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Characterizing the spatial and seasonal dynamics of the whiting population in the Celtic Sea from the analysis of commercial catch and effort data and scientific surveys data.

by

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Abstract

Most demersal and benthic fish populations exhibit spatial and seasonal patterns in relation to their annual life cycle. Many fish migrate from spawning area to feeding areas at some periods of the year. Scientific surveys do not provide a sufficient seasonal coverage to help delineating the periods that characterise the main demographic stages. In contrast, commercial data represent a lot of information with a good spatial and temporal coverage over the year. However, commercial data provide no information on young individuals below minimum legal size. This paper proposes an approach to use the information contained in both scientific surveys and commercial data, i.e. Catch Per Unit Effort (CPUE) computed at the spatial scale of the ICES statistical rectangle, in order to determine spatial and temporal distributions of recruitment (survey data) and spawning stock (survey and commercial data) of exploited populations. The approach is based on maps of spatial distributions and on multivariate descriptive methods including ordination and classification techniques. It is applied to the whiting population from the Celtic Sea.
Maps of whiting CPUE by age groups obtained by autumn scientific surveys, show that most age groups are mainly caught in the same area, i.e. the North of the Celtic Sea. This pattern of distribution is different from that obtained from the analysis of CPUE commercial data at the same time of the year. Results from analysis of commercial data show a widespread spatial distribution. Further analysis must be conducted so as to discriminate which of these two patterns best reflects the spatial and temporal distribution of whiting in relation with its life cycle.

Keywords : spatial and seasonal distributions, CPUE, commercial catch and effort data, survey data, whiting, factorial analysis, Celtic Sea

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1. Introduction

Most demersal and benthic fish populations exhibit spatial and seasonal patterns in relation to their annual life cycle. Many fish migrate from spawning areas to feeding areas at certain times of the year (Nicholsky 1968). Despite the importance of spatial and seasonal aspects, most population dynamic models omit the spatio-temporal structure of resources. The problem of surexploitation could be in part solved by designing spatio-seasonal management measures, like openings or closures of areas and seasons. Testing the pertinence of such measures requires both structured models in space and time and a good knowledge of the biological cycles of the populations. The aim of this paper is to determine spatial and temporal distributions of the different demographic stages of an exploited population from information of various origins. Scientific surveys and records from the commercial fishery are in general the two sources of data available for this purpose, in addition to prior knowledge extracted from literature. In this paper, we propose to use these two type of data in a complementary way, in order to have the most complete picture of the life cycle of the studied population, from a spatial and temporal point of view.

Scientific data have many advantages, notably they are obtained from standardised and reproductible protocols which make their analysis easier, and they generally provide a complete coverage of the area of distribution of the population. Yet, the major interest of scientific surveys for our purpose is to give information on the spatial distribution of the youngest individuals (O-group and l-group), which is not available from commercial data as these age groups are generally below the minimum landing size. However, one of the limits of scientific data for our purpose is that they do not provide a sufficient seasonal coverage to help delineating the areas and periods that characterise the main demographic stages. Furthermore they represent few fishing hours.

In contrast, commercial data represent a much larger set of information with a good coverage over the year. The fishery logbooks provide a set of catch and effort data with both broad temporal and spatial coverage. These data can be used to compute Catch Per Unit Effort (CPUE) at the spatial scale of the ICES statistical rectangle and the temporal scale of the month. In theory, this would allow to characterise spatial and seasonal distributions for individuals above the minimum landing size. Since CPUE is supposed to be an index of the relative abundance at a given time and place, it also allows to have relative abundance levels for each characteristic patch and season. However, commercial data have two major drawbacks. Firstly, fishing location is generally uncertain, and secondly bias may result from commercial data as fishermen target areas of highest fish abundance.

Scientific survey data were used to construct maps of spatial distribution of the species by age group for a given season. The analysis of commercial catch and effort data is based on multivariate descriptive methods including ordination techniques and classification techniques and is applied to whiting (***Merlangius merlangus,*** L. 1957) population from the Celtic Sea, an important commercial species for the French fishery[1].

2. Material

2.1. The whiting population in the Celtic Sea

The Celtic Sea groundfish fisheries

The Celtic Sea is a continental Sea bounded on its eastern and northern sides by France, the United Kingdom, and Ireland. It covers subdivisions Petite Sole (7h1), Shamrock (7h2), Jones-Melville (7h3), Cockbum-Labadie (7g1), Smalls (7g2), South Ireland (7g3), South Bishop (7e2), Trévose North Bishop (7f1), Grande Sole (j1), South-West Ireland (7j2). Whiting is one of the main commercial species caught in this area. The most important fleet fishing in this area is French, but fishermen from

[1] This work is a part of a PhD thesis conducted in laboratory MAERHA (Nantes, France). The aim of the thesis is to analyse existing commercial and scientific data to determine spatio-seasonal distributions of exploited populations, and, based on these results, to construct a population model taking into account characteristic seasons and areas. The approach is applied to the Celtic Sea fishery.

others countries also participate : UK, Ireland, Belgium and Spain. The French fleet is made up of medium-sized (18-25 m long) bottom trawlers that operate all year round, during trips of 10-20 days. Landings of whiting from the Celtic Sea are made by bottom trawlers targeting gadoïds (whiting, hake, cod), trawlers targeting benthic species and Nephrops fishing boats for which whiting is a by-catch. The minimum legal size of whiting is 27 cm north of 48°N. The largest share of annual catches is taken in 7g3 and North of Cornwall, and during the first quarter of the year while mature individuals concentrate for spawning. In September, a second peak of catches is observed, which may be linked to a trophic concentration on the Smalls (Charuau and Biseau 1989).

Area of distribution
Whiting has a large distribution over the entire Celtic Sea. The identity of the Celtic Sea stock and the Western English Channel one is not fully established (IFREMER and MAFF 1993).
Whiting is a demersal species living at a depth of 10-200m, with a preferendum at 30-100m (Quéro and Vayne 1997). Juveniles are located near the coast : South of Ireland (7g3), St Georges Channel (7fl) and around Cornwall (Ould el Kettab 1993). A discard study on the Nephrops fishery showed that juveniles are also found during winter at Smalls (7g2) (Charuau and Biseau 1989). At maturity, whiting migrate toward shallow waters. Whiting then become less abundant toward the South and in deeper waters (Ould el Kettab 1993).

