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MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH

FISHERIES RESEARCH TECHNICAL REPORT No. 84

Determination of the distribution of the planktonic and small demersal stages of fish in the coastal waters of England, Wales and adjacent areas between 1970 and 1984

J.D. RILEY, D.J. SYMONDS and L.E. WOOLNER

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CONTENTS

1. Introduction

Man first used the sea as a source of food and as a means of transport. In the last hundred years or so these uses have persisted but they have been joined by many others such as waste disposal, sand and gravel extraction, culminating recently in the offshore oil and gas developments.

Before 1960, MAFF fisheries research was concentrated on the biology and management of several stocks, mostly away from the coastal areas of England and Wales. The increasing frequency of sea use enquiries in the late 1960's were, however, concerned with just these coastal areas. As no comprehensive data were available, a programme was designed to define and measure the spawning grounds and the distribution of small demersal fish in these areas. In particular, there was a need to be able to judge the relative importance of quite small inshore areas to the stocks of commercial fish.

Ecological studies centred on plaice between 1963 and 1969 (Riley and Corlett, 1965), had indicated that most young stages of our commercial demersal fish were found inshore before recruitment to the fisheries and that some species also spawned close inshore. The information in the scientific literature on both the inshore plankton and trawl catches dated back to the 19th century but was individually restricted to small areas of coast close to a marine laboratory and was not easily compared with other data sets from different areas. Wallace (1923), formerly of this Ministry, however, reported on experimental hauls with small trawls in certain inshore areas off the English east coast and compared the importance of the Wash and the Thames Estuary as nursery grounds for flatfish. For the greater part of our coastal areas there was no information and the programme described here was devised to fill the gaps and update the historical information which existed.

2. Scope of the survey

The initial six-year programme was planned to study each of the three coasts of England (with Wales) twice. Accordingly, the east coast was surveyed in 1970 and 1973, the south coast in 1971 and 1974 and the west coast in 1972 and 1975; further surveys of the most important areas have continued in more recent years (Table 1). In the period 1972 to 1975, the distribution of the ichthyoplankton was surveyed in February, April/May, June and September/October to cover the spawning periods of most common fishes. Small fish were normally sampled from early September to mid-October when the majority of the demersal fish which spawn in the spring and early summer have adopted a bottom living habit and are found in shallow water. Earlier, in 1970 and 1971, the surveys of both plankton and young fish were less comprehensive than in the years to follow. The chartered vessels used in small fish sampling were normally open boats of between 6 and 12 m length which, on account of their size, could fish into shallow water (sometimes <2 m). In addition, the expertise and local knowledge of their skippers and crews were essential for the completion of successful surveys in areas unfamiliar to MAFF staff.

3. Sampling gear

The three gears used to sample fish eggs and larvae were all based on the 76 cm high-speed townet described by Beverton and Tungate (1967). The encased 30 cm sampler (Riley, 1974) was used in 1970 and 1971 and the unencased 50 cm sampler (Lockwood, 1974) in 1973 and 1974, whereas these same gears, in tandem, were used in 1972 to give a comparison of catch rates between the two and to maintain continuity of sampling. The encased sampler, used in 1975 and 1984, was similar to the unencased version but with the addition of a moulded fibreglass body. In all cases, the sampler was fitted with a nylon net of nominally 24 meshes/cm. The rate of water flow was controlled by the aperture size in the nosecone which in the 30 cm sampler was 250 cm^2 and in the 50 cm sampler was 324 cm^2. An internal flowmeter was fitted into the nosecone.

The small fish populations were sampled using two small-meshed gears, the 1.5 m pushnet from the shore and the 2 m beam trawl from small boats. These gears were designed and rigged to be as similar as possible so that the catches were comparable when fished at standard speeds. Details of the pushnet have been given by Riley (1971). The beam trawl (Figure 1) consists of a hardwood beam supported 30 cm above the sea bed by galvanised steel trawl heads at each end, positioned so that the width of the trawl opening is 2 m. The shoe of each head has two eyes 30 cm apart; three ticklers are attached to the forward one and the ground chain of the net to the after one. A standard rig of these chains was adopted after experiments to find the most efficient arrangement for catching small fish. They are positioned so that the distance behind the trailing edge of the beam to the first chain is 35 cm, the second is 50 cm and the third is 65 cm with the ground chain at 75 cm. The net is constructed of nylon of mesh size 90 rows/yard (98 rows/m) with a codend of 144 rows/yard (157 rows/m). A liner of knitted terylene netting of mesh aperture 3 mm diameter is fitted inside the codend to retain small fish. Five metre bridles, attached to the trawl heads, come together at a central point to be towed from the boat by a single warp. A distance meter is incorporated into one trawl head to measure the distance travelled over the sea bed by the trawl (Figure 2).

A summary of the gear used on each survey is given in Table 1.

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Table 1 Summary of the sampling surveys

Coast	Date	Gear					Factor sampled			
		High-speed townet			2m beam trawl	1.5m pushnet	Fish eggs and larvae	Young fish	Temp.	Salinity
		30cm encased	50cm encased	50cm unencased						
East	1970 30.4-19.5	40	—	—	—	—	√	—	√	√
	26.8-10.10	9	—	—	105	6	√	√	√	√
South	1971 16.4-25.5	41	—	—	—	—	√	—	√	√
	7.8-14.9	8	—	—	102	13	√	√	√	√
West	1972 16.2-25.2	50	—	—	—	—	√	—	√	√
	17.4-28.4	54	—	—	—	—	√	—	√	√
	20.5-11.6	52	—	—	—	—	√	—	√	√
	4.9-12.10	7	—	—	377	65	√	√	√	√
East	1973 20.2-26.2	—	—	42	—	—	√	—	√	√
	19.4-24.4	—	—	49	—	—	√	—	√	√
	26.6- 1.7	—	—	53	—	—	√	—	√	√
	4.9-18.10	—	—	10	243	54	√	√	√	√
South	1974 5.2-13.2	—	—	40	—	—	√	—	√	√
	17.4-22.4	—	—	55	—	—	√	—	√	√
	13.6-20.6	—	—	57	—	—	√	—	√	√
	4.9-10.10	—	—	8	415	41	√	√	√	√
West	1975 6.2-15.2	—	88	—	—	—	√	—	√	√
	17.4-26.4	—	89	—	—	—	√	—	√	√
	5.6-12.6	—	89	—	—	—	√	—	√	√
	1.9- 8.10	8	—	—	436	74	√	√	√	√
East	1979 2.9- 7.10	—	—	—	317	64	—	√	√	√
West	1980 1.9-21.9	—	—	—	149	17	—	√	√	√
South	1981 2.9-21.9	—	—	—	235	29	—	√	√	√
East and South	1984 26.3- 4.4	—	37	—	—	—	√	—	√	√
	23.4- 3.5	—	89	—	—	—	√	—	√	√
	15.5-26.5	—	89	—	—	—	√	—	√	√
	17.6- 5.7	—	89	—	—	—	√	—	√	√

Numerals: number of valid stations
√: factor sampled
—: no sampling

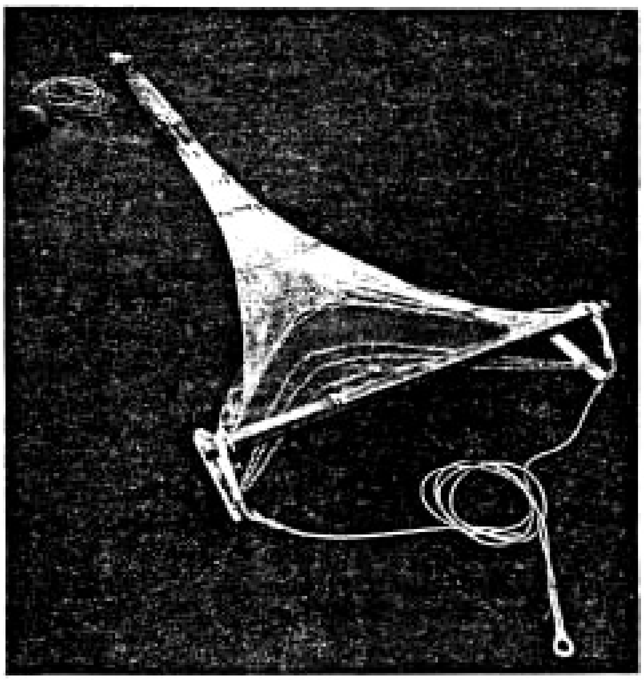

Figure 1 A standard Lowestoft 2m beam trawl.

