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Comparing commercial and research survey catch per unit of effort: megrim in the Celtic Sea

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Correlation between maps of research survey and commercial catch data was thought to improve the spatial analysis of fishing mortality and catchability. Maps were produced at the spatial scale of the ICES statistical rectangle and commercial cpue (catch per unit of effort) were linearly regressed on research survey cpue. The analysis was performed for two seasons (spring and autumn) over a time interval corresponding to the survey dates. The analysis focused on megrim in the Celtic Sea because of its large spatial extension over the area covered by both research surveys and commercial fishing. Simple mean and variance of commercial cpue were computed using those boats which reported their catch per ICES rectangle in their logbooks and which operated in a period close to the survey dates. Average research survey cpue in the ICES rectangles were estimated by block kriging after modelling the variogram of the survey data. The variance of commercial cpue within rectangles was evidenced to be an important parameter when relating research survey cpue to commercial cpue. It showed strong spatial and seasonal patterns. It was related with fishing strategy in autumn and to a biological cause in spring. Different uses of the variance in the commercial cpue were discussed, in particular for planning research surveys. Selecting those rectangles with low commercial variance allowed fitting a linear regression between commercial and scientific cpue. Differences in the slope was small in autumn for the two years studied but important between autumn and spring.

Keywords: catchability, fishery statistics, geostatistics, research surveys, sample support, spatial aggregation, variance.

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Introduction

The use of geo-referenced commercial catch and effort data to analyse the spatial distribution of fish (Vigneaux *et al.*, 1998) and fishing effort (Jennings *et al.*, 1999) is still scarce in the fisheries literature. Combination of research survey data with commercial logbook data is also scarce (Fox and Starr, 1996; Potier *et al.*, 1997). In particular, fisherman logbook records are thought to be potentially biased but Fox and Starr (1996) have shown that the information is relevant in their case. The building of spatial modelling of fish populations will require in the future the simultaneous use in a combined way of geo-referenced data provided by research survey and fishery statistics. Research survey index and commercial catch per unit of effort (cpue) are two different measures of the same species abundance but there is often a discrepancy between them. The objective of the present paper is to improve the understanding of the differences between data provided by research surveys and fishery statistics. Discrepancies should be mainly attributed to differences in catchability as well as to sampling design. In other words, do the two types of data provide a similar spatial pattern of the species distribution and if not, is the difference interpretable? For that purpose, the correlation between maps derived

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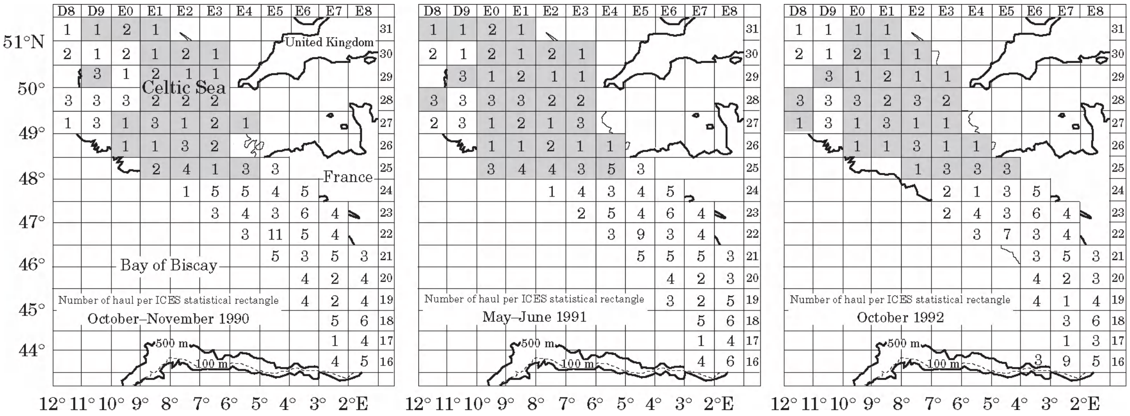

Figure 1. Area covered by the French EVHOE bottom trawl research surveys. Squares are the ICES statistical rectangles. Numbers in the squares are the number of hauls in each rectangle. Shaded rectangles are those retained in the study.

from research survey data and commercial log-book data was studied.

The area selected in this study was the Celtic Sea (Figure 1), an important fishing area for the bottom trawlers from Brittany. The species selected was megrim (*Lepidorhombus wiffiagonis*, Walbaum 1792) because of its biological and fishery characteristics which makes the species a good candidate for the comparison between research survey and commercial data. Megrim is a flat fish living on sandy sediments at depths 100–300 m. It is largely distributed all over the Celtic Sea (ICES subdivisions VIIe,g,h,j) and often occurs in the research survey data. The fish lives at sediment surface and does not bury itself deep in. Therefore accessibility and vulnerability to both commercial and scientific gears are potentially good (Aubin-Ottenheim, 1986). Further, megrim is an important commercial species but is not a target nor a by-catch species and has been classified as an intermediate species (Biseau, 1998).

In the ICES area, commercial log-book records enable to access catch and effort data at the scale of the ICES statistical rectangle. Because survey data are not gathered at the same space scales, we used the geostatistical procedure of kriging as an interpolating technique to estimate research survey means at the same spatial scale as the commercial data, i.e. the ICES statistical rectangle.

Materials

Research survey data

IFREMER carries out each year since 1987 EVHOE bottom trawl surveys on the eastern continental shelf of the Bay of Biscay (ICES, 1991, 1996, 1997). The surveys are aimed at evaluating and mapping marine populations (Poulard, 1989; Amara *et al.*, 1998) and species assemblages (Souissi *et al.*, 2001). The survey area was extended to the Celtic Sea (between 48°30′N and 51°30′N, Figure 1) in 1990 (October–November), 1991 (May–June) and 1992 (October–November). Data collected during these three surveys are used in the present study.

