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DESCRIPTION AND EVALUATION OF THE INTERNATIONAL BEAM TRAWL SURVEYS OF THE EUROPEAN CONTINENTAL SHELF

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ABSTRACT
Samples of the demersal fish fauna have been collected during beam trawl surveys in the coastal waters of North-west Europe (49° - 57° N, 8°W - 9°E) by the UK, The Netherlands, Germany and Belgium, since the mid 1980s. The purpose of the surveys is to collect year class strength information for commercially important demersal species, especially sole and plaice, for use in assessment. Catch densities for all other non-target fish, most by length group, are also collected. The by-catch of invertebrate macrofauna is recorded. This paper provides a technical description of the survey methods, a summary of the data that are routinely produced, and an analysis of the quality of the data. Opportunities for making better use of the surveys, for improving the quality of the data collected, and for developing the scope of the surveys, are discussed.

1. INTRODUCTION

The development of the modern heavy beam trawl in the 1960s allowed increased exploitation of flatfish stocks (sole, *Solea solea* and plaice, *Pleuronectes platessa*), in the shallow and predominantly sandy coastal waters of the southern North Sea, and later into parts of the western waters of the UK (Millner & Whiting 1996). The need to monitor these demersal populations as part of the annual assessment of stock size led to the gradual introduction of fisheries independent surveys using beam trawls. By 1988 a number of countries which border the North Sea had developed beam trawl surveys which targeted different age ranges of flatfish and used beam trawls and vessels of different size and specification. Collation and analysis of some of the data derived from these surveys was initially focused on the North Sea and eastern English Channel. At the ICES Statutory meeting in 1990, it was resolved to broaden the remit of the Beam Trawl Study Group and to evaluate all surveys in subareas IV and VII

(ICES 1991). This paper describes the development of the surveys from this date and the progress made in achieving a combined abundance index from all surveys. It also discusses the range of uses of the data and future opportunities for improvement.

2. SURVEY DESIGN AND SAMPLING METHODOLOGY

During the 1980s, five countries which border the North Sea and western waters of the UK had developed a range of beam trawl surveys (Table 1; Figure 1). Some of these surveys were designed to sample pre-recruit (0- and 1-group) sole and plaice on nursery grounds with light gears, while others used beam trawls of commercial design to catch juveniles and adults. Six of these surveys were modified following recommendations of the Beam Trawl Study Group to develop a more standardised sampling protocol (Table 1) (ICES 1990; ICES 1991; ICES 1993; ICES 1994). Despite some differences in beam trawl design, the surveys currently operate during daylight hours only, tow at a constant speed of 4 knots and for a duration of 30 minutes. The cod-end of all gears is fitted with a fine mesh cod-end liner to retain small and juvenile fish (Table 2). The following section describes some recent modifications to the surveys and summarises the current sampling techniques used by each country.

2.1 Belgium

In 1992 Belgium replaced the 8m beam trawl with a 4 m beam trawl with flip-up ropes and chain mat because of problems encountered with the previous gear while fishing on hard substrates. The survey area covered was generally the western part of the southern North Sea, where up to 4 hauls were taken at fixed positions within each rectangle (Figure 2a). The position of these hauls was selected in order to spread the sampling effort throughout the rectangle.

All commercial fish species were first removed from the catch and measured to the nearest cm, using an electronic bar code measuring board. For particularly large catches a subsample was measured. Samples within each length group of sole, plaice and dab were retained so that a minimum of three otoliths per size class could be collected. All brill and turbot were otolithed, and their weight and sex was recorded. The catch of non-commercial species and benthos was normally subsampled, and raised to the total volume of by-catch taken. All finfish species were counted, and selected species were measured.

2.2 Germany

The survey in the German Bight conducted since 1976 was designed to sample the spring sole fishery of the area. Sampling was generally undertaken at night, and haul duration was variable and depended on the substrate. Since 1992 the survey has been undertaken during the third quarter using a pair of 7 m beam trawls towed for 30 minutes during daylight hours. No fixed sampling grid was used, but effort was concentrated in areas where abundance of flatfish was highest (Table 2; Figure 2b).

Sole, turbot and brill were sorted from the catch of both beam trawls, and all other fish were taken from the catch of one trawl and identified to species or species group.

Sole, plaice, dab and turbot were measured to the nearest cm below and otoliths taken. All other species were counted and selected species measured, but a subsample was taken if particularly large catches occurred. Invertebrate benthos from the catch of one trawl was identified to species, genus or family and weighed when occurring in large numbers, otherwise they were counted separately.