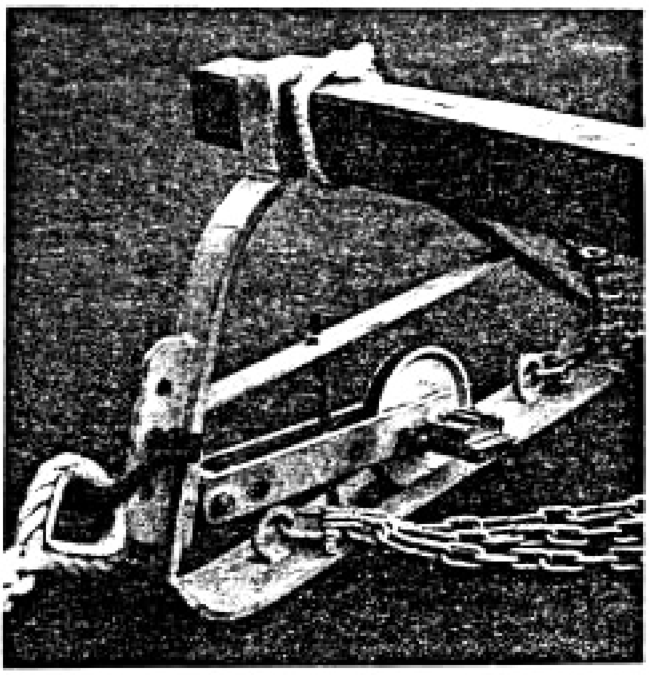

Figure 2 Detail of distance measuring wheel.

4. Sampling procedure

Most of the sampling for fish eggs and larvae occurred within 10 miles of the coast (Figure 3). However, more detailed grids of stations were worked in confined sea areas, such as the Irish Sea and Bristol Channel, and occasionally sampling was carried out between headlands and in transects from headlands into deeper water. Additionally, some hauls were made in river estuaries such as the Humber, Thames, Tamar and Mersey. In 1984, samples covered the eastern English Channel west to 0° meridian out to the median line and in the North Sea east to 2°E and north to 55°N and included some collected from research vessels from the Dutch and Belgian National Laboratories.

During sampling, the net was used to complete a series of oblique tows at standard speeds. On those boats without a log, this was achieved by trial and error by timing a float streamed out astern on 50 m of twine. Sampling time was usually not less than 20 min and in shallow water several dives would be possible whereas in deeper water only 1 dive would be completed in the allotted time. The flowmeter was read before and after each sample was taken.

Free-flow calibration tows (i.e. without a net in place) were made at least once every cruise on each vessel used and were repeated if the flowmeter was changed, so that estimates of filtration efficiency could be made during the actual sampling. The volume of sea water filtered at each station was usually between 50 and 100 m^3.

Using the free-flow (no net) calibrations, the number of flowmeter revolutions required to sample 100 m^3 of water (n) can be obtained from

$$n = \frac{r^1 - r^2}{d \cdot (a \cdot c)} \cdot 100$$

where r^1 = flowmeter reading at the start of the haul,
r^2 = flowmeter reading at the end of the haul,
d = distance travelled during the haul (m),
a = area of nosecone aperture (m^2),
c = water acceptance coefficient.

At each station when a sample was taken, the number of flowmeter revolutions is known so that, by simple proportion, the number of fish eggs and larvae in 100 m^3 water can be calculated.

The distribution of demersal fish, particularly young flatfish, is precisely zoned depending in part on water depth (Riley, Symonds and Woolner, 1981). Consequently, to cover the depths occupied by the common species, sampling was carried out down to 20 m and, in selected areas, to 40 m either by tows perpendicular or diagonal to the coast from shallow to deep water or by a series of tows parallel to the shore in different depths. Pushnetting from the shore covered the depth range 0–1 m.

Both beam trawl and pushnets were used where possible at a speed over the ground of 35 m/min but, due to different powered boats, variable tidal currents and weather conditions, beam trawl speeds between 20 and 75 m/min, as calculated from the distance meter readings, were accepted. A 10 min tow at these speeds gave, on average, a satisfactory sample of fish but, on the other hand, was small enough to be handled in a reasonable time.

On the larger research vessels (CORELLA (a former MAFF vessel, 459 t gross; LOA 41 m) and CLIONE (495 t gross; LOA 47 m)) continuous recordings were made of surface seawater environmental factors such as temperature and salinity. At most stations on other vessels, seawater samples were collected for subsequent salinity estimations and surface sea temperatures were recorded.

5. Treatment of samples

After collection, the plankton samples were preserved in 4% neutral formalin and later, in the laboratory, fish eggs and larvae were sorted and identified. All fish caught by the beam trawl and pushnets were separated from the remainder of the catch and small fish were preserved in 4% neutral formalin to be identified and measured in the laboratory. Larger fish, which could be positively identified, were measured and discarded at sea. Species identification and nomenclature (including the fish eggs and larvae) followed Wheeler (1969, 1978) and fish lengths were measured to the 0.5 cm below.

6. Treatment of data

During the initial six-year programme, fish eggs and larvae were sampled at all the stations given in Figure 1. However, not all stations were worked in each year that a particular coast was sampled. This was especially true during the 1970, 1971 and 1972 surveys when sampling was restricted by the size and capabilities of the vessels being used.

After 1983, plankton samples were allocated to sea areas of about 112 nautical miles square (15 nautical miles north-south and 7.5 nautical miles east-west) and were identified in documentation by the ICES six-digit alphanumeric sub-rectangle code (see Appendix 1).

The coastline covered by the young fish surveys was divided into regions based, where possible, on major geographical features which frequently separate areas of differing general environment but which are large enough to retain a variety of habitats. These are shown in Figure 4 and the 2742 valid beam trawl and pushnet hauls have been assigned to these regions.

