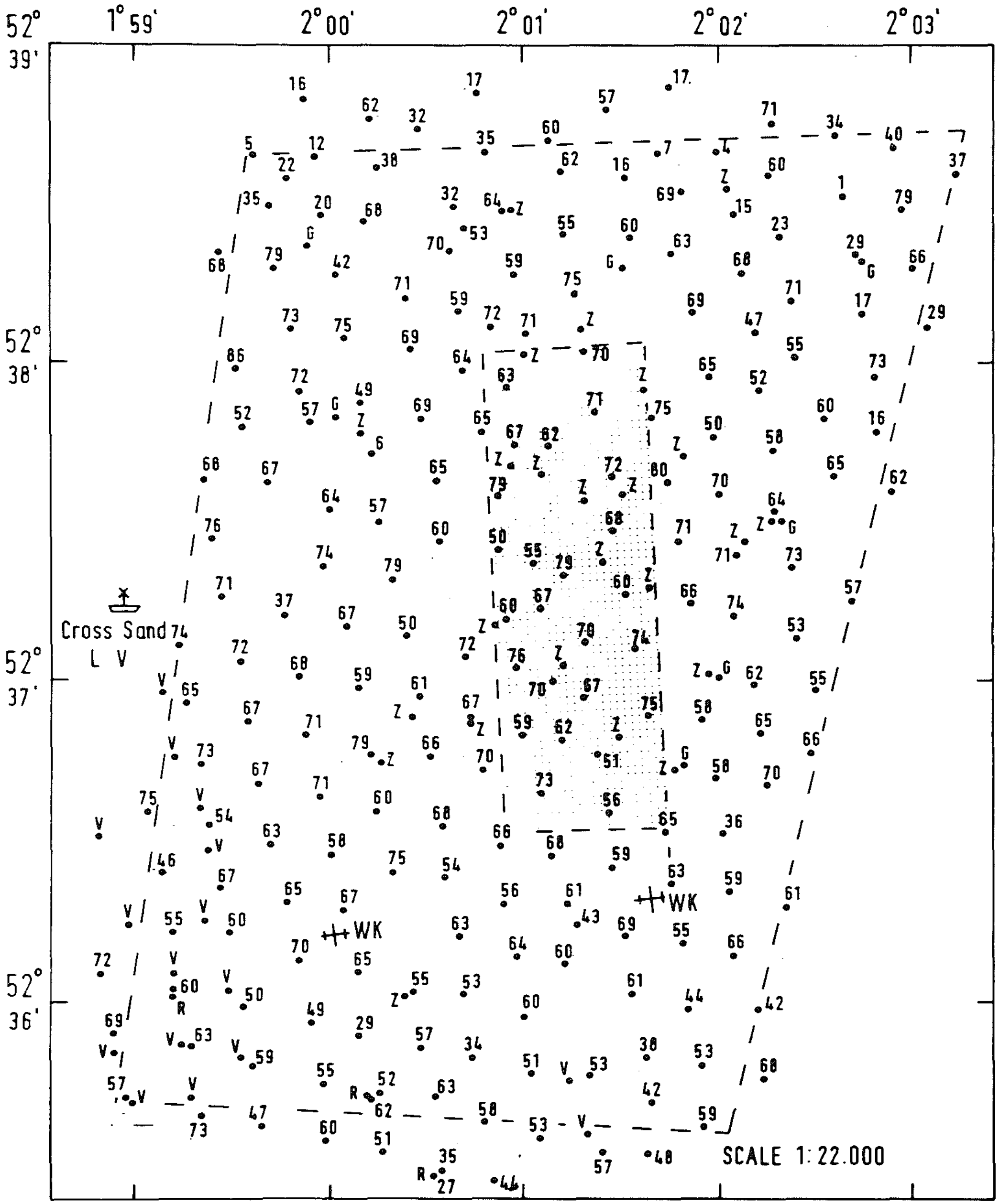
In the case of deep extraction attention must be paid to the erosion of the bottom layers.

E <u>Gravel and sand dredging</u>

Extracted gravel and sand should be separated where it will cause least environmental damage.