2.3 The Netherlands

This is the longest running survey to use a consistent gear and sampling technique. In the southern part of the survey at least three hauls were made in each rectangle, while in the north only one or two hauls were taken. These stations were allocated over the fishable area of the rectangle on a 'pseudo-random' basis to ensure that there was a reasonable spread within each rectangle. No attempt was made to return to the same tow positions each year (Table 2; Figure 2c).

The catch of one of the paired trawls (chosen at random at the start of each survey) was sampled for all large fish species from a conveyor belt. Catches of sole, turbot, brill and rays were also sampled from catch in the other trawl. Smaller fish species and epibenthos were sorted from a subsample taken from the catch at the beginning, middle and end of the sorting process. All fish were measured to the cm below and raised to the catch number per hour fishing. The benthic animals were counted.

2.4 UK

All surveys in divisions VIIa, VIId, VIIf, VIIg have used the 4m beam trawl with chain mat and flip-up ropes, and since 1992 a tow duration of 30 minutes (previously the duration was 15 minutes in VIIa). As the distribution of juvenile flatfish was related to depth, a depth stratified survey design was used in area VIIa, f &g, where considerable variation in depth occurred within the survey area. Stations were allocated to different depth zones depending on the abundance of fish within each zone (Figure 2d) (Symonds & Vince 1992).

After the catch of the trawl had been emptied, all fish and commercial crustacea (edible crabs, lobsters and Nephrops) were separated from the benthos. Fish were identified to species, weighed in bulk and individuals measured to the cm below. Plaice, sole, megrim and elasmobranchs were weighed and measured by sex; subsampling (by weight) was occasionally necessary when the catch of the species was large. Length stratified samples of major species including plaice, sole, lemon sole, megrim, turbot, brill, dab, whiting, cod and anglerfish were taken for age determination. Crustacean species were weighed by sex and the carapace lengths recorded to the mm below. Since 1993, the benthos taken in VIId has been removed at selected stations and sorted to species where possible. Bulk weights of each species were recorded. In VIIa, f & g, the numbers of benthic species or groups was assessed visually after fish had been removed, and recorded using a logarithmic scale of abundance (0, 0-10, 11-100, 101-1000, 1001-10000, 10000+).

The UK survey in VIIe is similar to those in other parts of area VII, but has been undertaken by a chartered commercial beam trawler MFV Carhelmar (Table 2, Figure

2d). Two 4m beam trawls were used. The catch from each trawl was sorted separately on a conveyor belt, where all commercially important species were removed from both nets at every haul. At selected hauls, non-commercial species were picked out and measured or counted. Length stratified samples of otoliths were taken from sole, plaice, lemon sole, and anglerfish. Since 1991 otolith samples have been further stratified on the basis of distance from the coast. Edible crab, lobster and scallops were measured from all hauls.

3. RAISING AND COMBINING THE DATA

Fish catches at each station were raised to numbers caught per hour; to allow comparison between different gears, these abundances have been standardised to an 8 m beam trawl width. The mean catch of each species per unit area was calculated as the unweighted average of all stations in each rectangle, so where surveys of several countries overlapped a mean catch rate was calculated for all surveys, with no correction for gear efficiency (ICES 1993).

$$C_a = \sum R_i \,/\, {}_nA$$

C_a is the catch per hour in an area,
R_i is the mean catch in the ith rectangle,
${}_nA$ is the number of rectangles in the area.

Catch numbers by 5 cm length group were also available for most species, and these were also raised to the 8 m beam trawl per hour.

4. DATA USES AND QUALITY

4.1 Recruit series

The primary purpose of the beam trawl surveys is to provide indices of recruitment for sole and plaice stocks for use in assessment (ICES 1997). As the distribution of fishing station positions is generally towards the shallow coastal areas, where juvenile fish are most abundant, and as all trawls use a fine meshed cod-end liner to retain juvenile flatfish, the age composition is generally skewed towards younger ages (Figure 3) (ICES 1996).

The performance of the various recruitment series produced for the different stocks, using the diagnostic output from the VPA programme 'XSA', was recently analysed (ICES 1996). The results are reproduced in Table 3. For each stock, standard errors were derived either from the regression of abundance against CPUE (Reg se in Table 3) or from the variation around the mean log catchability (SE [log q] in Table 3). In the younger age groups, the first statistic was usually the most appropriate. The results showed that survey indices all performed reasonably well, with lowest values for standard errors occurring between ages 2-4.

4.2 Community analysis

Catch data for the demersal species (commercial and non-target finfish) have also been used to describe the distribution and community structure of the assemblage

sampled by the beam trawl. Annual Study Group reports show the distribution of selected species as abundance by rectangle, and also as mean catch within ICES Divisions and Round Fish Areas. More detailed analysis of catches have also been presented for the eastern Channel (Ramsay 1992), and for the entire survey area (Rogers *et al.* 1997).