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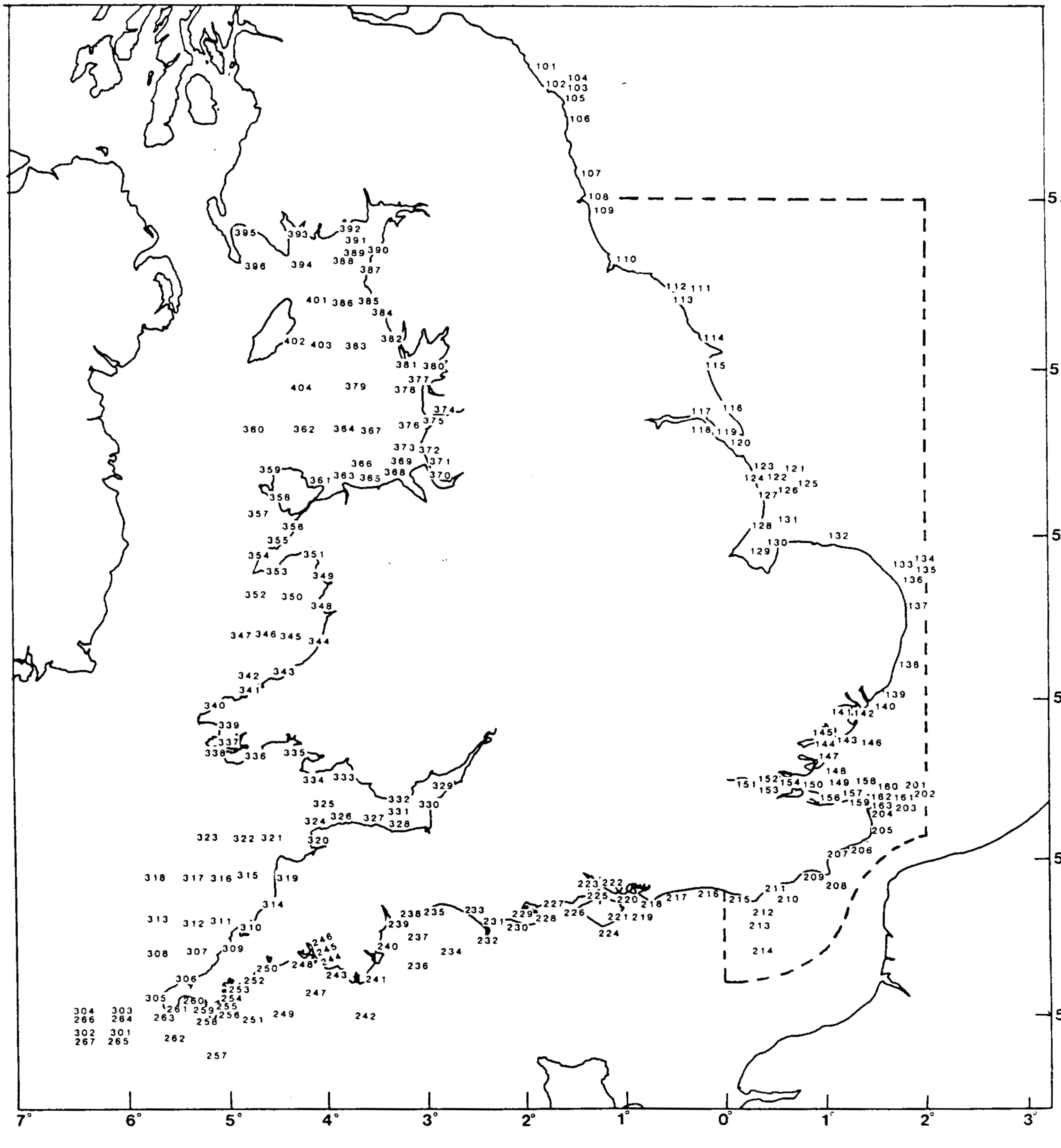

Figure 3 The location of plankton sampling stations and areas: — — — 1984 sampling area.

The actual depth of water was recorded at each station. However, as tidal range varies considerably throughout the sampling area (from 2 m off the East Anglian coast to over 10 m in the Bristol Channel), the recorded water depth at a geographical position depends on the state of the tidal cycle. An attempt has been made to reduce the tidal effect and to make the depth measurements comparable by relating the observed depth to the previous low water at the sampling position. When fishing is carried out in shallow water at high tide, the calculation of the relative depth can result in it being negative. An example of the relative depth calculations is given in Appendix 2. Using the corrected depths the stations were then grouped into five zones corresponding to the depth contours at 1, 3, 6 and 10 fathoms (2, 6, 12 and 20 m respectively), on charts current at the time and published by the Admiralty, Taunton.

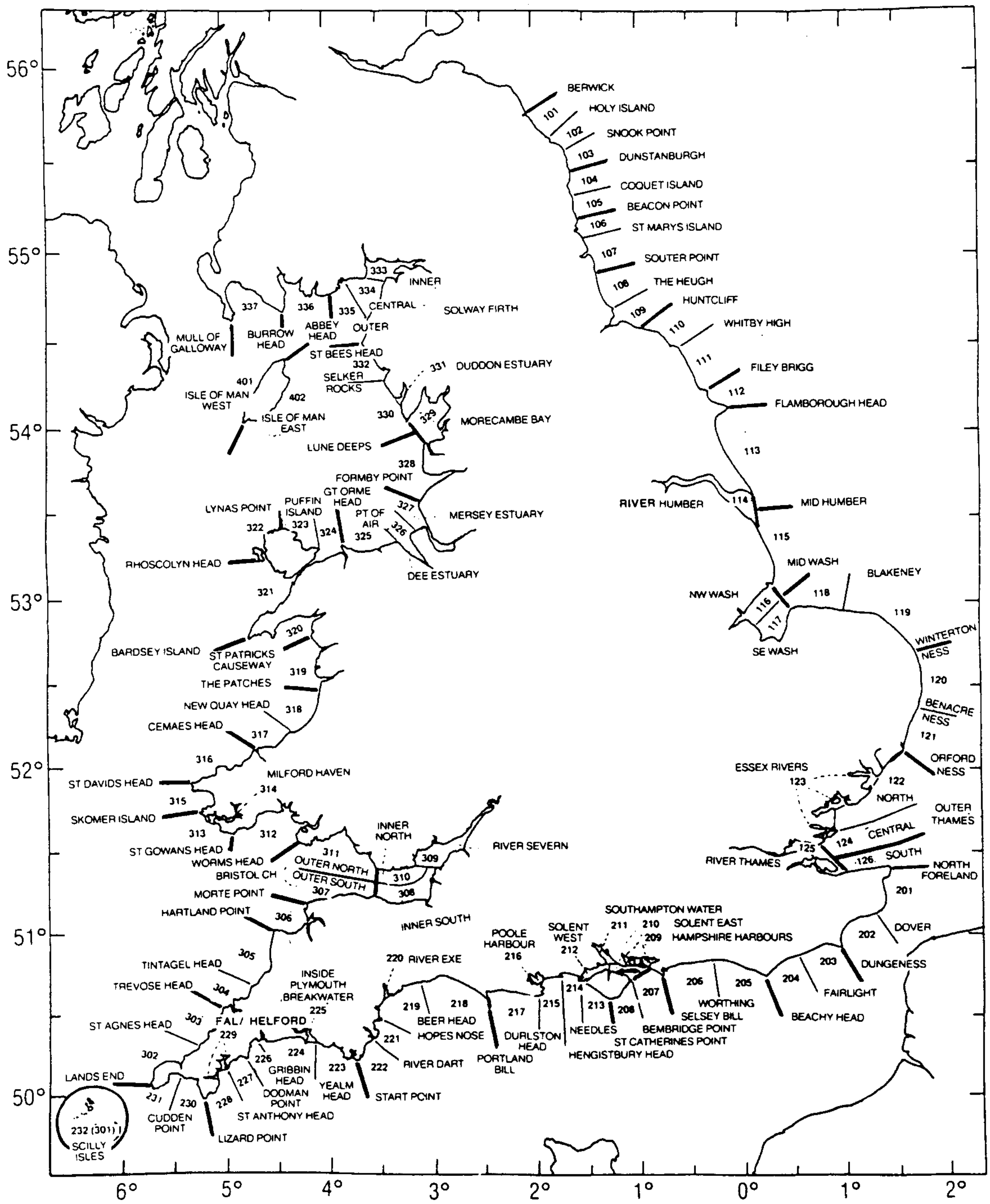

Figure 4 Division of the coastline into young fish survey regions: bold line indicates grouped regions (see Figure 6)

All fish were aged, as far as possible, by inspection of the length compositions. In some species the age/length relationship is well known and 0- group fish (those in the calendar year in which they were spawned) and, in a few cases, 1- group could easily be separated from older age-groups, called 2+ group. In those species when 1- group fish could not be distinguished from the older fish, they were called 1+ group and when no separation by age could be made, all fish were designated 0+ group.