Reproduction
Maturity is reached around 32 cm corresponding to an age of about 2 years (Charuau and Biseau 1989). The spawning period is quite long occurring during the first quarter in the Celtic Sea and in the Western English Channel from January-February to May-June, with a peak in March-April. Whiting rather spawn in shallow waters (Ould el Kettab 1993). Following Potter, Gardner et al. (1988). the Bristol Channel is an important nursery area for this stock, with a reproduction peak in April. In this area, the O-group (4-10 cm) remains near the coast and is not caught by commercial fisheries.

2.2. French scientific surveys (EVHOE)

Since 1990, IFREMER annually undertakes bottom trawl surveys in the Celtic Sea. One of the aims of the surveys is to map the spatial distribution of marine populations.
The gear used is a GOV 36/47 with a 20 mm codend liner. The trawl is deployed with plane oval trawl boards of 1300 kg and with 10-20 cm rubber discs on the footrope. Haul duration is 30 minutes and towing speed 4 knots. Trawling is carried out during day time only. The vessel used is the N/O Thalassa II (Poulard, Peronnet et al. 1993). The sampling scheme is randomly stratified with a pseudo regular grid of stations.
In this paper, we used data collected during the last three surveys to describe spatial distributions of the whiting per age group. These three groundfish surveys were carried out from 5 October to 9 November 1997, from 11 October to 22 November 1998 and from 11 November to 22 December 1999. Fifty one, 56 and 61 trawls were hauled respectively in 1997, 1998 and 1999 in the Celtic Sea area (Table 1). Catch weights and numbers were recorded for all species and all fish were measured.
Whiting sex and length were recorded. Age-length keys by sex were available from these surveys, from otolith examination, and used to transform the length distributions observed at each trawl station into age distributions. Whiting scientific CPUE is calculated as the catch weight by age per 30 minutes hauling time.

2.3. Commercial data

Commercial catch and effort data were extracted from Ifremer's database of fisheries statistics, based on the information collected by the Regional Centre of Statistical Processing (CRTS) of the French administration.
In this study, data were compiled from groundfish bottom-trawl vessels working in the Celtic Sea. The selected areas for analysis of whiting distribution are subdivisions 7e1, 7e2, 7f1, 7g1, 7g2, 7g3, 7h1, 7h2, 7h3. The Western English Channel (7el) was kept in the analysis because the identity of both stocks is not fully established. Although whiting distribution spreads in part in this area. subdivisions

7jl and 7j2 were excluded because French whiting catch is negligible there. Our data.selection only includes the single and the twin bottom trawl gears. Data on nominal fishing effort in trawling hours per ICES statistical rectangle (0.5” Latitude x 1” longitude) are reported for each trip in the vessels logbooks. Catch data (in kg per species and market category) are provided by the census of sales on the market hall. Sales data indeed correspond to landings. In lack of detailed information about discards, we assume CPUE to be equal to Landings Per Unit Effort.
Because fishermen are not mandated to give an estimation of catch by species per rectangle in a given trip, the catch per rectangle is known only if the vessel fished exclusively within a single rectangle. Otherwise, catch and rectangle could not be unambiguously matched. In this paper, these specific trips are called “single rectangle trips”. Table 2 shows the number of these trips compared to the number of total trips for the years and areas considered in this study. Although single rectangle trips roughly represent 37% of the total trips, they are the most suitable data for our purpose.
As fishing activity quickly evolves, we chose to extract data of a quite reduced number of years to have homogeneous data and make the interpretation of the results easier. Therefore, the period examined extends from 1993 to 1997.
Information for each trip were grouped by month and simple averages were computed by rectangle. Single rectangle trips were not sufficiently numerous to analyse each year separately. A mean CPUE of all years was thus calculated for each statistical rectangle as the sum of catch divided by the sum of fishing time, taken over all single rectangle trips between 1993 et 1997. Aggregation over the years may be justified by the fact we are interested in characterising the average spatial and seasonal patterns of distributions, which are supposed to follow an unchanged life cycle for a given species. We are not so much interested in analysing inter-annual variability of distribution patterns. Nevertheless, the validity of pooling data from all years will be checked.
Celtic Sea fisheries are mixed fisheries and whiting catch depends on both the fishing strategy of a “metier” targeting a set of species and the individual fishing efficiency. Aggregation over trips is intended to smooth out as much as possible the “metier” and fishing power effects.
Market categories are used as rough proxies for the demographic stages of the population. There is some uncertainty due to the manual sorting of catches in the market hall, but accounting for market categories allows to distinguish at least mature and immature stages. Market category are weight classes. An inversion of the length-weight relationship ($W=2.76\times10^{-3}L^{3.358}$, Ould el Kettab 1993) allows to obtain correspondence in length. Resulting length classes are defined as follows : 23.44≤mark.cat.40<30 cm, 30≤mark.cat.30<33 cm, 331 mark.cat.20<37 cm and mark.cat. 10 >37 cm.

3. Method

3.1. Analysis of scientific survey data

The number of hauls, number of null catches and total whiting catches were collected for the 1997, 1998 and 1999 surveys. Then, basic statistics (mean, maximum, minimum and coefficients of variation) were computed on whiting CPUEs data for age groups 0, 1, 2 and 3+ (Table 1). CPUE data were aggregated by ICES statistical rectangles, to allow a comparison of the results obtained with commercial data. Finally, maps of distribution of whiting CPUE by age group were constructed for the 3 surveys (Figures 2a and 2b).

3.2. Commercial data analysis

First, analyses of variance were used to detect factors which have a significant influence on the spatial and temporal distribution of the studied population, and in particular to check for possible crossed effects between year and other factors.
Data have a numeric response (CPUE) and four categorical variables (factors) are tested : rectangle, year, month, and market category (mark. cat). Analysis of variance also allows to test for interactions between two or more factors. These interactions between factors are : rectangle*year ; rectangle*month ; year*month ; rectangle*mark.cat ; year*mark.cat ; month*mark.cat ; rectangle*year*month ; rectangle*year*mark.cat ; rectangle*month*mark.cat ; year*month*mark.cat ;

rectangle*year*month*mark.cat. Data were log-transformed in order to normalise the data distribution (zar, 1974).