It is possible that beam trawls of the same design but of different widths may not show a linear relationship in their catch rates of all demersal species, and that the use of different attachments (chain mat, flip-up ropes, etc.) will also affect gear efficiency. Comparative fishing exercises (Groeneveld & Rijnsdorp 1990; ICES 1993) compared the 4 m beam trawl with chain mat and flip-up ropes and the 8 m beam trawl with tickler chains and flip-up ropes. During surveys in 1990 and 1991, catch ratios of dab, sole and plaice between the two gears were consistently different (ICES 1993). Catch efficiency was shown to be a function of both fish size and species and, without further extensive work on this topic, it has been assumed that, for the analysis of community structure, the catches of all demersal fish species are in direct proportion to the width of the trawl.

The species compositions in the beam trawl catch will be biased towards the proportion of flatfish, compared to species compositions in the catch of other demersal gears such as otter trawls (Knijn *et al.* 1993) (Table 4). It should be emphasised, however, that no gears accurately represent the true species composition.

The relative proportions of species in a population, and their total number, are used in a range of indices to describe community diversity (Hill 1973). As all diversity indices rely to a greater or lesser extent on species richness and evenness, these descriptions of community structure can be made more precise by excluding species which are not normally considered as typical of the demersal community, and for which the catch efficiency is low. Accurate recording of the abundance of rare species is only of value if the same rare species are identified on all surveys. Some species, for example sandeels (*Ammodytidae*), are difficult to identify in the field, so the allocation of species such as these to genera or family, is acceptable provided it is uniformly applied.

The total number of species in a region will clearly be dependent on the level of sampling within it (Figure 4). Analysis of rarefraction plots showing the accumulation of taxa with increased sampling effort suggests that, at the scale of an ICES division, sampling is more than adequate to achieve a good estimate of species richness. Even after several hundred trawl hauls, however, these curves failed to reach an asymptotic level (Figure 5), suggesting that further effort would be required to sample the entire fauna (Rogers *et al.* 1997)

5. FUTURE DEVELOPMENTS

Several improvements and additions to survey protocol and data handling are feasible, and these are identified here to improve the quality of the survey indices.

1. Catch data and fishing station details are currently stored in a number of electronic formats, and so the development of a common format is an important next

step. Recent discussions have initiated the process of converting data to the ICES International Bottom Trawl Survey (IBTS) database format, which will allow greater access to the data by the international scientific community.

2. Quality of the catch data could be improved if all countries identified a predetermined list of species, to include finfish and crustacea, to the same level of accuracy. This would improve estimates of species richness in each region, and allow simple combination of catch data between surveys. This standardisation could also be extended to identifying those species which are measured, and those species which are only counted.

3. In addition to sampling the commercially important and non-target fish, large quantities of invertebrate macrofauna are also caught, and recorded during each survey. Improving and standardising the sampling protocol for this invertebrate fauna, and including these data with the fish catch, would be a valuable extension to the surveys.

4. Other surveys are undertaken in the coastal waters of the North Sea targeting 0-group and 1-group flatfish, and these have not been included in the analyses of the Study Group (Table 1). Nevertheless the catch data are relevant and could be included in the considerations of the Study Group.

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Table 1

Summary of all beam trawl (BT) surveys targeted on sole and plaice in the North Sea and Sub-area VII, describing their original specification. (from ICES, 1990; 1991). (areas marked * currently contribute to the Study Group on Beam Trawl Surveys)

Country	Area surveyed	Start year	Survey date	Gear used	Target species
Belgium	Belgian coast	1970	August-October	6 m BT	0-,1-group sole, plaice
"	* S North Sea	1985	August-October	8/4 m BT	1-,2-,3+ group sole, plaice
France	French coast, VIId	1977	August-October	2.7/4.5 m BT	0-,1-group sole, plaice
Germany	German coast, N. Sea	1972	August-October	3 m BT	0-,1-group sole, plaice
"	* German Bight	1976	June	7 m BT	2-,3+group sole, plaice
UK	English coast, North Sea	1974	September	2 m BT	0-,1-group sole, plaice
"	* VIId	1988	August-September	4 m BT	1-,2-,3+ group sole, plaice
"	* VIIe (English coast)	1984	August-September	6/4 m BT	1-,2-,3+ group sole, plaice
"	* VIIf & g	1988	August-September	4 m BT	1-,2-,3+ group sole, plaice
The Netherlands	Dutch and Danish coast, N. Sea	1969	August-October	6 m BT	0-,1-group sole, plaice
"	Wadden Sea and Scheldt	1969	August-October	3 m BT	0-,1-group sole, plaice
"	* Southern N. Sea	1985	August-October	8 m BT	1-,2-,3+ group sole, plaice

Table 2

Details of the beam trawl surveys currently undertaken by each country.