A GOV 36/47 bottom trawl was used with a 20 mm mesh codend liner. Haul duration was 30 min at the towing speed of 4 knots. All hauls were performed during day time. The vessel used was the R/V “Thalassa”. In the Celtic Sea (North of 48°N), the sampling scheme was a pseudo regular grid of stations while the Bay of Biscay area was stratified according to latitude and depth. Catch weights and catch numbers were measured for all species. Megrim length and sex were recorded for all individuals. Otolith and tail fin rays were taken and examined to build age/length keys by sex.

Megrim scientific cpue was estimated as the weight of the catch of megrim of length greater than 25 cm (i.e., corresponding to age group 4+) per 0.5 h of trawling. The lowest commercial megrim length landed in the two-month period around the surveys was 25 cm.

Commercial data

The activity of the French trawlers operating in the Celtic Sea was classified in three “métiers” (i.e., type of fishing activity) from the spectrum of target species (Biseau, 1998; Bertignac, 1992). These métiers are: the demersal métier, targeting gadoids (i.e. cod and whiting); the nephrops métier, targeting Norway lobster; and the benthic métier, targeting anglerfish. Megrim was classified by Biseau (1998) as an intermediate species, i.e. not a target nor a by-catch species. Moreover, Pinot (1974) divided the Celtic sea in two major areas according to the substrate. South of 50°N (ICES Division VIIh) sandy sediments prevail while north of 50°N (ICES

Division VIIg) the substrate is more heterogeneous with mud, sand and rocks. The three identified métiers operate in space according to this substrate typology, the demersal and nephrops métiers being distributed in the north and the benthic métier in the south (Charuau and Biseau, 1989). The variability in the catch of a species like megrim may depend on the fishing strategy and/or on the aggregative spatial behaviour of the species and/or on the heterogeneity of the substrate. We therefore considered major target species together with megrim and extracted from the French commercial database the landings of megrim, cod, whiting, nephrops and anglerfish together with fishing effort.

French vessels working in the Celtic Sea go for trips of 10–20 days. They land their catches in the harbours of south Brittany from Douarnenez to Lorient. We sorted all harbours along the west coast of France by decreasing order of megrim landings over the two-month period centred on the survey dates. The EVHOE survey over the Celtic Sea lasted about 15 days. Five harbours were retained. These are: Concarneau, Le Guilvinec, Loctudy, Saint Guénolé et Lorient. They accounted for 80% of the total megrim landings in France during the periods considered.

The selection of harbours provided a list of vessel-trip-rectangles. Each line of our data set was identified by a code for the interaction between vessel, trip and rectangle. We selected those lines for which the vessel operated during its trip in only one rectangle so as to be sure of the spatial association between catch and rectangle. The numbers of vessel-trip-rectangle retained were respectively 874, 1113 and 983 for each survey from 1990 to 1992. For each line, we knew the vessel (and its engine power (kW)), the number of fishing hours spent per ICES statistical rectangle and the catch weight (kg) for the main species. Catch per unit of effort (cpue) for a given species was estimated as the catch of that species divided by the number of fishing hours and the engine power of the vessel (Salthaug and Godo, 2001). Units were $kg \cdot 10^{-3} h \cdot kW^{-1}$.

For the present study we selected those rectangles for which we had values for both the research survey cpue and the commercial cpue. The numbers of ICES statistical rectangles selected were: 26, 32, 29 respectively from 1990 to 1992. The selected rectangles are shaded on Figure 1.

Methods

Mean of survey cpue by ICES rectangle

It was necessary to estimate the average research survey cpue by ICES rectangle. For doing so, geostatistics was used. The kriging method allowed to estimate optimally the process value at any location given experimental values in the surroundings and given a spatial correlation function known as the variogram. The variogram indicates the increase in variance between points for increasing distance between them. More details can be found in Matheron (1971) and Chiles and Delfiner (1999) for the theory and in Petitgas (1996, 2001) and Rivoirard *et al.* (2000) for applications to fisheries. The variogram was estimated for each survey and modelled by an isotropic spherical model with a nugget effect. The model was fitted by eye to pass through the experimental points. Various models were good candidates. The one retained, as suggested by Matheron (1971), was the one which best reproduced the data variance over the surveyed area. Once the variogram is known, process variance (also termed dispersion variance by Matheron, 1971) can be estimated at different spatial scales. The dispersion variance over a given area is defined as the average of the variogram for all distance combinations over that area. The dispersion variance over the total area surveyed is a model-based estimate of the variance in the population. Therefore, its value should be close to that of the data variance. Computations were carried out with the software EVA2 (Petitgas and Lafont, 1997). The dispersion variance was also computed within an ICES rectangle to evaluate variance at that smaller scale.

The average of the research survey cpue per ICES rectangle was estimated by block kriging (Matheron, 1971). Kriging allows using samples outside the rectangle to estimate the rectangle mean. This is interesting when too few points are available inside as is the case in the EVHOE surveys (Figure 1). Kriging is an unbiased linear interpolator which has minimum variance by construction. Block kriging is equivalent to estimate at points on a fine grid inside the block and then take the average over the block. Block kriging performs the estimation in one step. The method requires to estimate average values of the variogram for all distance combinations (i) between sample points, (ii) between points of the block and sample points, and (iii) between points of the block. Therefore, the ICES rectangles were discretized with a fine grid of 25 by 25 cells. The number of sample points used to estimate the mean of a rectangle was controlled by selecting only those sample points which were inside a disc of fixed radius located at the centre of each rectangle (kriging with moving neighbourhood). Kriging was performed with different neighbourhood radii and for each the overall mean of the block estimates was calculated. The neighbourhood radius retained was the one for which the mean of the kriged blocks was closest to the data overall mean, meaning that there was no overall bias in the estimation.