While the adoption of some such code might be thought to impose heavy restrictions on concession-holders, it should be remembered that in the case of one of the countries principally concerned with offshore mining (Netherlands) it will shortly become law, and these measures are evidently thought to be both practicable and necessary.

Using data from an existing concession area off the Norfolk coast (supplying the Dutch market), Figures 19 to 21 illustrate the type of detailed information which would be required under such a code in support of an application for a



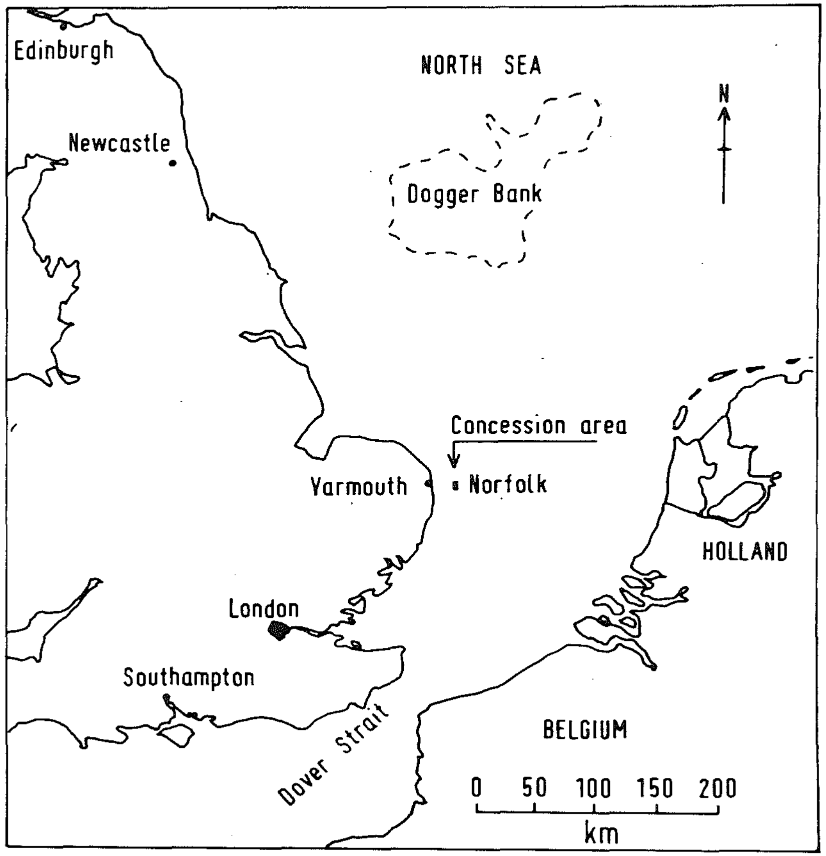


Figure 19 Norfolk coast concession: detailed sampling grid worked during prospecting.