In a second step, multivariate descriptive methods were implemented. This approach is chosen because spatial information is limited to ICES statistical rectangle, and not the precise location of hauls. Another type of analysis could be used if information were available at the scale of the fishing operation (haul). Among these methods, a Principal Component Analysis (PCA) is performed on a matrix where columns (i.e. variables) are the four commercial categories, and the rows (i.e. individuals) are the ICES rectangle-months. Each cell value of the table is the mean CPUE per market category over all trips corresponding to a given rectangle-month. This typology leads to group rectangle-months according to the abundance of the four market categories. Mean CPUE is computed per month for each rectangle, and are coded as illustrative individuals (Pelletier and Ferraris 2000).
PCA is carried out on log-transformed data as a log-transformation stabilize variance. The data matrix X of numerical values x_{ij} is transformed as follows : $x_{ij} - x_{.i}$ (mean of the i^{th} row) $- x_{j.}$ (mean of the j^{th} column) + $x_{..}$ (total mean). This "bicentration" of the data allows to accentuate the interrelations between the four market categories following their abundance in the rectangles and months.
In a third step, the individuals are clustered using their coordinates on the principal axes obtained from the PCA in a Hierarchical Classification Ascending (HCA) procedure following the method used by Pelletier and Ferraris (2000). The aim of the HCA is to group individuals into clusters as homogeneous as possible with respect to the variables. The groups obtained are clustered using a moving'centers procedure in order to improve the class homogeneity.
Test values are used to discriminate among variables for cluster characterisation. In the case of a quantitative variable, the test-value of the variable in a group of individuals is a measure of the distance between the general mean of the variable in the whole data set and the mean of this variable in the group (Lebart, Morineau *et al.* 1997). HCA assigns each individual "rectangle-month" of the data set to a cluster. Finally, monthly maps of spatial distribution of the clusters obtained by HCA are constructed by considering for each month, the cluster to which the rectangle-month belongs (Figure 7). A map of spatial distribution of the clusters to which illustrative individuals are assigned is also constructed (Figure 6). These multivariate analyses were carried out with the software SPAD.N (CISIA 1996), and analysis of variance and maps were constructed with the software Splus (Statistical Sciences 1993).

4. Results

4.1. Scientific surveys

Table 1 shows that the number of hauls and the number of null whiting catches are quite consistent between the three surveys. In 1999, the total whiting catches were significantly higher than in the two previous years. Perhaps, this can be attributed to the fact that 1999 survey took place later in the year. Histograms of CPUE by age groups for each survey (Figure 1) show that age groups 0 and 1 were the most abundant in the 1997 and 1999 surveys. In the 1998 survey, age groups 3 and 4 were the most abundant.
The spatial distributions of the CPUE values (kg/0.5h) of whiting for age groups 0, 1, 2 and 3+ are mapped for the 3 surveys (Figures 2a and 2b). The main feature arising from these maps is that the spatial patterns are quite consistent between the surveys. Indeed, we can observe that the bulk of the catches for all age groups were concentrated in the North of the Celtic Sea (ICES subdivisions 7g3, 7g2 and 7g1), in autumn. No spatial separation appears between young and old individuals at this season.

4.2. Analysis of commercial catch and effort data

4.2.1. Quantitative comparison of single rectangle trips number and total number of trips

Table 2 shows a comparison between the number of single rectangle trips and the total number of commercial trips. Mean percentage over all years of single rectangle trips is 37.40%. These percentages are the greatest in 1997 and 1993. So, the data used in this analysis correspond to a number of single rectangle trips ranging from 1700 to 3700 trips in the years studied.

4.2.2. Results of the analysis of variance

The significant and non significant factors from the analysis of variance are shown in Table 3. The four factors tested are significant. The 2^{nd} order interactions are all significant except the interaction year*month. The 3^{rd} order interactions are non significant except the interaction rectangle*year*month. The 4" order interaction is non significant.
It is interesting to examine the interaction between the three factors rectangle, month and market category closely, as in the following PCA and HCA, we analyse the mean of cumulated years from 1993 to 1997. So, a 3-factor analysis was carried out on the cumulated data (without the factor Year). The factors rectangle and month are significant but the factor mark.cat. is not significant. The non significant interaction between month and market category seems to indicate that the abundance of the different market categories is not much explained by monthly variations, but rather by their spatial distribution (significant interaction rectangle*mark.cat). This could explain why the interaction between rectangle*month*mark.cat. is non significant. The aim of the following PCA and HCA is to detect which entity of each factor leads to heterogeneity of the spatial and temporal distribution of whiting, without hypothesis on data distribution.

4.2.3. Principal Component Analysis

The data relative to single rectangle trips were formatted into a table of 560 individuals with 502 active individuals (the available combinations of rectangle and month) and 58 illustrative individuals (12 months and 46 rectangles) and 4 actives variables (the four market categories).
The percentage of inertia and cumulated percentages of the first three principal axes are shown in Table 4. The inertia of the data set may be seen as a measure of the variability of the data set. Individuals are best discriminated in the first axis which has the highest contribution of the data set. The first two principal axes enable to explain about 75% of variability of the data with 42 % explained by axis 1, and 33 % explained by axis 2. Consequently, the three first axes allows to have a good representation of the data set.
Figure 3 shows the projections of variables on factorial plane l-2 and on plane 2-3. Axis 1 is representative of younger individuals, and separates market category 40 (negative correlation with this axis) from market category 30 (positive correlation). Axis 2 is representative of all the market categories, and separate oldest individuals (the market categories 10 and 20) from youngest individuals (market categories 30 and 40).
The projections of individuals are not shown because the number of individuals are very numerous in comparison with variables.