The spatial analysis was performed in the orthogonal plane to the earth's sphere. This was obtained by multiplying the longitudes by the cosine of the mean latitude over the area, the latitudes being kept unchanged.

Mean and variance of commercial cpue by ICES rectangle

Commercial cpue was first estimated for each vessel-trip. Data were then grouped by rectangle and mean and variance were computed between vessel-trips in each rectangle. When the same vessel operated for different trips in the same rectangle in the period considered, the different trips of this vessel contributed to the mean and variance as if they were from different vessels.

Relating commercial and scientific cpue

Rectangle average of commercial cpue were regressed on research survey ones. A linear model was fitted by least squares. The regression was not forced to have zero intercept. The R-square was used to measure the goodness of fit. At first, no relation existed as some rectangles had high megrim commercial cpue for low research survey megrim cpue. But the use of the variance of commercial cpue by rectangle allowed to evidence a linear relationship between the variables for particular rectangles. This was evidenced using the following sequential procedure. Rectangles were ranked in decreasing order of their variance of commercial cpue. Regressions were fitted as follows: (i) using all rectangles, (ii) using all rectangles except the one with the highest variance, (iii) using all rectangles except the two with the two highest variance . . . etc, until 10 rectangles remained. This number was empirically chosen so as to provide sufficient points for the linear model fit. The regression selected was the one which had the largest R-square and a positive slope.

Interpreting variation in the variance of the commercial cpue

We would not have found any relationship between commercial and research survey cpue without considering the variance of the commercial cpue within the ICES rectangles: excluding the rectangles with highest variance enabled to evidence for those with a low variance a linear relationship between commercial and research survey cpue. Therefore an additional analysis was conducted to interpret the variation in the variance of the commercial cpue. This variance was interpreted in terms of fish aggregation pattern as well as in terms of fishing strategy. The impact of the fishing strategy was analysed by studying correlation between commercial cpue of the target species of the different métiers. Correlation between species cpue was analysed by applying Principal Component Analysis (PCA, Lebart *et al.*, 1995) on the correlation matrix X^tX, where X was the matrix where columns were the average cpue of the various species (cod, whiting, nephrops, anglerfish and megrim) and rows the ICES rectangles. Then passive variable (i.e. which did not participate in the definition of the principal components) were projected on the factorial space and their coordinates on the principal axes computed. The interest in the procedure (Lebart *et al.*, 1995) was to evidence correlation between the passive variable and the principal components. The method was used to interpret how the variance of commercial megrim cpue was related to the métiers. Active variables were the average cpue for cod, whiting, nephrops, anglerfish and megrim, by rectangle. Passive variables were the variance of the commercial megrim cpue in the rectangles and the latitude of the rectangle centres. Latitude was considered to reflect the major north–south bottom sediment gradient of the Celtic Sea described by Pinot (1974). The correlation between variables and principal components was evidenced simply by the angle of the vectors in the correlation circle.

Table 1. Basic statistics for megrim age group 4+ caught north of 48° N. Units are kg/0.5 h.

	Autumn 1990	Spring 1991	Autumn 1992
Number of hauls	69	79	62
Number of zero values	11	9	10
Maximum	6.5	5.95	6.49
Average	1.45	1.71	1.34
Variance	2.28	1.91	2.09

Results

Research survey cpue

Basic statistics for megrim research survey cpue were consistent through the three surveys (Table 1). The spatial pattern was also consistent, the bulk of the distribution being in the centre and south of the Celtic Sea (Figure 2). Experimental variograms displayed a clear spatial structure in each year (Figure 3) and fitted variogram models had similar characteristics for the three surveys (Table 2). In particular, the nugget effect was important representing from 43 to 71% of the total variance (C_0+C_1). The dispersion variance within an ICES rectangle varied from 73 to 83% of the overall data variance. Basic statistics of the survey data used in the kriging were compared with that of the rectangle kriged mean estimates (Table 3). The average values compared well which meant that there was no overall bias in the estimation. The neighbourhood disc diameter retained was 1.2 degrees (72 nautical miles) which was close to the variogram range. The map of the rectangle block kriged means showed that the bulk of larger values was in the centre and south of the Celtic Sea (Figure 4).