	Belgium	Germany	Netherlands	UK	UK	UK
Survey area:	IVb&c west	IVb east	IVb&c east	VIId	VIIe	VIIa, f&g
Year survey started:	1992	1991	1985	1988	1988	1988
Dates:	August	early September	end August	early August	late September	late August
Ship:	RV Belgica	RV Solea	RV Isis	RV Corystes	MFV Carhelmar	RV Corystes
Ship length:	50 m	35 m	28 m	53 m	22 m	53 m
Beam trawl length:	4 m	7 m	8 m	4 m	4 m	4 m
Number of beams fished:	1	2	2	1	2	1
Trawl duration (min):	30	30	30	30	30	30
Tow speed (knots):	4	4	4	4	4	4
Cod end liner stretched mesh (mm):	40	44	40	40	40	40
Number of ticklers:	0	5	8	0	0	0
Attachment:	*	(none)	(none)	*	*	*
Station positions:	fixed	pseudo-random	pseudo-random	fixed	fixed	fixed
Benthos sampling since:	1992	1992	1985	1991	1992	1992

* chain mat & flip-up rope

Table 3

Comparison of standard errors of the regression of abundance against CPUE (Reg se) or standard errors of the mean log catchability (Se [log q]), for ages 1-6 from the different beam trawl surveys (ICES, 1996).

SOLE		Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
North Sea (IV)	Reg se	0.17	1.18	-	-	-	-
	SE (log q)	-	-	0.21	0.35	0.40	0.66
Irish Sea (VIIa)	Reg se	0.11	0.13	-	-	-	-
	SE (log q)	-	-	0.34	0.43	0.43	0.40
Celtic Sea (VIIf&g)	Reg se	0.55	0.18	0.26	-	-	-
	SE (log q)	-	-	-	-	-	-
English Channel east (VIId)	Reg se	0.44	0.51	-	-	-	-
	SE (log q)	-	-	0.41	0.37	0.19	0.94
English Channel west (VIIe)	Reg se	0.20	0.20	0.12	0.15	0.27	0.25
	SE (log q)	-	-	-	-	-	-

PLAICE		Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
North Sea (IV)	Reg se	-	-	-	-	-	-
	SE (log q)	0.41	0.3	0.28	0.39	0.32	0.42
Irish Sea (VIIa)	Reg se	0.13	-	-	-	-	-
	SE (log q)	-	0.24	0.40	1.07	-	-
Celtic Sea (VIIf&g)	Reg se	-	-	-	-	-	-
	SE (log q)	1.04	0.66	0.49	0.38	0.51	-
English Channel east (VIId)	Reg se	0.10	0.20	-	-	-	-
	SE (log q)	-	-	0.38	0.36	0.29	0.35
English Channel west (VIIe)	Reg se	0.39	0.31	0.18	-	-	-
	SE (log q)	-	-	-	0.32	0.24	-

Table 4

The number of finfish and shellfish species, and species groups, collected during the beam trawl surveys (1990-1996) by category.

	Number of species
Demersal non - target	88
Demersal commercial	24
Pelagic	22
Invertebrate	19
TOTAL	153