Knowing the distance travelled by the sampling gear and its width, the area of the sea bed swept was obtained and the catch rates, (numbers/1000 m^2), for the different age-groups of each species were calculated. No correction of catch rate for the efficiency of the sampling gear hass been made; the efficiency of the 2 m beam trawl on 0- group plaice (*Pleuronectes platessa*) has been estimated at 35% (Edwards and Steele, 1968) and the value for most small flatfish will be of the same order but the efficiency on 0- group pelagic and semi-pelagic fish and all older fish will probably be considerably lower.

7. Analysis, filing and availability of catch data

A species list of fish caught, together with the life cycle stage, is given in Table 2. Positive identification was made of 29 species of eggs, 63 species of larvae and young demersal stage fish of 97 species.

Initial tabulations, preserving all the details, proved to be unweildy both for use and publication, so the data are stored on our ICL 2966 computer as a series of sequentially ordered files. Within each coast's file, data are held in station (region code) order for the survey.

Table 2 List of species (nomenclature — Wheeler, 1978) and the stage of their life history when sampled. (Eggs and larvae: √ definite identification, — not positively identified. Young fish: see text for explanation of symbols)

Family	Species	Stage sampled		
		Eggs	Larvae	Young fish
Scyliorhinidae	*Scyliorhinus stellaris*	—	—	1+
	S. canicula	—	—	1+
Triakidae	*Mustelus mustelus*	—	—	1+
	M. asterias	—	—	1+
Rajidae	*Raja batis*	—	—	0+
	R. undulata	—	—	0+
	R. naevis	—	—	0+
	R. montagui	—	—	0+
	R. clavata	—	—	0+
	R. microocellata	—	—	0+
	R. brachyura	—	—	0+
Engraulidae	*Engraulus encrasicolus*	√	√	0
Clupeidae		—	√	—
	Sardina pilchardus	√	√	0, 1+
	Sprattus sprattus	√	√	0, 1+
	Clupea harengus	—	√	0, 1+
Argentinidae	*Argentina sphyraena*	√	√	—
Osmeridae	*Osmerus eperlanus*	—	—	0, 1+
Anguillidae	*Anguilla anguilla*	—	√	1+
Belonidae	*Belone belone*	√	√	—
Syngnathidae		—	√	—
	Syngnathus typhle	—	—	0, 1+
	S. acus	—	—	0, 1+
	S. rostellatus	—	√	0+
	Entelurus aequoreus	—	√	0, 1+
	Nerophis lumbriciformis	—	—	0, 1+
	N. ophidion	—	√	0+
Gadidae		√	—	—
	Merlangius merlangus	—	√	0, 1+
	Trisopterus luscus	—	√	0, 1+
	T. minutus	—	√	0, 1+
	Pollachius pollachius	√	√	0
	P. virens	—	—	0, 1+
	Gadus morhua	√	√	0, 1+
	Melanogrammus aeglefinus	—	—	0, 1+
	Molva molva	√	√	1+
	Raniceps raninus	—	√	—
	"Rocklings"	√	√	—
	Gaidropsarus mediterraneus	—	—	0
	Enchelyopus cimbrius	—	√	—
	Ciliata mustela	—	—	0, 1+
Merlucciidae	*Merluccius merluccius*	—	√	1+

Table 2 (Continued)

Family	Species	Stage sampled		
		Eggs	Larvae	Young fish
Zeidae	*Zeus faber*	—	—	0, 1+
Caproidae	*Capros aper*	—	√	—
Percichthyidae	*Dicentrarchus labrax*	√	√	0, 1+
Carangidae	*Trachurus trachurus*	√	—	0
Mullidae	*Mullus surmuletus*	√	—	0, 1+
Sparidae	*Spondyliosoma cantharus*	—	√	0
Labridae		√	√	—
	Crenilabrus melops	—	—	0, 1+
	Ctenolabrus rupestris	—	√	0, 1+
	Labrus mixtus	—	—	0, 1+
	L. bergylta	—	√	0, 1+
	Centrolabrus exoletus	—	—	0
Ammodytidae		√	√	—
	Gymnammodytes semisquamatus	—	√	0, 1+
	Ammodytes tobianus	—	√	0, 1+
	A. marinus	—	√	0, 1+
	Hyperoplus lanceolatus	—	√	0, 1+
	H. immaculatus	—	—	0+
Trachinidae	*Echiichthys vipera*	√	√	0, 1+
Scombridae	*Scomber scombrus*	√	√	—
Gobiidae		—	√	0+
	Lebetus scorpiodes	—	√	—
	Crystallogobius linearis	—	√	0
	Aphia minuta	—	—	0
	Gobiusculus flavescens	—	—	0
	Pomatoschistus pictus	—	—	0+
	P. microps	—	√	0+
	P. minutus complex (Webb, 1980)	—	√	0+
	Gobius niger	—	—	0+
	G. paganellus	—	—	0+
Callionymiidae		√	√	—
	Callionymus reticulatus	√	—	0, 1+
	C. lyra	√	√	0, 1+
Blenniidae		—	√	—
	Lipophrys pholis	—	√	1+
	Parablennius gattorugine	—	√	0
Pholididae	*Pholis gunnellus*	—	√	0, 1+
Stichaeidae	*Chirolophis ascanii*	—	√	—
Zoarcidae	*Zoarces viviparus*	—	—	0+
Mugilidae	*Chelon labrosus*	—	—	0
Atherinidae	*Atherina presbyter*	—	—	0, 1+
Triglidae		√	√	—
	Eutrigla gurnardus	√	√	0, 1+
	Aspitrigla cuculus	—	—	1+
	Trigla lyra	—	—	1+
	T. lucerna	—	—	0, 1+
Cottidae		—	√	—
	Myoxocephalus scorpius	—	√	0, 1+
	Taurulus bubalis	—	√	0, 1+
	T. lilljeborgi	—	—	0

Table 2 (Continued)

Family	Species	Stage sampled		
		Eggs	Larvae	Young fish
Agonidae	*Agonus cataphractus*	—	√	0, 1+
Cyclopteridae		—	√	—
	Cyclopterus lumpus	—	—	0
	Liparis liparis	—	√	0+
	L. montagui	—	√	0+
Gasterosteidae	*Gasterosteus aculeatus*	—	—	0
	Spinachia spinachia	—	—	0
Scophthalmidae		√	√	—
	Scophthalmus maximus	√	√	0, 1, 2+
	S. rhombus	√	√	0, 1, 2+
	Zeugopterus punctatus	√	√	0, 1+
	Phrynorhombus regius	—	√	0, 1+
	P. norvegicus	√	√	1+
Bothidae		—	√	—
	Arnoglossus laterna	√	√	0, 1+
Pleuronectidae		√	√	—
	Limanda limanda	√	√	0, 1+
	Plactichthys flesus	√	√	0, 1, 2+
	Pleuronectes platessa	√	√	0, 1, 2+
	Microstomus kitt	√	√	0, 1+
	Glyptocephalus cynoglossus	—	√	—
	Hippoglossoides platessoides	—	√	—
Soleidae	*Pegusa lascaris*	√	√	0, 1+
	Solea solea	√	√	0, 1, 2+
	Buglossidium luteum	√	√	0, 1+
	Microchirus variegatus	√	√	0, 1+
Gobiesocidae		—	√	—
	Apletodon microcephalus	—	√	0
	Diplecogaster bimaculata	—	—	0
	Lepadogaster lepadogaster	—	√	0
Lophiidae	*Lophius piscatorius*	—	—	1+
Unidentified		—	—	—

Each station's data consist of two parts:

(i) a 17-digit code representing 10 station parameters. These are location (coast, region and latitude), date (month, year), salinity, depth, gear, and number of observations recorded at the station;

(ii) species abundances expressed as numbers/100 m^2 for eggs and larvae and numbers/1000 m^2 for demersal stages. Each species is identified by a 3-figure numeric code (based on Wheeler, 1969) and a single figure staging code indicating eggs, larvae or demersal stage age-groups.