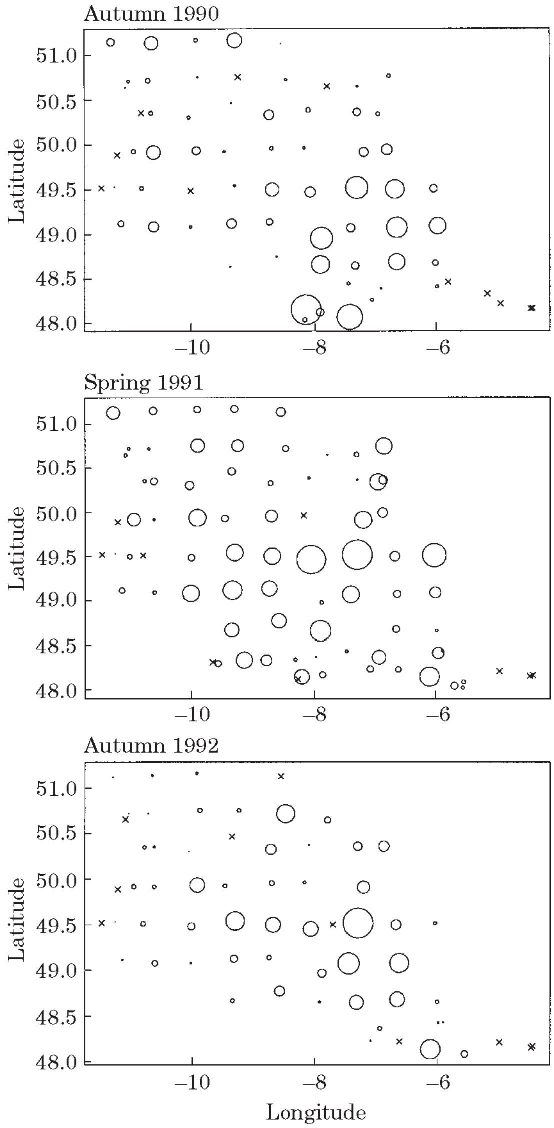

Figure 2. Proportional representation of megrim research survey cpue from the EVHOE surveys in the Celtic Sea. Circle Radius is linearly proportional to scientific cpue value, x denotes 0 catch. All years are scaled to the same value (1 inch for 20 kg/0.5 h).

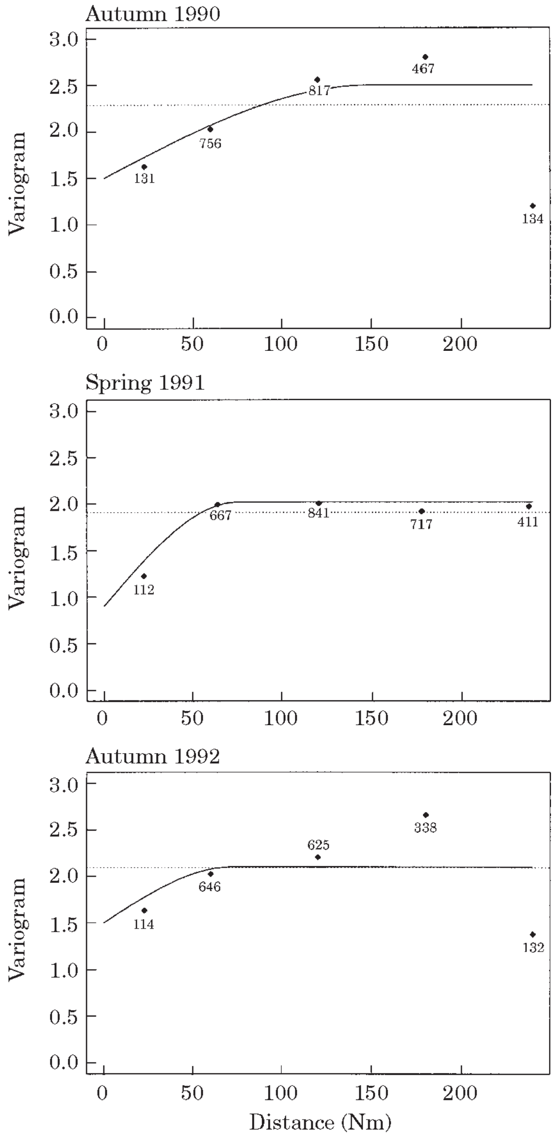

Figure 3. Experimental omni-directional variograms with their fitted spherical models. Numbers of pairs of points at each variogram lag are indicated. The dashed line represents the variance of the data. The model parameter values are in Table 2.

Commercial cpue

In spring 1991, the map of commercial cpue showed that the bulk of the larger densities was also in the centre of the Celtic Sea (Figure 5). Therefore maps of research survey and commercial cpue are coherent between each other in spring 1991. But in autumn 1990 and 1992, commercial cpue maps displayed larger cpue in the north than research survey maps (Figure 5).

The variance of the commercial cpue exhibited a strong spatial pattern and there were more differences in the spatial pattern between seasons than between years (Figure 6). In autumn 1990, the variance was highest in the north, moderate in the centre and small in the south. A similar pattern occurred in autumn 1992. In autumn, the northern area hosted high average cpue values, high variance values and moderate effort values. The southern area hosted moderate average cpue values, low variance values but high effort values. In contrast in spring 1991, the pattern was different. The central area hosted high average cpue values as well as high variance and effort values.

Table 2. Parameter values of the fitted variogram models and associated variances. Percent of variance in an ICES rectangle is the dispersion variance in the rectangle divided by the data variance over the surveyed area. The variogram model fitted $\gamma(h)$ was the sum of a nugget effect $C_0\delta(h)$ [with $\delta(0)=0$ and $\delta(h>0)=1$] and a spherical model $C_1[1.5(h/r)-0.5(h/r)^3]$ with r for range.

	Autumn 1990	Spring 1991	Autumn 1992
Nugget value (C_0)	1.5	0.9	1.5
Sill of spherical model (C_1)	1.0	1.2	0.6
Range of spherical model (r in degrees)	2.5	1.25	1.2
Data variance over the surveyed area	2.28	1.91	2.09
Dispersion variance over the surveyed area	2.29	2.02	2.06
Percent of variance in an ICES rectangle	73.4	65.3	83.5

Table 3. Basic statistics of the survey data and kriged estimates.

	Autumn 1990		Spring 1991		Autumn 1992	
	Survey hauls	Kriged means	Survey hauls	Kriged means	Survey hauls	Kriged means
Number	46	26	65	32	51	29
Minimum	0	0.11	0	0.56	0	0
Maximum	6.50	3.47	5.95	4.71	6.49	3.23
Mean	1.82	1.76	1.89	2.07	1.49	1.46

Relation between commercial and scientific cpue

In autumn of 1990 and 1992, for the rectangles that had a low commercial cpue variance (i.e. those in south and centre of the Celtic Sea), a linear relation existed between commercial and scientific cpue (Figure 7). In constrast in spring 1991, the scatter plot was much more dispersed. Regression lines were fitted excluding those rectangles with high variance.