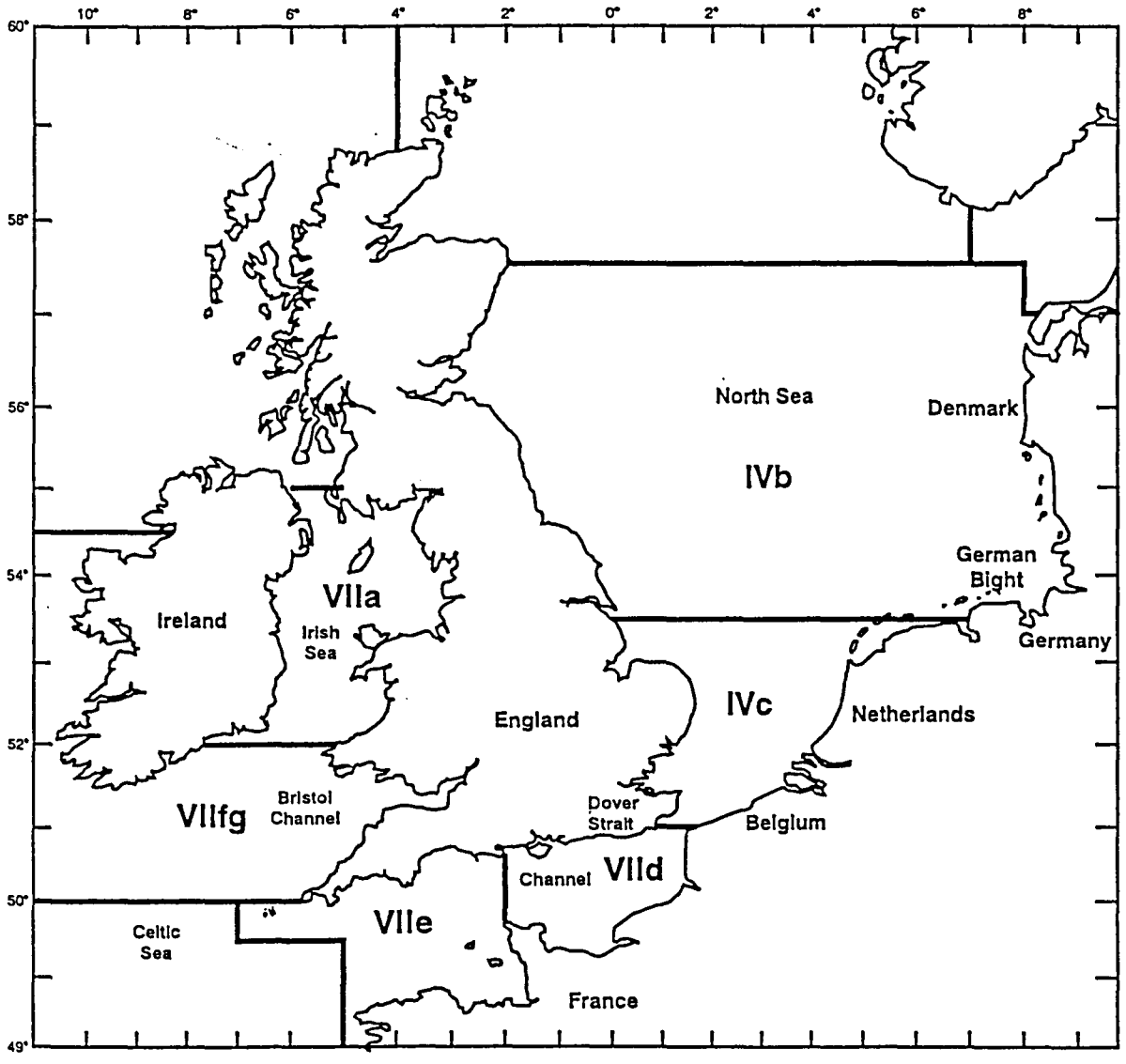

Figure 1. Map of the survey area showing ICES divisions and place names referred to in the text (redrawn from Rogers et al., 1997)