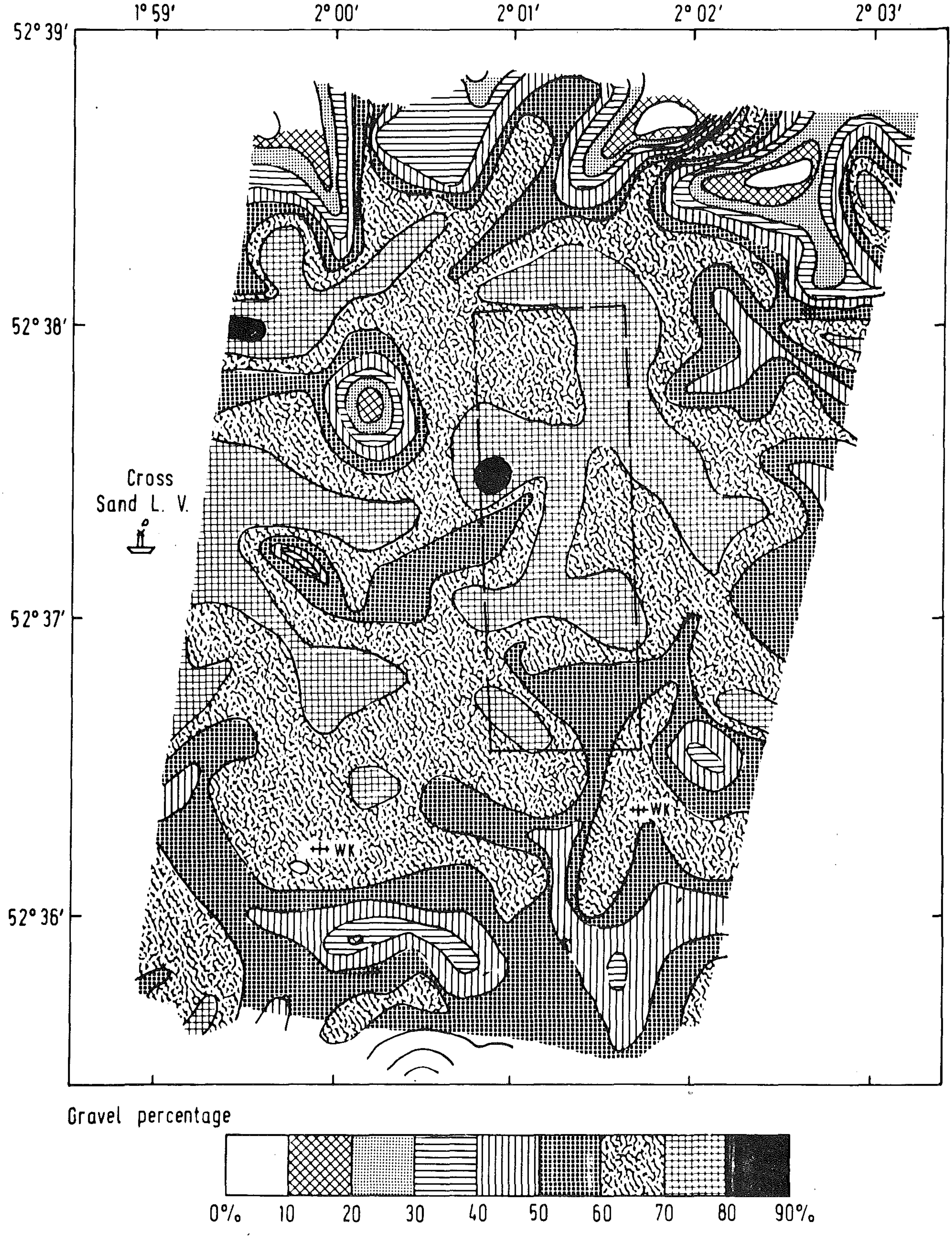


Figure 20 Norfolk coast concession: detailed chart of gravel concentration.