In autumn of 1990 and 1992 similar values were found for the slope, the intercept and the R-square of the regressions as well as for the number of rectangles retained in the regression (Table 4). In spring 1991 in contrast, the number of rectangles retained was higher, the regression was more noisy with a lower R-square and a smaller slope.

Interpreting the variance of megrim commercial cpue

The basic statistics of the commercial data for the selected ICES rectangles (Table 5) showed that the mean fishing effort was consistent across years and seasons, so was the average and variance of the megrim cpue. Cod, whiting and nephrops exhibited a seasonal variation: in spring there was a moderate decrease in the cod and whiting cpue but a marked increase in the nephrops cpue. Anglerfish showed a trend between years.

The PCA performed for each survey period showed a clear structure in the correlation matrix of the commercial cpue of the five species cod, whiting, nephrops, anglerfish and megrim (Figure 8). The first two principal components represented respectively 83%, 77%, and 81% of the total variance in the cpue matrix for the three survey periods in 1990, 1991, and 1992. A component of the structure was consistent across the survey periods. Cod, whiting and nephrops were positively correlated with the first principal component and were opposite to anglerfish. Latitude was well correlated with the first principal component which could thus be interpreted as a north-south gradient. Seasonal differences were also present. In autumn of 1990 and 1992, megrim was opposite to cod and whiting along the second principal component. Average megrim cpue (Meg) and variance of megrim cpue (VAR) were positively correlated along the first principal component. In contrast in spring 1991, the second principal component was clearly identified to the megrim cpue. Variables Meg and VAR were well correlated to the second principal component which meant that they were independent of the north-south gradient. Thus, in spring 1991 the characteristics of the megrim catches were different than those in autumn 1990 and 1992, relatively to the catches of the other species.

Discussion

Estimation of commercial cpue

Catch per unit effort was simply estimated as the ratio between catch and effort. The scatter plot of megrim cpue versus fishing effort showed no particular

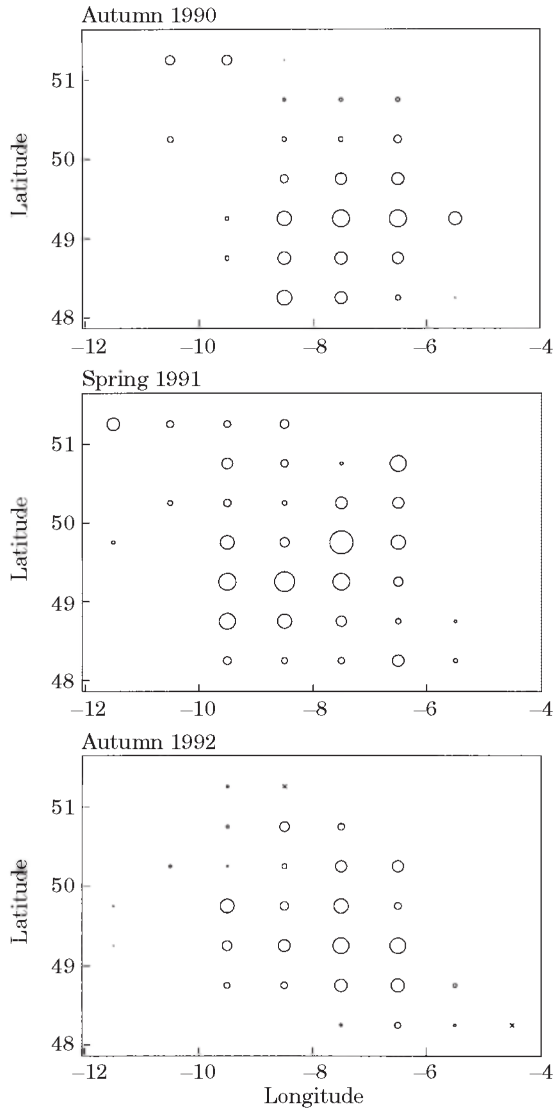

Figure 4. Proportional representation of research survey block-kriged megrim cpue per ICES rectangle in the Celtic Sea. Circle radius is linearly proportional to the kriged value, x denotes 0 value. All years are scaled to the same value (1 inch for 20 kg/0.5 h).