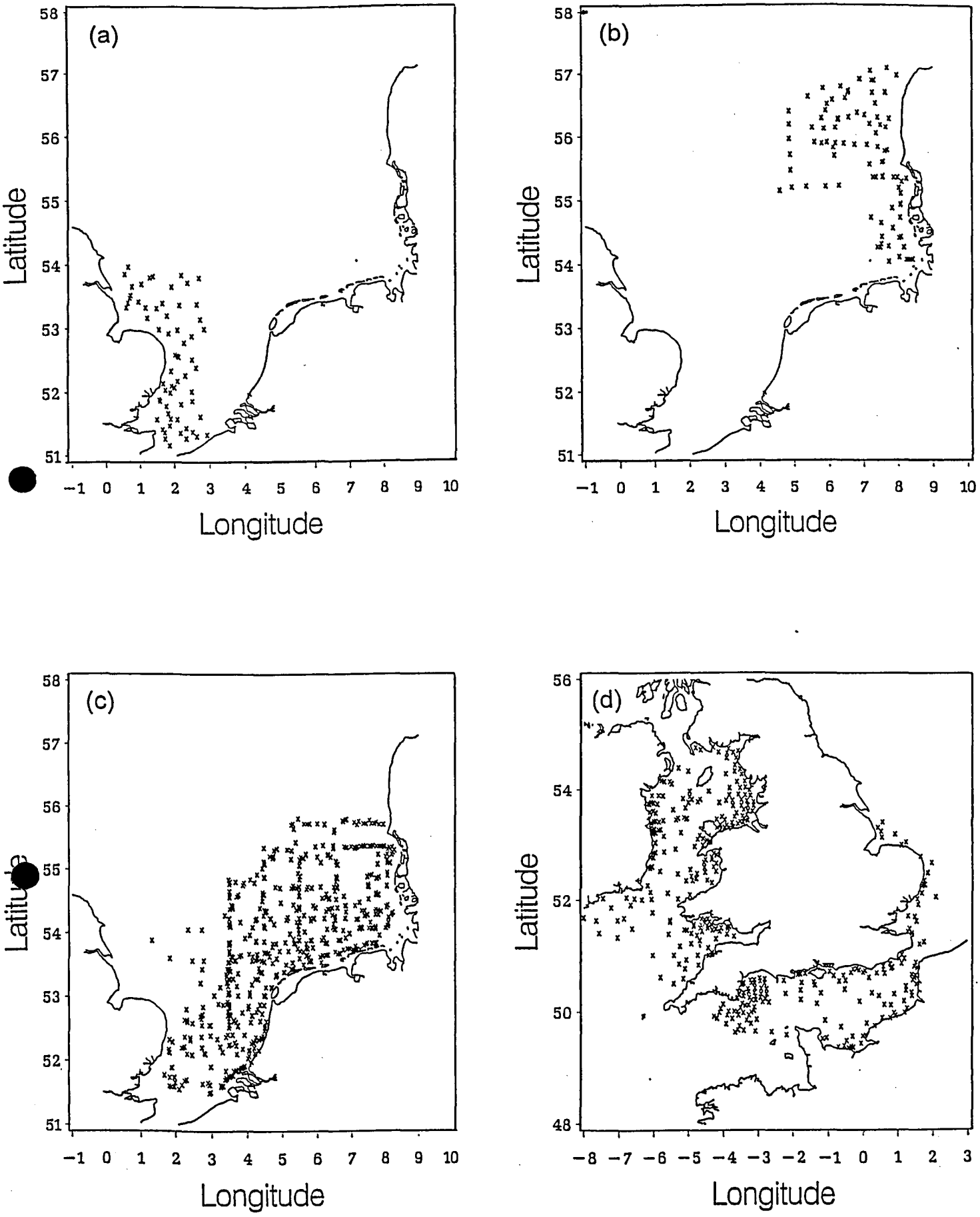

Figure 2. Station positions marked by 'x', fished during the beam trawl surveys of (a) Belgium (1992-96), (b) Germany (1993-95), (c) The Netherlands (1990-96) and (d) UK (1990-96).