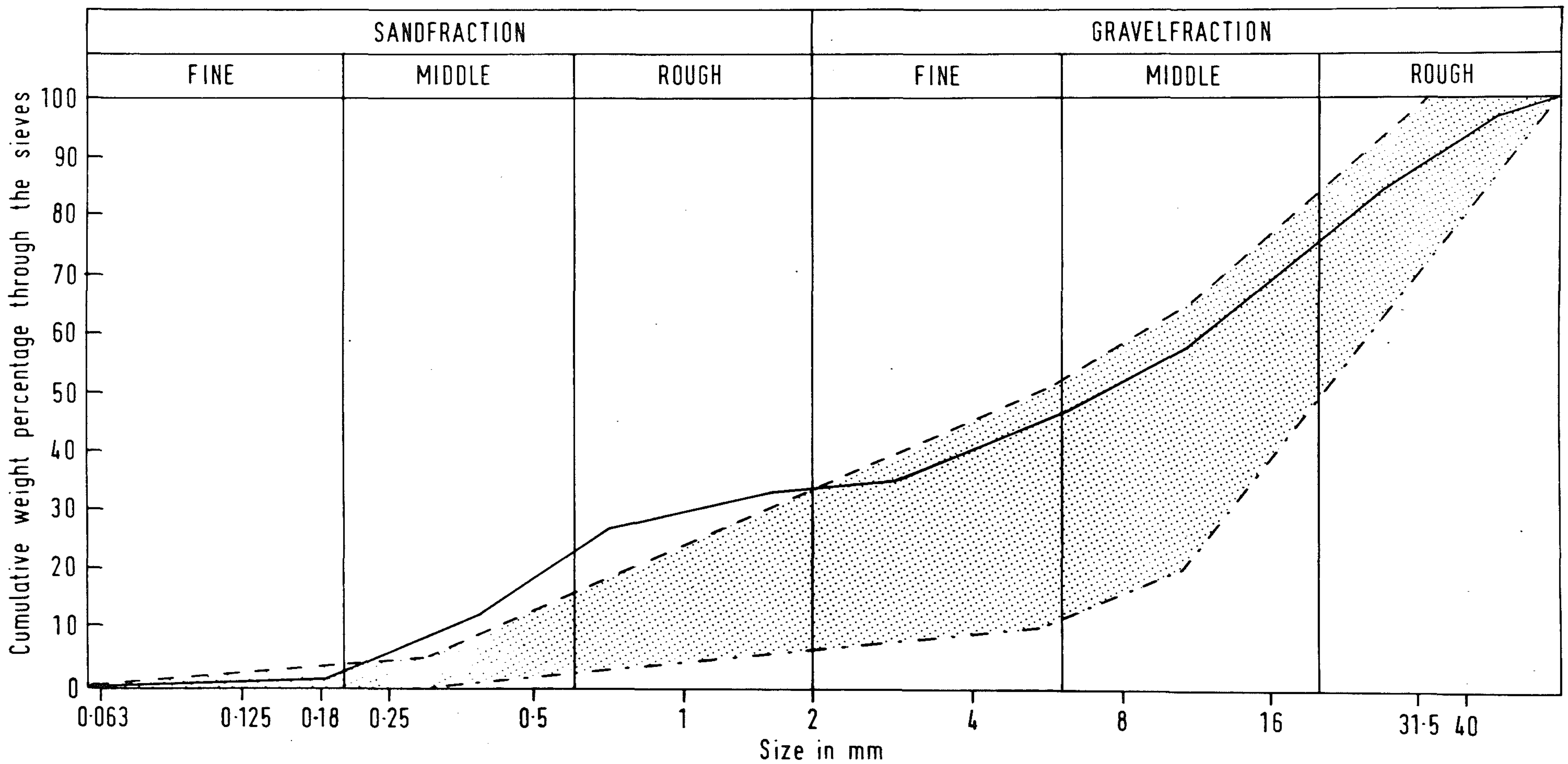


Figure 21 Norfolk coast concession: granulometric curve (the desired sediment size range is shaded).

production licence. To locate the precise type of sediment required (in this case, clean gravel) a detailed seabed sampling pattern has been worked across the area (Figure 19) and from this a chart of "gravel percentage" has been drawn up (Figure 20). From this chart the optimum working area (with most gravel and least sand) has been identified, and production will be concentrated in this small area. In cases where the required gravel percentage is specified by the client, this type of detailed preliminary survey is of course in the interests of the concession-holder (producer). Certainly, methods of separating sand from gravel aboard ship do exist whether by mechanical means (cyclones, vibration screens) or hydraulic means (countercurrent or ski-jump methods). However, these methods have disadvantages. They slow down the rate of dredging; if the fines are discharged on the spot they pollute the mining area (not only for fisheries, but for subsequent dredging also); if dumped outside the licence area they involve a loss of ship's capacity. Thus, it may be preferable from the outset to locate and mine only the richest gravel or, more generally, the precise type of sediment for which the concession was originally granted.

Charting the sediment quality in such detail implies the use of some advanced method of position-fixing aboard the dredger. In the proposed Dutch system Hifix will be mandatory and a sealed position-recording system will also be required as a check that the dredging activity was, in fact, confined to the concession area. (The cost of the Hifix equipment will be borne by the dredging company.)

Finally the size composition of the dredged aggregate would be reported in some convenient form for comparison with the composition specified in the dredging application. For the Norfolk concession under discussion this comparison is conveniently made using granulometric curves (Figure 21).