4.2.4. Hierarchical Classification Ascending procedure

Figure 4 shows the dendrogram representing the hierarchical relationships between identified groups. The dendrogram is cut at the most important level of the aggregation index. It shows.4 well-separated clusters. The market categories are used to characterise each cluster. A high positive/negative test-value indicates that a market category has a higher/lower frequency in the cluster than on average among the individuals. A first division separates groups 1-2 from groups 3-4 and a second division leads to the four clusters. Table 5 shows the characterisation of the clusters by their representative variables (market categories) and by their characteristics axes (test values in brackets). Assignments of illustrative individuals (months and rectangles) in each clusters are also shown in Table 5. Variables are ranked by decreasing test values. Clusters were named after their typical market categories composition. So cluster number 1 is named “old” because market categories 10 and 20 have high positive tests values, and market categories 30 et 40 have negative test-values. This class presents high CPUE for the oldest individuals and smaller CPUE for younger individuals. It is the biggest cluster, with a size of 231 "rectangle*month". This cluster is mainly characterised by principal axis 2 of PCA. Cluster number 2, presents high CPUE for market category 40 (test value of 12.69) and smaller CPUE for the oldest individuals. This cluster is mainly characterised by principal axis 2 of PCA. Cluster number 2, exhibits high CPUE for market category 40 (test value of 12.69) and smaller CPUE for the oldest individuals. This cluster named “very young” comprises 132 individuals and is mainly characterised by the first axis. Cluster 3 corresponds to high CPUE for young individuals (market categories 30 and 40), it is called “young” and includes 74 rectangle-months. The most characteristic axis of this cluster is axis 2. Cluster number 4 (65 individuals) corresponds to high CPUEs for market categories 30 and 20, and lower CPUEs for others market categories. Axis 1 is the most characteristic axis of cluster number 4.

The factor month explains partly axis 2, and consequently clusters 1 and 3. Indeed, the distribution of month between clusters shows an opposition between March, September and October, mainly found in cluster 3 and the others months found in cluster 1 (Figure 5). So, March, September and October are associated to high CPUE for market categories 30 and 40. The decrease observed in June, on axis 1, is not observed in the results of classification. The factor rectangle also explains axis 2. Figure 6. shows that, on average over the year, cluster 3 (young individuals) is rather located in the West of the Celtic Sea and. in St Georges Channel, and cluster 1 (old individuals) in the Centre of the Celtic Sea and the West of the English Channel.

4.2.5. Maps of the clusters obtained from HCA

Figure 7 shows that the identified clusters are widely scattered spatially and seasonally. Yet, it seems that possible spatial patches are rather distributed following a South-West/ North-East gradient. In October, a group of neighbour rectangles emerges for cluster 3, in the Centre of the Celtic Sea following this gradient.

In general, old individuals have a quite scattered distribution, except in October, where a square of neighbour rectangles is observed in the South-West of the Celtic Sea. A group of closed rectangles appears in May and June for cluster 2 at the West of West English Channel and in the Centre of the Celtic sea. In July, this cluster appears at the Centre-West of the Celtic Sea. A small group of neighbour rectangles is observed for cluster 4 in January in the Centre of the Celtic Sea. In general, the patches are not observed for consecutive months and render the interpretation of the results difficult.

5. Discussion-Conclusion

The aim of this paper was to try to detect possible seasonal variations of spatial patterns of whiting from available information, i.e. the literature, scientific and commercial data. This analysis shows that is it is hard to detect preferential seasons and areas in its life cycle. Literature is sometimes contradictory about the large-scale migrations of whiting, which is supposed to concentrate during the first quarter of the year for spawning. For instance, Desbrosses (1948) indicates that whiting spawns all over its area of distribution without migration for reproduction.

The analysis of scientific CPUE data shows a concentration of most age groups in the North of the Celtic Sea in autumn. Literature does not mention a concentration in this area at this period, but rather in the first quarter of the year. This spatial pattern is not found either by the analysis of commercial CPUE data, at the same period, for older individuals. This last analysis seems to show in October a concentration of older individual in the South-West of the Celtic sea. However, this pattern is not observed the next month. Indeed, in November older individuals seem to have a more scattered distribution. It is difficult to discriminate which of scientific and commercial patterns approximate at best whiting life cycle. Results are driven by the method of analysis of the data or the collection of data themselves. Further analysis must be conducted so as to discriminate among patterns obtained by the two types of data.

Petitgas et *al* (1999) analysed explicitly the correlation between scientific and commercial CPUEs. They show that variance is an important parameter for a study of catchability and that, in the case of megrim in the Celtic Sea, selecting rectangles with low commercial variance leads to a linear relation between the two types of CPUEs. It could be interesting in further work to consider the variance of CPUEs to see if it can explain the different patterns obtained with the two type of data. In addition, data from scientific surveys were simply cumulated by ICES statistical rectangles. It would be more accurate to use kriging to extrapolate data at this scale. However, the comparison with the logbook information would still remain at the scale of the statistical rectangle.

Analysis of commercial data.

One objective of PCA is to reduce number of variables. In our analysis number of variables is already low, but we are interested in still more reduce this number, in the perspective of modelling the population dynamics of whiting. We could expect to obtain only two distinct groups after PCA and HCA, for instance, one group of old individuals and one of young individuals. These two groups are observed but also two others groups, one of intermediate individuals (market categories 30 and 20), and one of the market category 40 opposed with market category 30, leading interpretation of the results more difficult. It must be notified that a study of discarding practices in the Celtic Sea, using data collected by observers onboard fishing vessels (Cotter et *al,* 1999) shows that almost all whitings of size below 35 cm are discarded. Above 40-45 cm depending on the "metier", whiting are generally no longer discarded. So, the catches of small commercial-size fish are quantitatively underestimated due to discards. Accounting for discards in the analysis would certainly improve the results, but the spatial and temporal coverage of the discard data were unfortunately not sufficient to take this information into account in our analysis.

Data collection

The determination of the distribution of the studied species could be widely improved if, for instance, effort location were known at a better resolution than the statistical rectangle. One of the most important drawbacks of commercial data is that catch (in this case) is not known per rectangle for about 60% of the trips. Restriction of the analysis to single rectangle trips is not desirable because the proportion of these trips may be variable from year to year and from one "metier" to the other. Results are in theory not extrapolable to the rest of the trips. Such extrapolation could be done if one could suppose that single rectangle data are a random sample of all the trips. An alternative to the analysis of single rectangle trips could be to allocate catches according to the time spent fishing in a rectangle during the trip. However, an implicit hypothesis of this option is that abundance is the same in all rectangles. This choice would also be inconsistent with what we tried to show, that is heterogeneity of abundance between areas and seasons.