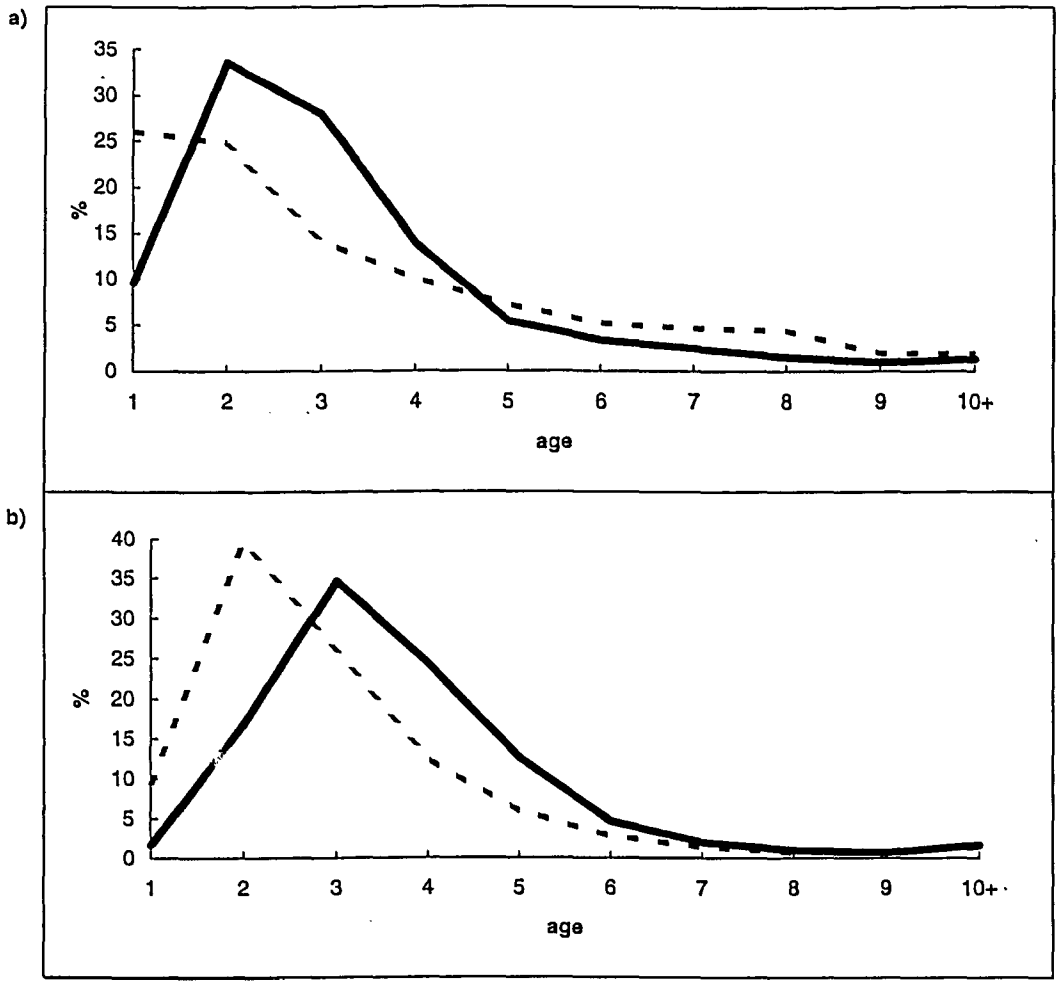

Figure 3. Mean catch numbers at age (1992-95) of VIId plaice (a) and sole (b) in the stock from VPA analysis (continuous line), and mean abundance index from CORYSTES beam trawl surveys (1992-95) (dashed line), expressed as a percentage of the total abundance (all data from ICES, 1996),

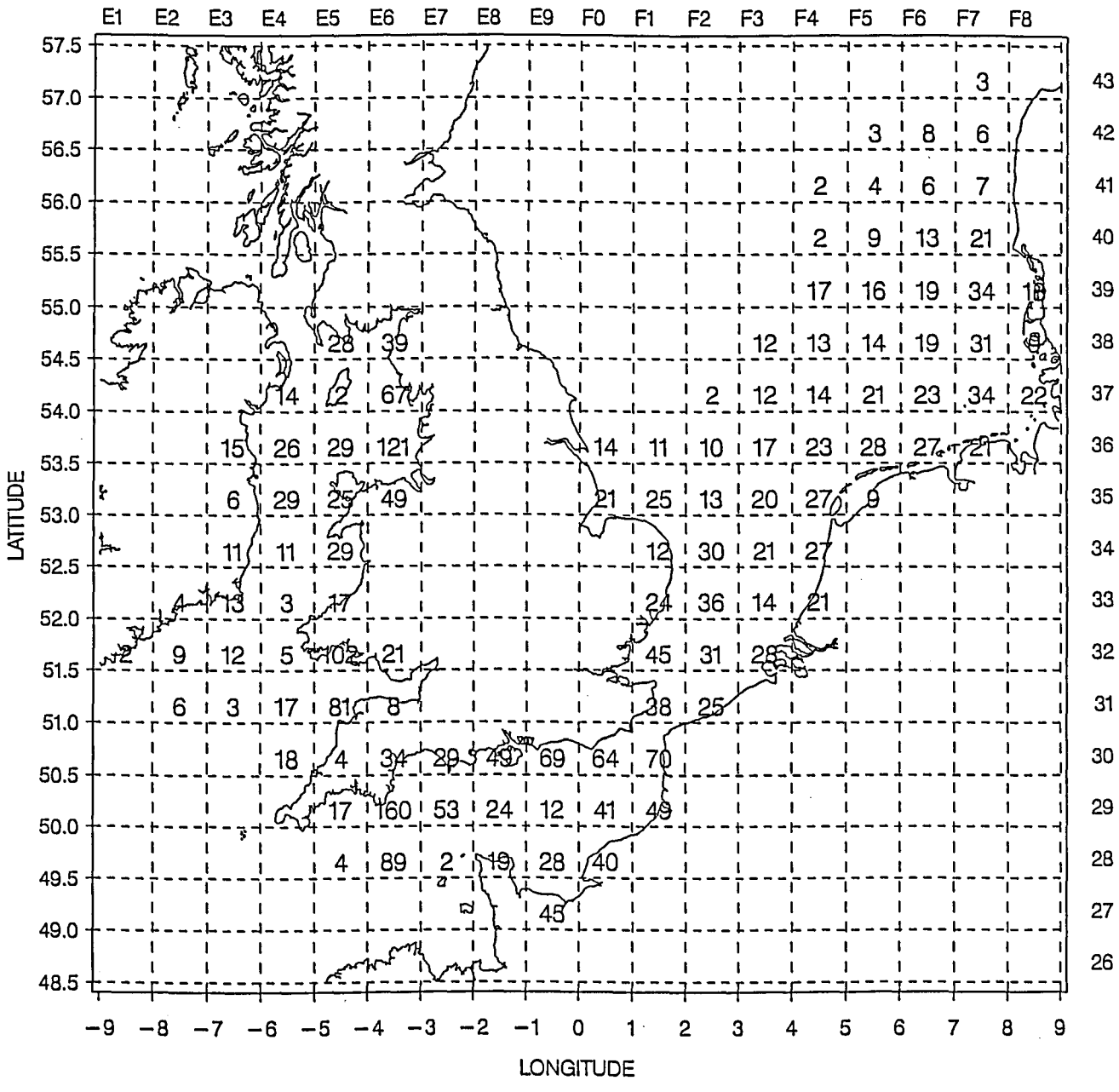

Figure 4. The total number of hauls by ICES rectangle for all countries, 1990-96.