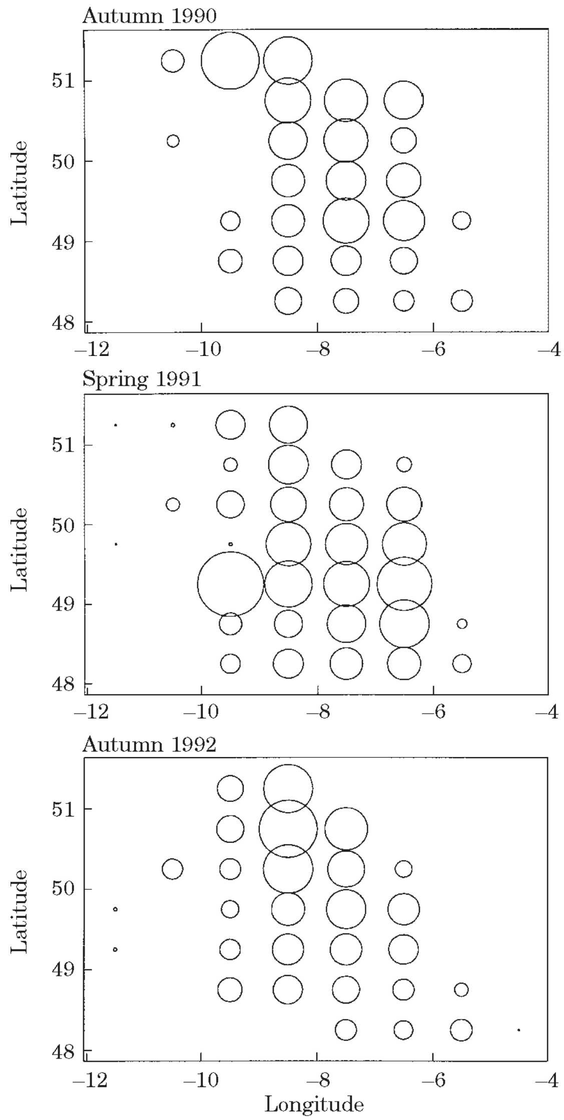

Figure 5. Proportional representation of average commercial megrim cpue per ICES rectangle in the Celtic Sea. Circle radius is linearly proportional to the mean value and all years are scaled to the same value (1 inch for 30 kg/1000 h kW).

relationship meaning that the standardization of catch per effort was satisfactory. In estimating the effort the time spent fishing per rectangle was not disaggregated in métiers. As megrim is caught by different métiers, this procedure is adequate for megrim. But it may lead to under-estimates of the cpue for the target species of the different métiers (cod, whiting, nephrops, anglerfish). This effect was not considered to affect the structure in the PCA performed on the species cpues and would thus not affect the interpretation of the variation in the variance of the megrim commercial cpue.

Variogram and kriging of research survey cpue

Because mean research survey cpue per rectangle were estimated by kriging, the choice of parameters used could potentially affect the relationship between commercial and research survey cpue and thus the sensitivity of the relationship to kriging parameters is of concern. Variograms were estimated for each year. It is possible that the differences between variograms were not significant and thus an all-year-average variogram could have been used for kriging in each particular year. But there was no need to consider that option which meant making inter-annual assumptions as structure was clear

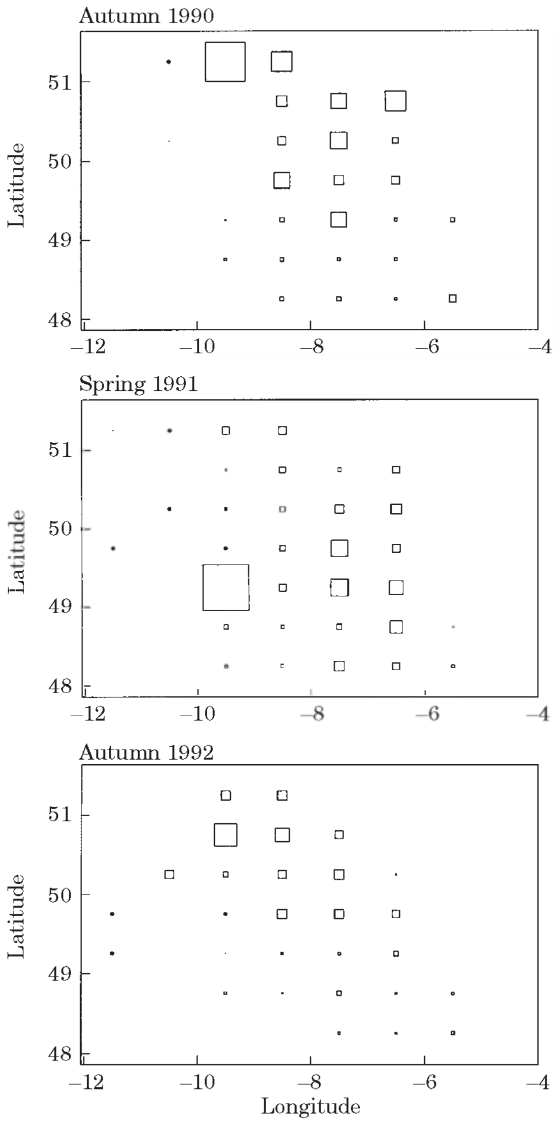

Figure 6. Proportional representation of the variance of megrim commercial cpue per ICES rectangle in the Celtic Sea. Squares are linearly proportional to the variance of the commercial cpue and all years are scaled to the same value (1 inch for 250 kg/1000 h kW square)