Choice of data coding. Improving results

Choices of data coding is of primary importance, and are guided by the objectives of the analysis, or by the structure of the data set. In our analysis the choice to bicentrate data is very important. It allows to avoid apparition of a "size effect" (all variables positively correlated) on axis 1. This effect would lead after an HCA, to clusters, that would be each of them characterised by a high CPUE for each one of the market categories. This analysis would not show what we are interested in, i.e. the relations between the four market categories following their spatial and temporal distributions.

One perspective for improving the analysis of commercial data could be to implicitly integrate spatial and temporal information by means of a neighbour matrix in multivariate analysis. This practice should help to identify groups of neighbour rectangles and months (Comillon, Amenta et *al. 1997).*

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Celtic Sea	1997				1998				1999			
	51				56				61			
Number of null catches hauls	35				35				29			
Total catches kg	438				346				1482			
Cpue kg/0.5 h	**age0**	**age1**	**age2**	**age3+**	**age0**	**age1**	**age2**	**age3+**	**age0**	**age1**	**age2**	**age3+**
Minimum	0	0	0	0	0	0	0	0	0	0	0	0
Average	9.94	12.63	6.06	20.03	3.65	1	2.77					
Maximum	49.01	62.73	20.74	59.76	30.74	14.00	21.35	106.65	334.6	308.0	221.4	134.95
C.V.	1.94	1.57	1.32	0.97	2.5	3.60	2.53	0.53	2.35	2.18	3.12	2.92

Table 1. Basic statistics for the 1997, 1998 and 1999 scientific surveys for whiting age groups 0, 1, 2 and 3+ (C.V.: coefficient of variation).

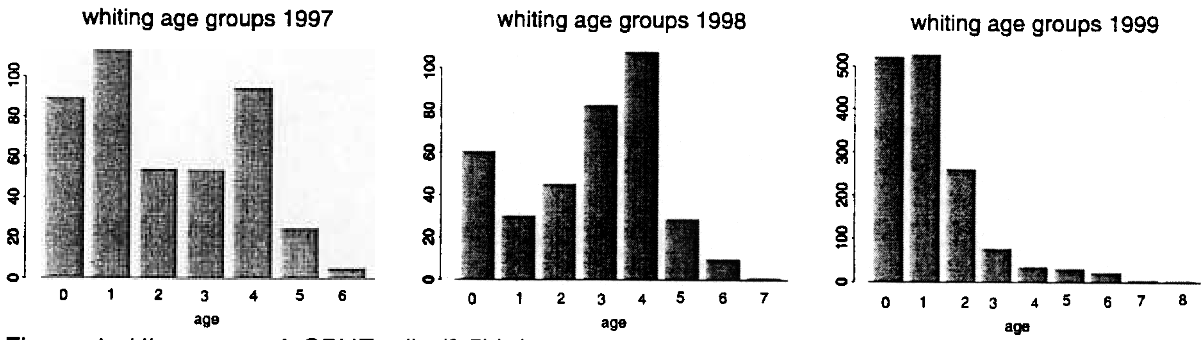


Figure 1. Histogram of CPUEs (kg/0.5h) by age groups, for the 1997, 1998 and 1999 scientific surveys.

Years	**1993**	**1994**	**1995**	**1996**	**1997**
Number of total trips	5816	5112	5287	5284	7545
Number of single rectangle trips	2188	1695	1802	1786	3647
Percentages	**37.62**	**33.16**	**34.08**	**33.80**	**48.34**

Table 2. Comparison of the number of single rectangle trips and the number of total commercial trips for the years 1993 to 1997.

	Significant factors	**Non significant factors**
4 factors	rectangle, year, month, mark.cat., rectangle*year, rectangle*month, rectangle*mark.cat., year*mark.cat., month*mark.cat., rectangle*year*month,	year*month, rectangle*year*mark.cat, rectangle*month*mark.cat, year*month*mark.cat, rect*year*month*mark.cat
3 factors	rectangle, month, rectangle*month, rectangle*mark.cat.,	mark.cat., month*mark.cat, rectangle*month*mark.cat

Table 3. Results from the analysis of variance of commercial data : significant and non significant factors of log-transformed CPUE data per rectangle, month, year and market category (4-factors and 3-factors analysis of log-transformed data).

	Percentage of inertia (%)	cumulated percentage (%)
Axis 1	42.36	42.36
Axis 2	33.11	75.47
Axis 3	24.53	100.00

Table 4. Results of the PCA performed on commercial data for whiting. Percentage of inertia and cumulated percentages of the first three principal axes.