It is the Ministry's intention to allow outside users access to the data and analytical facilities at cost. A proforma is available (see Figure 5 for facsimile) on which such requests can be made; Appendix 3 gives the instructions for its completion. The data can be accessed and analysed by coast and year or, if required, by groups of sequentially ordered regions or stations by time and, in the case of eggs and larvae, by months of the year.

Analyses available at present are listed in the proforma; some of these have already been reported (Riley *et al.*, 1981). Firstly, cluster analysis was used to describe species association of the demersal stages within individual and combined coastal regions; it can also be used to show species associations in eggs and larvae. This analysis is based on the determination of similarity coefficients (Sokal and Sneath, 1963) between species, firstly relating pairs of species most closely associated, then groups of species, gradually

ANALYSIS PROFORMA

ANALYSIS

A Cluster analysis	_______	Indicate with
B Distribution by Salinity/Depth/Latitude	_______	a tick which
C Basic catch data extractions	_______	analyses required
D Determination of abundance indices (demersal stages)	_______	

DATA SELECTION

1 Coast/Year

Coast: All ☐ East ☐ South ☐ West ☐

Range of years: From ☐☐ To ☐☐

2 Area

i) Demersal stages

Number ☐

Region range: From / To

ii) Eggs/Larvae

Number ☐

Position/Latitude range: From / To

3 Months

Number ☐

Months

4 Species Name

Number ☐

Stage Code

Figure 5 Proforma used for accessing survey data.

increasing the size of the cluster by lowering the admission criterion until all the species are included. Dendrograms can be constructed to give diagrammatic representation of the analysis for each of the three stages — eggs, larvae and fish.

A second application was the determination of distributions by salinity, depth and latitude of selected species. Apart from latitude (which was in single degree groupings), the physical parameter scales were divided into varying intervals. Depth was stratified in 2 m bands up to 12 m, 4 m bands from 12-20 m and finally a 20-40 m banding. The salinity groupings were 10-20, 20-25, 25-30, 30-32 ‰ and then single unit intervals. As well as determining arithmetic mean and standard error values for each interval, data were also log transformed (1 being added to each value to allow for zero values) and the corresponding parameter values for the log normal distribution (Aitchison and Brown, 1957) derived:

Table 3 Sole: the distribution of eggs in April, 1970–75 by salinity, depth and latitude

Salinity (‰)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
10–20	0.00		0.00		1
20–25	18.25	16.0	18.35	2.4	4
25–30	71.56	35.7	92.70	1.7	16
30–32	65.72	46.4	23.40	1.4	40
32	7.17	2.9	3.99	1.2	48
33	42.41	21.8	25.85	1.4	37
34	33.28	7.1	32.94	1.2	132
35	10.79	2.9	11.10	1.3	38

Depth (m)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
0– 2	1.50	1.5	1.54	2.0	2
2– 4	0.00	0.0	0.00	0.0	2
4– 6	156.00		156.00		1
6– 8	40.83	12.6	73.65	1.6	18
8–10	82.05	31.5	125.90	1.6	21
10–12	115.83	65.5	124.80	1.5	29
12–16	27.70	8.7	24.66	1.3	61
16–20	28.57	15.3	16.87	1.3	49
20–40	11.68	5.7	4.72	1.2	77

Latitude (°N)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
49	5.57	3.0	5.67	1.6	7
50	49.63	11.4	55.99	1.2	103
51	58.89	26.0	44.46	1.3	75
52	10.50	3.6	9.33	1.3	38
53	12.41	4.4	8.83	1.3	46
54	0.71	0.5	0.46	1.1	35
55	0.00	0.0	0.00	0.0	12

i.e. $y = \log_e(1 + \text{nos}/1000\ \text{m}^2)$.

$$\text{Mean nos}/1000\ \text{m}^2 = \exp(\bar{y}) . \exp\left(\frac{n-1}{n} \cdot \frac{s_y^2}{2}\right) - 1$$

where $\bar{y}$ = mean, s_y^2 = variance } of $\log_e$ values

$\exp(\bar{y})$ = geometric mean,

n = sample size.

Approximate 95% confidence limits for the mean nos/1000 m^2 (Jones, 1954) can then be obtained by multiplying it by

$$\exp\left(\pm t . \frac{s_y}{\sqrt{n}}\right)$$

where t = Student's t distribution,

p = .05 probability level for (n−1) degrees of freedom,

$\frac{s_y}{\sqrt{n}}$ = geometric standard error.

Table 4 Sole: the distribution of larvae in April, 1970–75 by salinity, depth and latitude

Salinity (‰)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Sample size
10–20	0.00		0.00		1
20–25	0.00	0.0	0.00	0.0	4
25–30	0.00	0.0	0.00	0.0	16
30–32	0.42	0.4	0.19	1.1	40
32	0.38	0.3	0.19	1.1	48
33	1.70	0.8	1.09	1.2	37
34	2.39	0.8	1.11	1.1	132
35	1.92	0.6	1.67	1.2	38

Depth (m)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Sample size
0– 2	0.00	0.0	0.00	0.0	2
2– 4	0.00	0.0	0.00	0.0	2
4– 6	0.00		0.00		1
6– 8	0.00	0.0	0.00	0.0	18
8–10	0.00	0.0	0.00	0.0	21
10–12	0.00	0.0	0.00	0.0	29
12–16	0.52	0.4	0.25	1.1	61
16–20	0.55	0.4	0.31	1.1	49
20–40	0.84	0.3	0.56	1.1	77

Latitude	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Sample size
49	5.29	2.0	5.98	1.5	7
50	3.54	1.1	2.17	1.1	103
51	0.48	0.3	0.26	1.1	75
52	0.39	0.4	0.19	1.1	38
53	0.37	0.4	0.16	1.1	46
54	0.49	0.5	0.22	1.1	35
55	0.00	0.0	0.00	0.0	12

In order to show the comprehensive picture for a particular species, given by extractions from this data set, the sole (*Solea solea*) has been chosen as an example as it spawns on all three coasts and the distribution of the early demersal stages is concentrated in shallow water. It is also, of course, a valuable commercial species. The distributions of eggs and larvae in April and the 0, 1 and 2+ groups in September by salinity, depth and latitude are given in Tables 3-7 while the catches of the young demersal stages at various water depths are illustrated in Figure 6.

The basic catch data of eggs and larvae can be used to describe the location and timing of spawning. As an example, Figure 7 shows the distribution of eggs and larvae of sole during the April and June surveys in the period 1973-75; in each of the years, few eggs and no larvae were found in February.