It is relevant at this stage to recall the purpose behind this requirement for detailed information from the mining company. Information on the extent, depth and quality of deposits is required for comparison with the proposed annual extraction rate in order to predict the likely state of the sea bed after dredging, e.g. will all the gravel (say) be removed or will an adequate bed of the original substrate remain after dredging? Together with a knowledge of current strength in the area, a knowledge of the size distribution of the sediment will enable some estimate to be made of, for example, the recovery-time of the sea bed after dredging, and the dispersion rate of the local fine material. The thickness and type of sediment may indicate that one method of extraction is preferable to another. These and other factors are therefore of importance in assessing the environmental impact of the proposed dredging activity. If a system exists whereby more than one company is permitted to apply for a production licence in a given area, it is understandable that a company, having surveyed the area, might be unwilling to lose commercial advantage by making this information public. However, in the Dutch system this situation will be avoided by restricting the size of the licence area and by granting unique production licences for each area.

In addition to recommending a common code of practice for dredging regulation, the Working Group also suggests that the member countries of ICES should take steps to exchange information on dredging activity in their sectors. Specifically, member countries are recommended to report this information annually to ICES on a standard double-sided form (included as pages 46 and 47

ICES FISHERIES IMPROVEMENT COMMITTEE

REPORT ON MARINE AGGREGATE PRODUCTION FOR YEAR ....

COUNTRY ....

ISSUING AUTHORITY ....

REPORTING PERIOD [IF DIFFERENT FROM ABOVE] ....

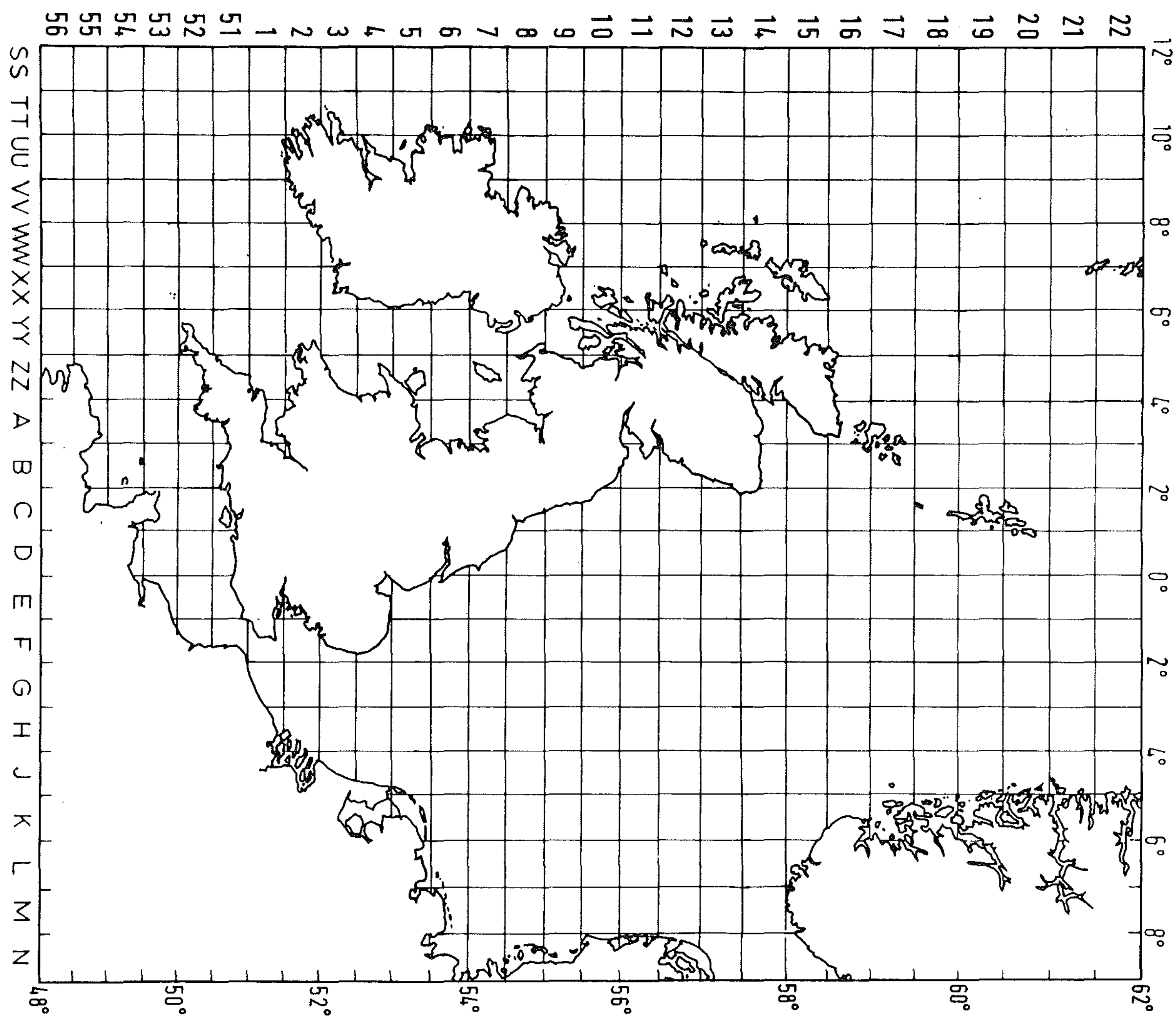
TYPE OF MATERIAL	SIZE RANGE*	TOTAL PRODUCTION million m^3	TOTAL PRODUCTION million tonnes	LOCALITIES (See overleaf)
SANDS	0.063-2.0 mm			
GRAVELS	2.0 mm-6.4 cm			
PEBBLES/COBBLES	> 6.4 cm			
CALCAREOUS SHELL LITHOTHAMNION OTHER [SPECIFY]	ALL SIZES			