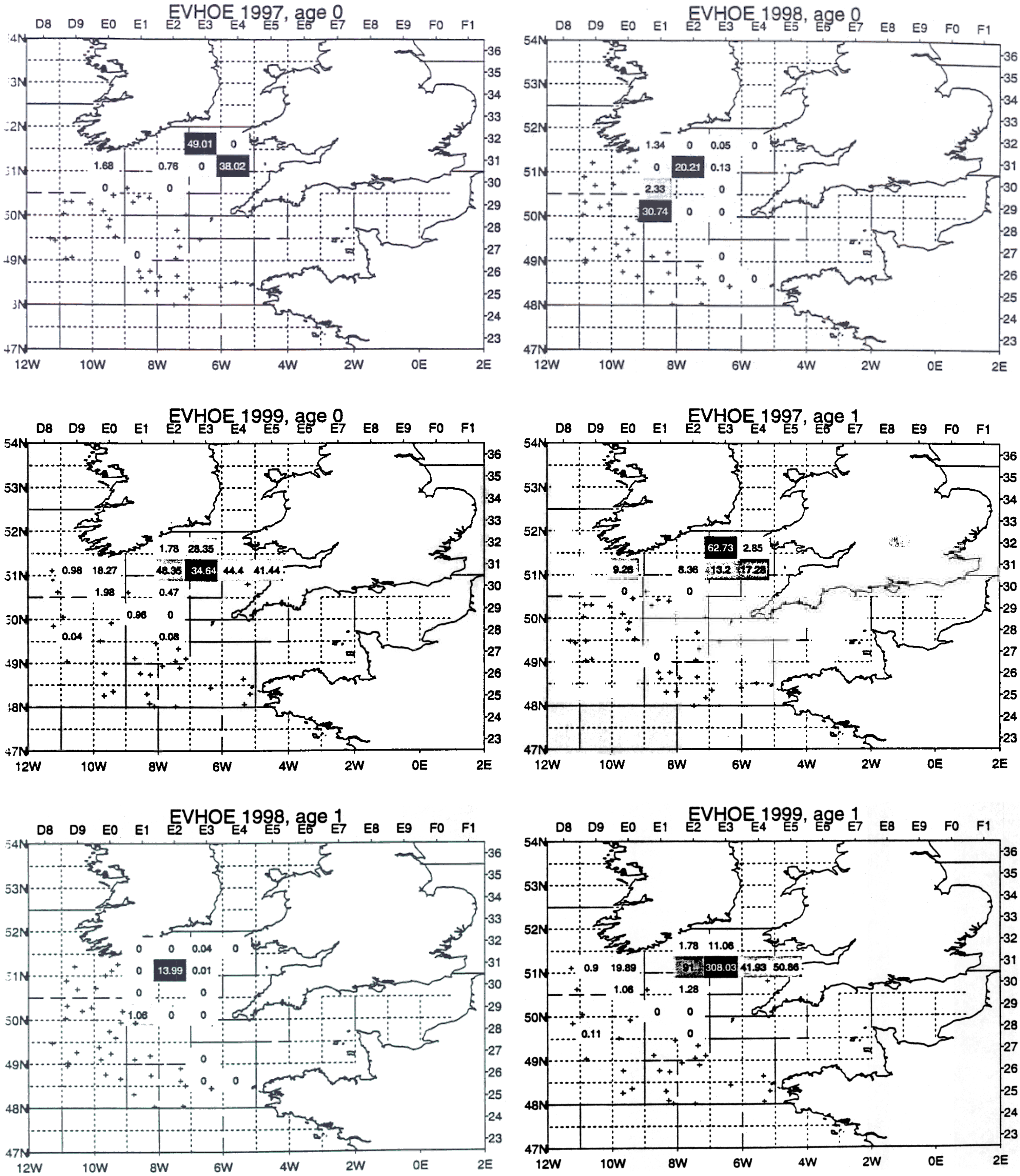


Figure 2(a). Distribution of cpue (kg/0.5h) of whiting age groups 0 and 1, cumulated by ICES statistical rectangle observed in the French survey EVHOE in 1997, 1998 and 1999. Grey levels are proportional to CPUE values. Symbols "+" indicates surveys points where catches of whiting were null.

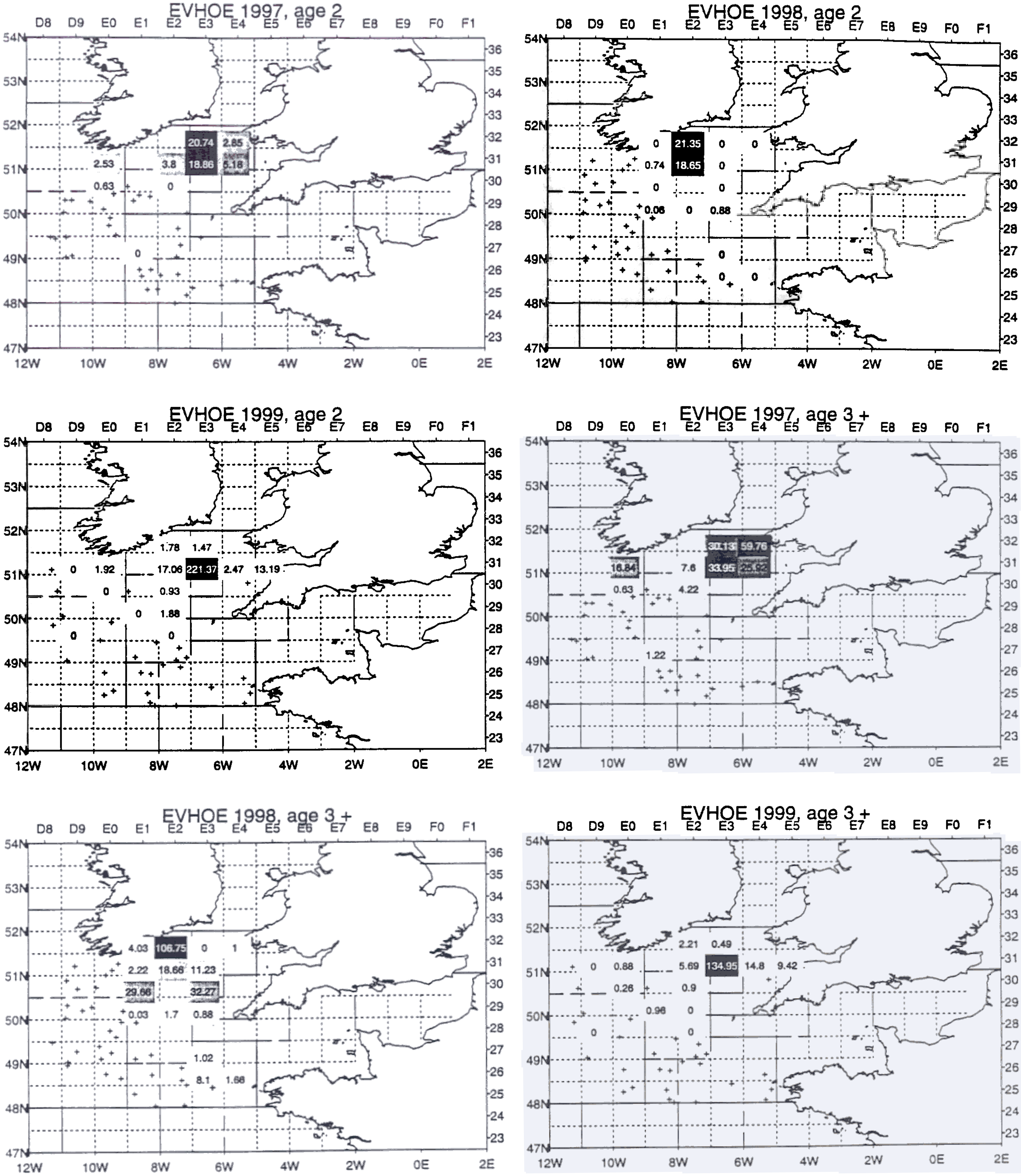
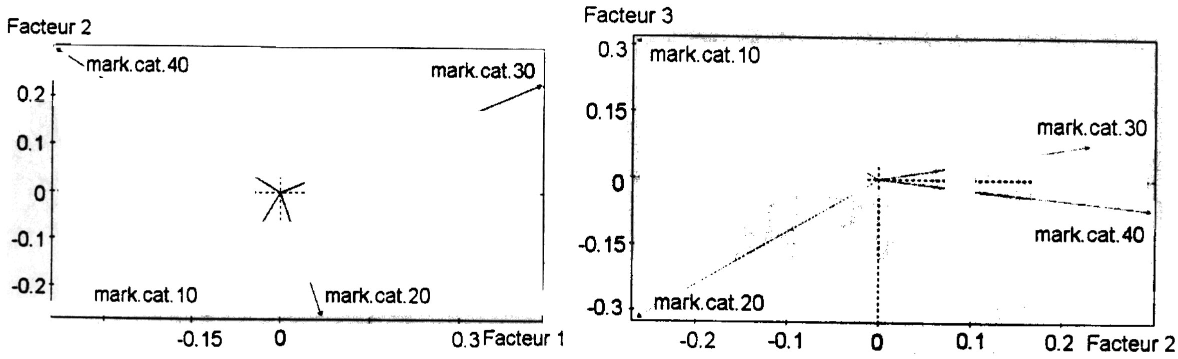