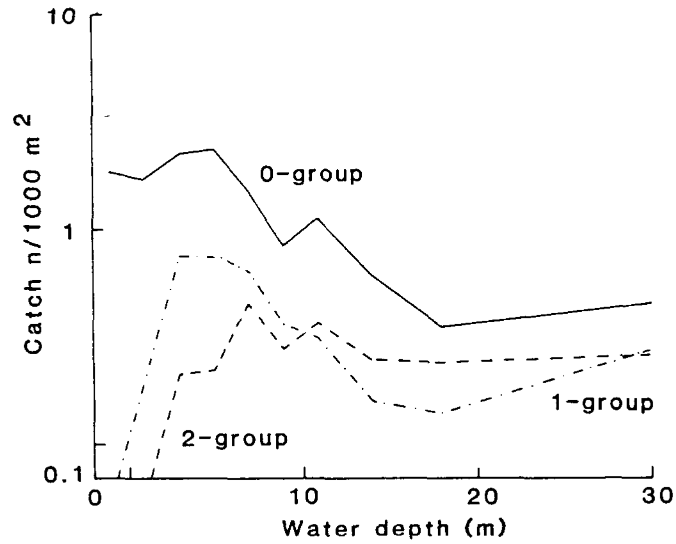

Figure 6 Sole: Catch of young demersal stages at various water depths.

Table 5 Sole: the distribution of 0-groups in September–October, 1970–75 by salinity, depth and latitude

Salinity (‰)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
10–20	3.63	1.9	2.79	1.3	19
20–25	11.46	4.5	9.27	1.4	24
25–30	12.24	6.7	5.41	1.2	59
30–32	3.93	1.5	2.50	1.1	73
32	7.40	2.7	4.01	1.1	154
33	2.05	0.5	1.18	1.1	274
34	1.57	0.2	1.02	1.0	558
35	0.31	0.2	0.14	1.0	185
Depth (m)	**Mean**	**Std error**	**Average**	**Std error**	**Number of samples**
<0	3.54	1.1	1.84	1.1	147
0– 2	3.69	1.1	1.67	1.1	385
2– 4	3.35	0.6	2.22	1.1	276
4– 6	4.68	1.4	2.31	1.1	305
6– 8	2.72	0.6	1.50	1.1	234
8–10	1.24	0.3	0.84	1.1	177
10–12	1.93	0.6	1.12	1.1	113
12–16	1.04	0.3	0.62	1.1	161
16–20	0.55	0.3	0.35	1.1	92
20–40	0.70	0.4	0.45	1.1	40
Latitude (°N)	**Mean**	**Std error**	**Average**	**Std error**	**Number of samples**
49	0.00	0.0	0.00	0.0	50
50	2.55	0.6	1.22	1.0	659
51	4.43	0.6	3.01	1.1	378
52	1.61	0.5	0.82	1.1	236
53	5.48	1.8	2.66	1.1	246
54	1.91	0.4	1.16	1.1	281
55	0.00	0.0	0.00	0.0	80

Finally, population indices of the demersal stages in each of the four depth bands down to 20 m can be determined from the catch per unit area values. The mean number /1000 m^2 per stratum was raised by its corresponding planimetered area (Table 8) to give a population index for the stratum, with the index for the grouped regions being determined by summing the individual stratum estimates. These can be used to demonstrate the geographical distribution and importance of coastal nursery grounds; an example using 0-group sole over the period 1973-75 is shown in Figure 8.

These analyses can readily be provided for all species caught on the surveys. It is hoped that, as more results become available from similar inshore surveys, they can be incorporated into the same data files.

Table 6 Sole: the distribution of 1-groups in September–October, 1970–75 by salinity, depth and latitude

Salinity (‰)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
10–20	0.05	0.1	0.05	1.0	19
20–25	0.83	0.4	0.68	1.1	24
25–30	1.22	0.5	0.87	1.1	59
30–32	2.63	1.0	1.46	1.1	73
32	0.58	0.3	0.36	1.0	154
33	0.70	0.2	0.44	1.0	274
34	0.63	0.1	0.42	1.0	558
35	0.24	0.2	0.10	1.0	185

Depth (m)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
<0	0.05	0.0	0.05	1.0	47
0– 2	0.32	0.1	0.22	1.0	385
2– 4	1.16	0.2	0.75	1.0	276
4– 6	1.24	0.3	0.75	1.0	305
6– 8	0.88	0.2	0.63	1.0	234
8–10	0.53	0.2	0.36	1.0	177
10–12	0.56	0.3	0.31	1.0	113
12–16	0.20	0.1	0.16	1.0	161
16–20	0.18	0.1	0.14	1.0	92
20–40	0.38	0.2	0.27	1.1	40

Latitude (°N)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
49	0.00	0.0	0.00	0.0	50
50	0.73	0.1	0.47	1.0	659
51	1.20	0.2	0.82	1.0	378
52	0.71	0.2	0.39	1.0	236
53	0.30	0.1	0.25	1.0	246
54	0.27	0.1	0.15	1.0	281
55	0.01	0.0	0.01	1.0	80