*The size ranges shown here are idealized, and are intended merely as a guide to the type of categorization required.

IMPACT ON FISHERIES

A CURRENT PRODUCTION Briefly specify the types of problem encountered as a result of aggregate production during the reporting period [if any]

B FUTURE PRODUCTION Detail the quantity, type and location of any proposed marine mining activity likely to be of international fisheries interest or concern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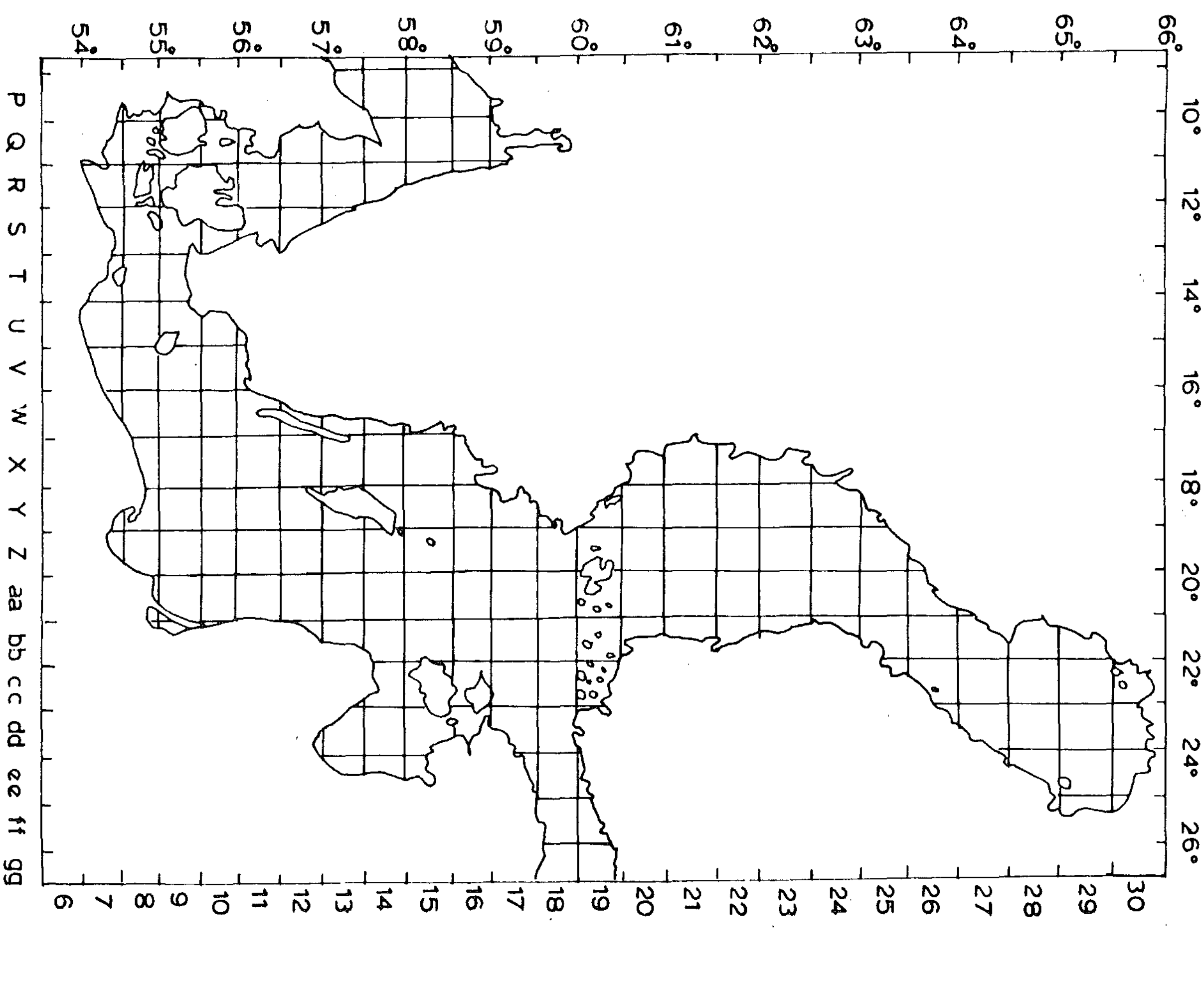
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of this report) for inclusion in the Administrative Report of the Fisheries Improvement Committee. This annual reporting will ensure the availability to members of the up-to-date information, important for such a fast growth industry, and will enable other nations to record objections to offshore mining in any part of the shelf if an international fishery is endangered.

6 WORKING GROUP RECOMMENDATIONS

The Working Group recommends that:

(i) In the light of (a) the recent expansion of the marine aggregate industry and the shift of extraction activities to deeper water (b) the need to protect herring spawning grounds, member countries of ICES should take immediate steps to try to delineate the herring spawning grounds in the North Sea, English Channel, Irish Sea and Baltic Sea as precisely as possible, and the ICES Working Group on North Sea Herring Larval Surveys should be requested to assist in this work (e.g. by making available immediately data collected to date on the distribution of yolk-sac larvae).