Figure 2(b). Distribution of cpue (kg/0.5h) of whiting by age groups 2 and 3+, cumulated by ICES statistical rectangles, in the French survey EVHOE in 1997, 1998 and 1999. Grey levels are proportional to the CPUE values. Symbols "+" indicate survey points where catches of whiting were null.



(a) (b)

Figure 3. Results of the PCA performed on commercial data for whiting. Active variables (the 4 market category) are shown in the factorial plane made by the two first principal axis (a) and in plane 2-3 (b).

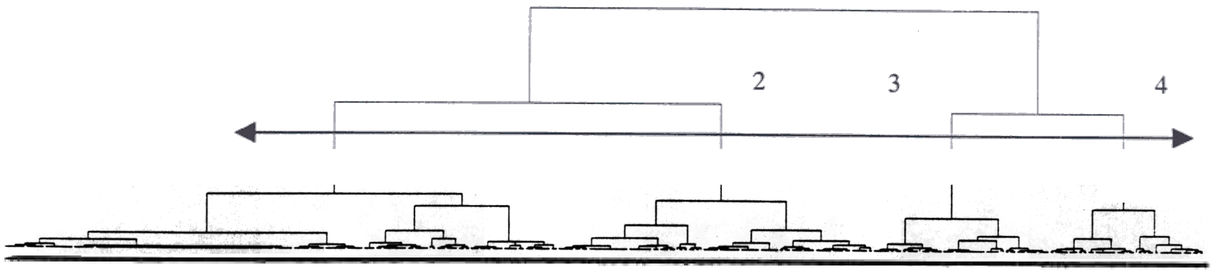


Figure 4. Dendrogram of the Hierarchical classification of individuals based on their factorial coordinates of the PCA.

Cluster N° and names	Cluster size	Months	Rectangles	Axes	Representative variables of the cluster
1 old	231	1, 2, 4, 5, 6,7,8,11,12	26E4 ,25E4, 28E5 28E4, 31E3 , 26E5, 29E6 , 28E6, 27E6 27E7, 32E4, 29E4, 32E2, 27E3 , 29E3 28E3, 29E2 , 28E2, 26E1 , 30E3	AXE 2 (-12.264) AXE 3 (2.416) AXE 1 (0.470)	10 (+9.26) 20 (+5.92) ; 30 (-4.84) 40 (-8.15)
2 very young	132		30E4 , 31E1 , 29E7 , 31E5 , 26E2 , 29E5, 27E1	AXE 1 (-14.623), AXE 3 (-3.452), AXE 2 (1.265)	40 (+12.69) & 10 (+0.95) ; 20 (-0.61) & 30 (-12.75)
3 young	74	3, 9, 10	25E2, 26E3 , 25E3, 32E3 ,28E7, 30E1, 31E4, 31E2 ,30E2, 27E2, 27E5, 26E6, 27E4, 25E1, 29E1, 28E1, 30E5	AXE 2 (14.028) AXE 3 (2.943) AXE 1 (0.851)	30 (7.64) 40 (7.44) 10(-6.86) 20 (-10.88)
4 intermediate	65		25E5, 26E7	AXE 1 (15.262) AXE 3 (-2.631) AXE 2 (0.943)	30 (+13.37) 20 (+3.97) 10 (-6.93) 40 (-11.01)

Table 5. Results of the Hierarchical Classification Ascending procedure performed on commercial data for whiting. Characterisation of the clusters by their representative variables (market category, with test values in brackets) and their characteristic axes (test values in brackets), and assignment of illustrative individuals (months and rectangles) in each clusters, clusters size, numbers and names.