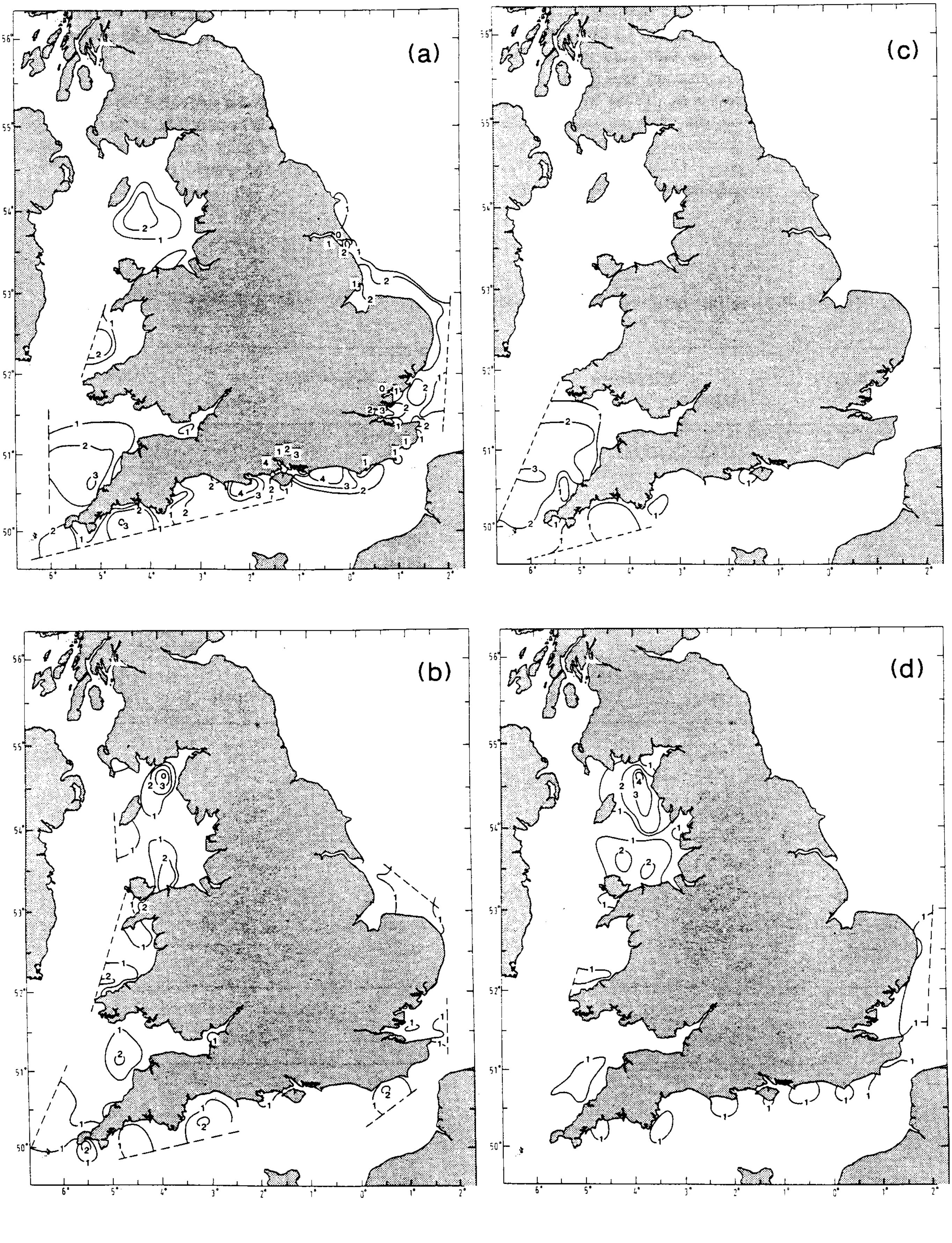

Figure 7 Sole: distribution of eggs and larvae in April and June 1983-85:
(a) eggs–April; (b) eggs–June;
(c) larvae–April; (d) larvae–June.

Table 7 Sole: the distribution of 2+ groups in September–October, 1970–75 by salinity, depth and latitude

Salinity (‰)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
10–20	0.00	0.0	0.00	0.0	19
20–25	0.21	0.2	0.15	1.1	24
25–30	0.02	0.0	0.02	1.0	59
30–32	0.21	0.1	0.17	1.0	73
32	0.44	0.2	0.30	1.0	154
33	0.15	0.0	0.12	1.0	274
34	0.38	0.1	0.30	1.0	558
35	0.28	0.2	0.13	1.0	185

Depth (m)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
<0	0.01	0.0	0.01	1.0	147
0– 2	0.07	0.0	0.06	1.0	385
2– 4	0.26	0.1	0.21	1.0	276
4– 6	0.28	0.1	0.22	1.0	305
6– 8	0.68	0.2	0.45	1.0	234
8–10	0.36	0.1	0.28	1.0	177
10–12	0.52	0.2	0.37	1.0	113
12–16	0.29	0.1	0.25	1.0	161
16–20	0.29	0.1	0.24	1.0	92
20–40	0.30	0.1	0.26	1.1	40

Latitude (°N)	Arithmetic Mean	Arithmetic Std error	Logarithmic Average	Logarithmic Std error	Number of samples
49	0.00	0.0	0.00	0.0	50
50	0.37	0.1	0.27	1.0	659
51	0.57	0.1	0.43	1.0	378
52	0.04	0.0	0.04	1.0	236
53	0.14	0.0	0.12	1.0	246
54	0.14	0.0	0.11	1.0	281
55	0.07	0.1	0.06	1.0	80

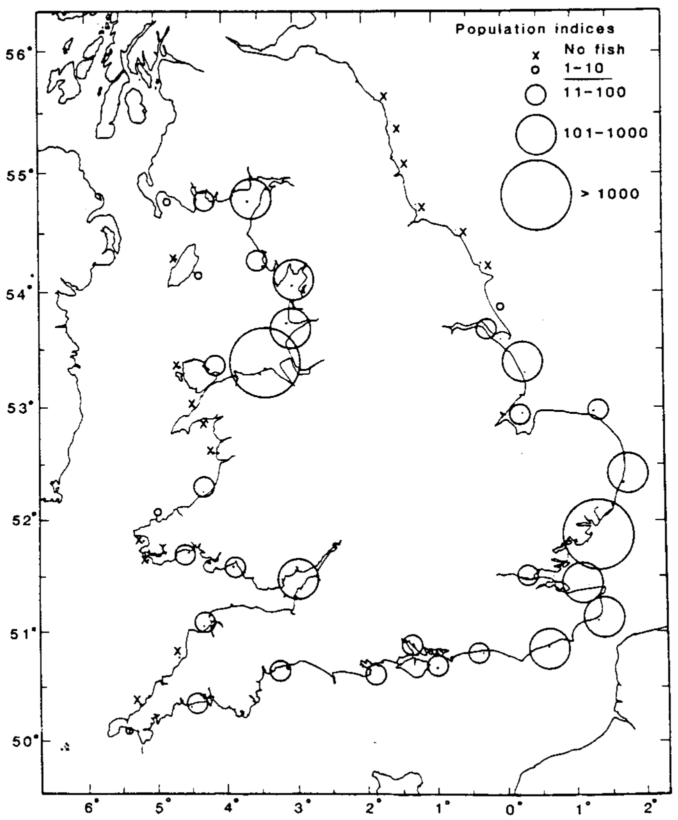

Figure 8 Population indices of 0- group sole, for groups of survey regions (see Figure 2).

Table 8 Areas (in millions m^2) of each depth zone in individual or grouped regions

Regional code	Region	Depth zones (m)				
		0-2	2-6	6-12	12-20	0-20
101-3	Berwick-Dunstanburgh	13	12	29	66	120
104-5	Dunstanburgh-Beacon Point	9	5	24	25	63
106-7	Beacon Point-Souter Point	2	8	16	20	46
108-9	Souter Point-Huntcliff	8	20	45	73	146
110-1	Huntcliff-Filey Brigg	8	17	22	46	93
112	Filey Brigg-Flamborough Head	1	4	11	12	28
113	Flamborough Head-mid Humber	11	37	201	487	736
114	River Humber	36	77	57	36	206
115	Mid Humber-mid Wash	7	61	392	587	1047
116-7	Wash	75	75	84	53	287
118-9	Mid Wash-Winterton	38	289	388	641	1356
120-1	Winterton-Orford	20	52	140	186	398
122-4	Thames Estuary North	148	240	408	481	1277
125	River Thames	29	34	47	24	134
126	Thames Estuary South	108	265	193	313	879
201-2	North Foreland-Dungeness	33	82	115	141	371
203-4	Dungeness-Beachy Head	50	103	414	459	1026
205-6	Beachy Head-Selsey Bill	27	86	212	285	610
207-8	Selsey Bill-St Catherine's Point	17	20	66	315	418
209-12	Solent area	39	80	57	50	226
213-7	St Catherine's Point-Portland Bill	29	45	98	682	854
218-22	Portland Bill-Start Point	19	38	76	219	352
223-9	Start Point-Lizard Point	24	37	79	124	264
230-1	Lizard Point-Lands End	15	4	15	43	77
232(301)	Isles of Scilly	9	10	9	22	50
302-3	Lands End-Trevose Head	6	16	24	57	103
304-5	Trevose Head-Hartland Point	6	7	21	61	95
306	Hartland Point-Morte Point	10	11	31	81	133
307	Outer Bristol Channel South	1	8	17	67	93
308-10	Inner Bristol Channel	43	87	231	279	640
311	Outer Bristol Channel North	18	54	103	202	377
312	Worms Head-St Gowans Head	44	80	94	128	346
313-4	St Gowans Head-Skomer Isle	6	10	19	36	71
315	Skomer Isle-St Davids Head	4	7	17	48	76
316	St Davids Head-Cemaes Head	10	6	10	34	60
317-8	Cemaes Head-The Patches	7	21	47	213	288
319	The Patches-St Patrick's Causeway	10	34	216	358	618
320	St Patrick's Causeway-Bardsey Isle	16	57	131	209	413
321	Bardsey Isle-Rhoscolyn Head	19	30	67	161	277
322	Rhoscolyn Head-Point Lynas	6	4	11	27	48
323-4	Point Lynas-Great Orme Head	14	30	65	57	166
325-7	Great Orme Head-Formby Point	75	192	247	329	843
328	Formby Point-Lune Deeps	43	119	260	341	763
329	Morecambe Bay	50	36	20	11	117
330-2	Lune Deeps-St Bees Head	25	79	109	399	612
333-5	Solway Firth	105	152	168	234	659
336	Abbey Head-Burrow Head	16	22	39	88	165
337	Burrow Head-Mull of Galloway	8	25	77	242	352
401	Isle of Man West	9	9	60	77	155
402	Isle of Man East	12	12	58	89	171
	TOTAL	1338	1809	5340	9218	18705