(ii) Member countries of ICES should (a) be encouraged to seek the view of the Council on the fisheries aspects of proposals to extract sand and/or gravel in their sectors of the continental shelf whenever such proposals are considered likely to affect international fisheries (b) submit to the Council on an annual basis details of marine sand and gravel extraction within their respective sectors.

(iii) In view of the limited scientific resources available for the study of the effects on fisheries of marine aggregate extraction and the urgent need for knowledge of these effects, member countries should take steps to (a) pool information and the results of research programmes (b) assist each other whenever possible in the conduct of relevant investigations.

(iv) Bearing in mind the recent increase in interest with regard to dredging for Lithothamnion for use in the fertilizer industry in France, the UK and Ireland, investigations into the possible effects of such dredging on fisheries and shellfisheries should be started in these countries as soon as possible and steps be taken to exchange findings.

(v) In order to improve our ability to predict the likely effects of marine sand and gravel dredging on fisheries and shellfisheries and to minimize damage to fish and shellfish stocks and to fisheries, national codes of practice for the dredging industry more rigorous than the majority of those currently in force are required. The member countries of ICES should be encouraged to move towards the adoption of more rigorous codes, preferably a single uniform code, and in doing so should take note of research findings and regard the code of practice proposed by the Netherlands (page 40) as a basis for discussion.

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