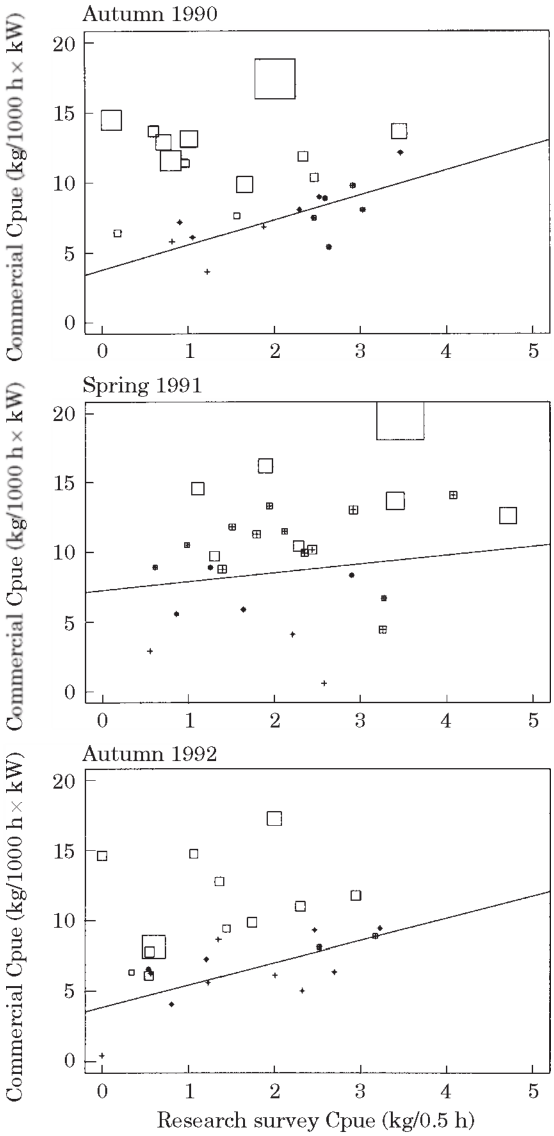

Figure 7. Relation between commercial and research survey cpue of megrim with their fitted linear regressions. Crosses indicate the points used in the regressions which corresponded to the rectangles with low variance of the commercial cpue. Squares are linearly proportional to the variance of the commercial cpue. All years are scaled to the same value (1 inch for 250 kg/1000 h kW square)

in each year. Another concern is that kriging neighbourhood will affect the smoothness of the kriged map. A large neighbourhood will tend to increase the effect of the overall mean in the estimation of each local rectangle thus reducing the range of values for research cpue. A small neighbourhood will tend to constrain the local estimate of the rectangle to the local neighbourhood mean with the risk that the kriged map average does not honour the data overall mean. We therefore considered the overall data average as a control parameter for choosing the neighbourhood. Its dimension was close to that of the variogram range thus in coherence with the structure in the data.

Conclusion

Variance of the commercial cpue proved to be an important control parameter in the present study and allowed to subset commercial data which agreed with research survey data. In autumn, in the south and centre

Table 4. Parameters of the linear regression of the commercial cpue on the scientific cpue of megrim. The regression was fitted on commercial and scientific mean estimates per ICES rectangles. The number of rectangles retained in the fitted regression is given.

	Autumn 1990	Spring 1991	Autumn 1992
Nb. Rectangles	13	20	14
Slope	1.78	0.63	1.58
Intercept	3.77	7.25	3.88
R-square	0.524	0.268	0.462

of the Celtic Sea where the variance of the megrim commercial cpue was low, a positive linear relation between commercial and research survey cpue was evidenced. The slope of the regression varied little between the two autumns studied. Therefore, it can be concluded that catchability for megrim in autumn was little variable between years. In spring in contrast, in the south and centre of the Celtic Sea, the variance of the commercial cpue was high. A positive linear relation between commercial and research survey cpue was much less clear than for the autumn surveys (high dispersion around the regression line). The slope of the regression in spring was different than that in autumn (more years would be necessary for performing a test). Therefore, it can be concluded that catchability for megrim has most probably a seasonal variation.

In autumn, in the centre and south of the Celtic Sea the variance of the megrim commercial cpue was low while in the north of the Celtic Sea the variance was higher. The centre and south are areas worked by the benthic métier whereas the north is worked by various métiers which target at different species. Therefore, it can be concluded that in autumn, the difference in fishing strategy of the different métiers explained the high variance of the commercial cpue as well as the lack of agreement between commercial cpue and scientific cpue. It was thus likely that in the north of the Celtic Sea, the biomass of megrim accessible to fishermen and to research surveys was different, whereas in the centre and south there was less difference in the accessibility of megrim to fishermen and research surveys.

In spring, the variance of the megrim commercial cpue was high in the central part of the Celtic sea corresponding to the area worked by the benthic métier. Such behaviour was different than that in autumn and can be explained by biological parameters (i.e. recruitment to the fishery, migration, aggregation). Poulard *et al.* (1993) evidenced an east–west gradient in the spatial distribution of the life cycle of megrim: age classes 0–4 are located in deeper waters in the western part of the Celtic Sea, age classes 7–14 in the eastern part and age classes 4–6 are in the central part. Maturity is attained at about 25–30 cm for females corresponding to an age of 4 years and spawning occurs at the western shelf break in march (Aubin-Ottenheimer, 1986). Minimum landing size was fixed at 25 cm prior to 1 January 2000, thus recruitment in the landings occurred at age 4 and in the centre of the Celtic Sea. The biological situation could explain the spatial pattern of the variance of the cpue of megrim in spring while fishing strategy (i.e. métiers) enables to interpret the spatial pattern of the variance in autumn.

The variance of the cpue served as an important guiding parameter to understand what the fish and the fishermen did. The ecological processes generating small scale aggregations are generally considered responsible for variability in the catches. Fishermen take advantage of this situation to increase their catches while research surveys will hit high density patches at random because of their design. Thus the variance of the commercial cpue by ICES rectangle could serve as a prior knowledge for the planning of research surveys as well as the analysis of survey data. For instance, a robust scientific abundance estimate could be constructed by weighting research survey values using the variance of the commercial cpue or by excluding high research survey values in the rectangles with high commercial variance. Also,

Table 5. Basic statistics of the commercial data per ICES rectangles. Units of effort are in 1000 h kW and units of cpue are in kg/1000 h kW. Min and max denote minimum and maximum values, m, the simple average and, s/m, the coefficient of variation.