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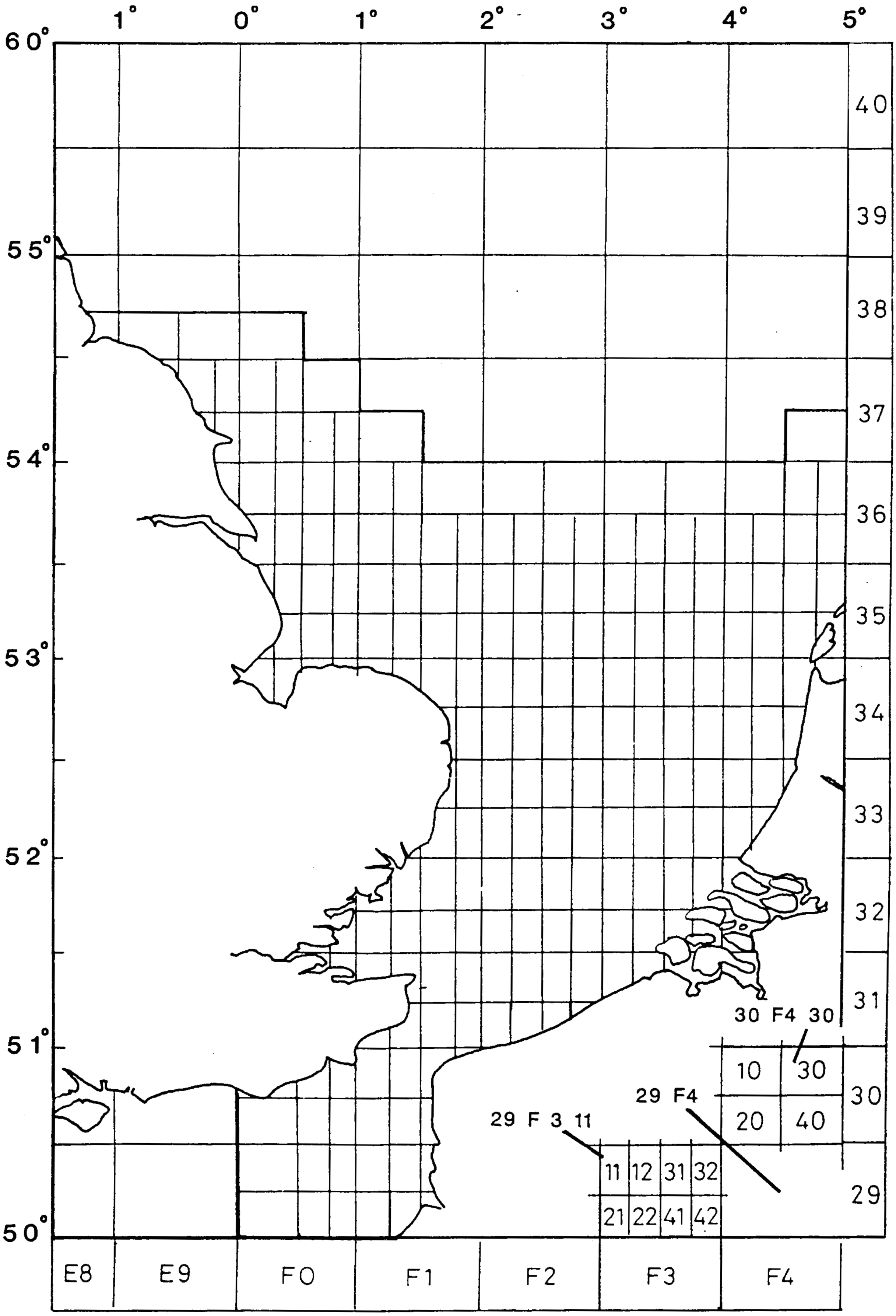
Appendix 1. Chart showing the derivation of the ICES six-digit, alphanumeric sub-rectangle code: see bottom right-hand corner for examples of code.



Appendix 2. Calculation of relative depth

A record was kept at each station of the sampling position, date, time of sampling and the water depth. Thus, for station Q141, the details in the logbook include:

Position	: Saundersfoot Bay
Date	: 8.10.75
Time	: 1106–1116 GMT
Depth	: 12m

From the Admiralty Tide Tables for 1975 (Hydrographer of the Navy, 1974) the following information applicable to the above station is available:

Standard port	: Milford Haven
Secondary port (sampling station)	: Tenby
Time of previous low water standard port	: 0315 GMT
Low water correction for station position	: −15 min
∴ Time of previous low water, sampling station	: 0300 GMT
High water height, standard port	: 6.4m
Low water height, standard port	: 1.4m
Height corrections for station position, high water	: +0.4m
Height corrections for station position, low water	: +0.2m
∴ Tidal range at station	: 6.2m

Using the time interval between the previous low water and time of sampling, a factor can be interpolated from the mean tidal curve for Milford Haven given in the Tide Tables and this factor, when multiplied by the tidal range, gives the height of the tide above low water. The sampling depth relative to low water is obtained by subtracting this figure from the actual depth recorded.

Thus:

Time interval between low water and sampling	: 11.11-3.00 = 8.11 h
∴ Tidal factor	: 0.69
∴ Height of tide above low water	: 4.3 m
∴ Relative depth	: 12.0-4.3 = 7.7m.

Reference

Hydrographer of the Navy, 1974. Admiralty Tide Tables 1975. HMSO, London, 406pp.

Appendix 3. Notes on filling in the Analysis Proforma

1. **Coast/Year**

COAST not required = 0
required = 1. If ALL coasts required, fill in first box and leave remaining three in column blank.

YEARS = Last two digits (e.g. 77)
= 00 if all years required. Both boxes must be filled in for single/all years.

A separate form is required for **each** coast where analysis is to be by individual coasts. Otherwise, the assumption will be that the specified coasts are to be analysed collectively.

2. **Area**

NUMBER = 0. Level of selection not required (i.e. analysis restricted to coast(s)), otherwise
= number of areas to be identified.

For demersal stages, areas are defined by the region numbers at the extremities of the area (the full list of regions is given in Figure 4). Note that abundance indices are based on grouped regions (see also Table 8). Eggs/larvae areas are defined by position ranges in 1970-75 and latitude ranges in 1984.

3. **Months**

NUMBER = 0. Demersal stages (September only) or, for eggs and larvae, level of selection not required, otherwise
= number of months within year to be accessed.

Identify month by its first three letters (e.g. JAN). Months for which data are available in 1970-75 (though not necessarily all years) are nominally February, April, June, September and in 1984, March, April, May and June. Analyses will be carried out by individual months.

4. **Species**

This section is to be completed **only** for analyses B–D. NUMBER = number of species in species list.

Give only species name and stage code (see Table 2). Species code will be entered at Lowestoft.

Stage codes are 0 Demersal stage, age group 0
1 Demersal stage, age group 1
2 Demersal stage, age group 2+
4 Demersal stage, age group 0+
5 Demersal stage, age group 1+
6 Eggs
7 Larvae

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