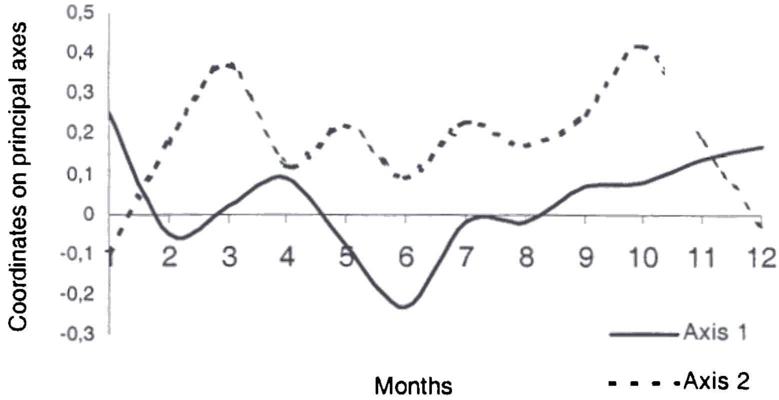


Figure 5. Results of the PCA performed on commercial data for whiting. Coordinates of each illustrative individuals "months" (monthly mean on all rectangles) on principal axis 1 and 2.

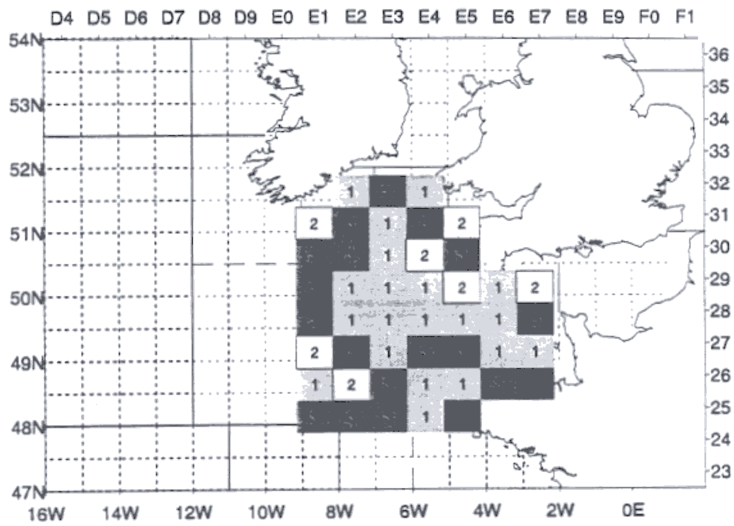


Figure 6. Results of the Hierarchical Classification Ascending procedure performed on commercial data for whiting. Map of the clusters numbers associated to each illustrative individuals "rectangle" of the PCA.

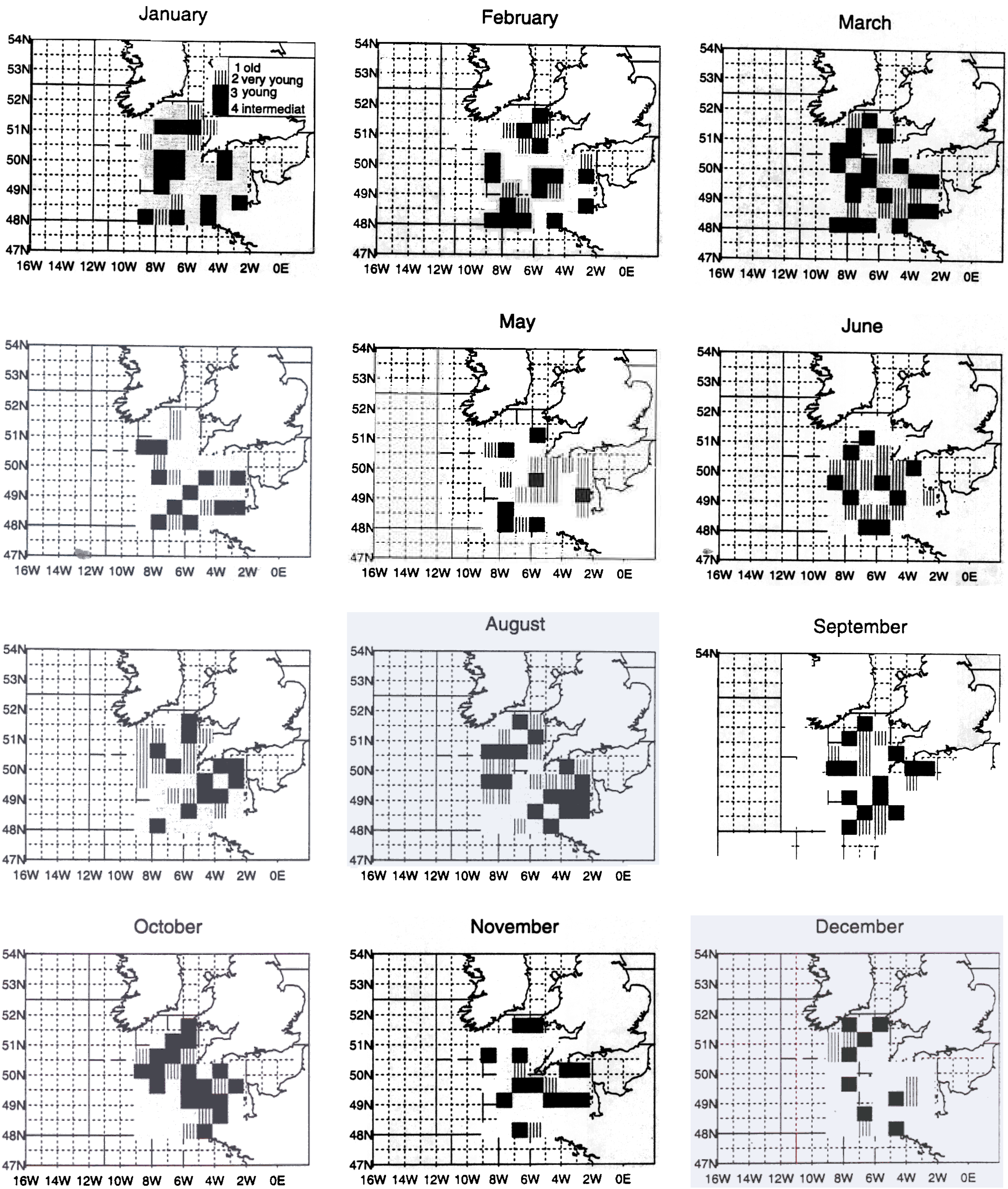


Figure 7. Monthly maps of spatial distribution of clusters coming from Hierarchical Classification Ascending procedure.