		Autumn 1990				Spring 1991				Autumn 1992			
		min	max	m	s/m	min	max	m	s/m	min	max	m	s/m
Effort	Sum	20	5031	987	1.14	1.0	3766	1108	0.93	5	2310	1006	0.82
Megrim	Cpue	3.64	17.38	9.72	0.34	0.55	19.72	8.83	0.55	0.43	17.25	7.92	0.50
Megrim	Var. cpue	1.49	201.11	45.82	0.97	0.67	234.0	42.27	1.04	0.37	114.14	29.38	0.86
Anglerfish	Cpue	10.71	65.94	27.52	0.51	0	98.63	27.75	0.73	4.63	31.99	15.11	0.39
Cod	Cpue	1.55	39.51	13.38	0.86	0	28.31	8.53	0.91	0	35.28	12.96	0.76
Whiting	Cpue	0	34.57	6.84	1.43	0	26.79	3.06	1.76	0	39.65	7.83	1.36
Nephrops	Cpue	0	12.01	3.26	1.25	0	41.83	10.59	1.38	0	16.93	4.04	1.50

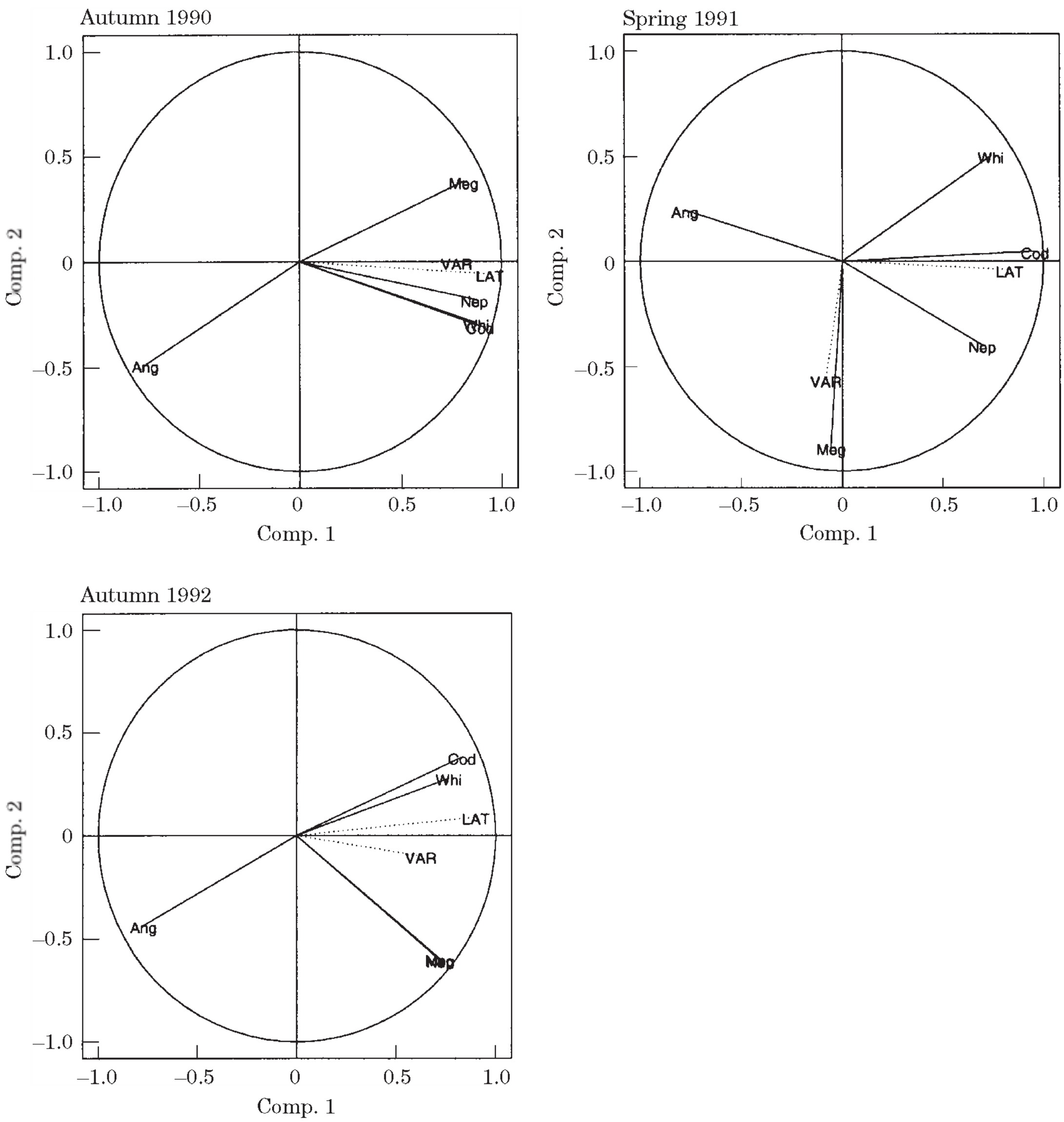

Figure 8. Results of the PCA performed in each year on the correlation matrix of the commercial cpue of megrim, anglerfish, cod, whiting, and nephrops. Variables are shown in the correlation circle in the plane of the first two principal axes. Passive variables are shown in dashed lines. Active variables: Meg: megrim, Ang: anglerfish, Cod: cod, Whi: Whiting, Nep: nephrops. Passive variables: LAT: Latitude of the rectangle centre, VAR: variance of megrim commercial cpue per rectangle. The labels for whiting and cod overlap in 1990 as well as for nephrops and megrim in 1992.

sampling effort could be allocated in relation to the spatial distribution of the variance of the commercial cpue.

Monitoring surveys of fish stocks have usually important time and spatial constraints that do not enable to perform many points per rectangle. These surveys over large areas often lack to sample adequately the variance at small scale which plays an important role in the precision of the estimation (ICES, 1992a,b). Here, 70 to 80% of the total variance was at a spatial scale smaller than the rectangles in which only one to three hauls were performed. This study also advocates for the need in bottom trawl surveys to understand the relation between the small scale variance and the precision of the overall mean.

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