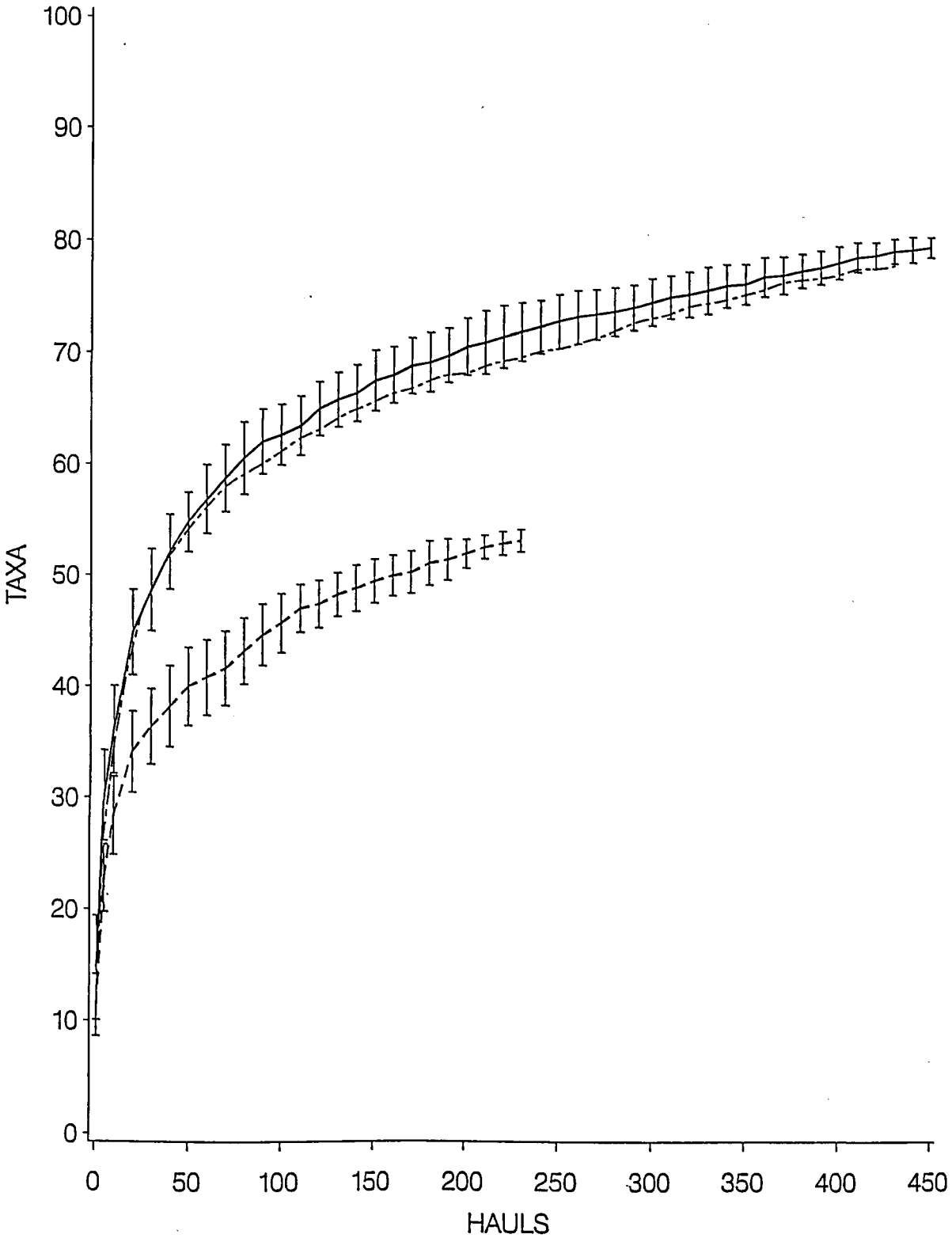

Figure 5. Mean cumulative number of selected demersal commercial and non-target taxa caught with increased number of trawl hauls in ICES divisions IVc (dashed line) and VIIa (continuous line) using all hauls in 1990-95, with the standard deviation of the mean. The cunulative abundance curve for ICES division VIId, for the same period, is shown by the dot-dash line, but without the standard deviation marked (for statistical technique used see Rogers, *et al.*, 1997)