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Differences between near bottom biomass spatial structure observed in the Irish Sea, the North Sea and the Barents Sea in recent years

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Abstract

Based on acoustic data and trawl catches collected during bottom trawl surveys, we compare the spatial structure of the biomass available in the first meters above the bottom in three different regions, the Barents Sea (1997-2002), the North Sea (1999-2003) and the Irish Sea (1997-2002). The objective was to compare areas with different levels of resource. Conclusions are conditioned to the number of samples available in each respective study area (large for Barents Sea, medium for the North Sea and small for the Irish Sea). This analysis combines acoustic and trawl data. The acoustic data were used to improve the knowledge of catch data spatial structure. Most of the time, hauls are too far to be correlated. Acoustic data could allow to take account spatial structures with shorter range since they are collected along the vessel track. The acoustic information can improve the accuracy in the catch spatial structures analysis. Two groups of species are distinguished: pelagic fish and demersal fish. Spatial structures are observed in the Barents Sea made of small scale heterogeneities and large scale structures of 300 nautical miles. Such a structure is consistent through time (i.e. from 1997 to 2002). Spatial patchiness is extremely important in the North Sea causing the classical geostatistical tools to be useless. Apart from the ecological interpretation of the density-dependency of spatial structures, we describe some possible ways to handle patchy distributions.

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Introduction

As a general statement, the spatial structures of fish communities are expected to depend on their biomass. The higher the level of resources, the more fish are expected to be structured. At the extreme, when very little fish remain in a given area, one may expect them to be concentrated in some very few local sanctuaries. Such tendencies have already been observed in practice. The spatial structure of haddock as observed from IBTS (International Bottom Trawl Survey) survey data for instance, happens to be stable until the level of the stock is too low (Rivoirard et al., 2000). Warren (1997) also pointed out that, in the case of the Canadian Northen cod stock, a trend, coincident with the decline of the stock was observed from a population with strong spatial structure to one with little or no structure. From a statistical this induces technical problems as the variables to study are strongly skew and from a geostatistical point of view the variogram becomes useless. Apart from the interesting question of the density dependency of the spatial structure, it has also long been observed that variograms of fish concentrations often give results that are difficult to interpret straightforwardly. The question of having operational tools for describing spatial distributions of skew variable mis then crucial and opened.

Direct stock assessments of sparse species face also directly this difficulty. Estimations based on highly skew data are deeply uncertain. In this context, the estimation of indices of abundance from bottom trawl surveys could be improved by the use of dense acoustic observations made during the vessel is shipping from one sampling station to the next. This is the main objective of the EU Framework 5 project CATEFA (Combining Acoustic and Trawl data for Estimating Fish Abundance) started in 2001. However, even if they are dense in space, acoustic values recorded between two sampling stations may happen to be as skew as the catch variables and the objective of having operational tools for describing their structures is relevant is some of the cases presented in this paper.

This paper, based on survey data of three different areas (Barents Sea, North Sea and Irish Sea) with different respective levels of biomass experienced in the past decade, attempts to describe these phenomena with geostatistics tools. In the first part, we use classical tools like variograms or cross variograms to describe spatial structures of catch and acoustic data. In the second part, we suggest the use of indicators as a a way to handle situations where variograms fail.

Material

Data of scientific bottom trawl surveys with coincident acoutic measurements in the North Sea (IBTS), the Irish Sea (Northern Irish Bottom trawl surveys) and the Barents Sea (Combined acoustic and bottom trawl surveys for cod and haddock) are used in this paper. For a given survey, characteristics such as tow time, vessel gear, trawl geometry, etc… are standardized to make data comparable. Two types of data are then available : catch numbers and acoustic energies (Fig. 1).

Catch numbers are collected during bottom trawls. Two groups of species are been used: demersal fish and pelagic fish (bottom fish are not considered here). For each group the total numbers of corresponding fish caught in the net are sum up.

Nautical Area Scattering Coefficient (NASC) as defined by MacLennan *et al.* (2002) are expressed in $m^2 \cdot n.mi^{-2}$ (the threshold use for the integration is -70dB). NASC values are available both during and between trawl tracks. For on station NASC, integration is over the all trawling station which is more or less stable for a given survey. Underway NASC are available at fixed Elementary Sampling Distance Units (ESDU). As these ESDU are different from tow lengths, underway NASC have been regularized to the nearest possible distance compatible with the mean towed distance, that is 3 n.mi in the Irish Sea, 1 in the Barents Sea and 2 n.mi in the North Sea. This insures statistical consistency between on station and underway NASC values. NASC values are provided by vertical layers: the ten first layers above the bottom are one-meter high and the next layers are ten-meters high. The layers used here are bottom referenced (Fig. 1).

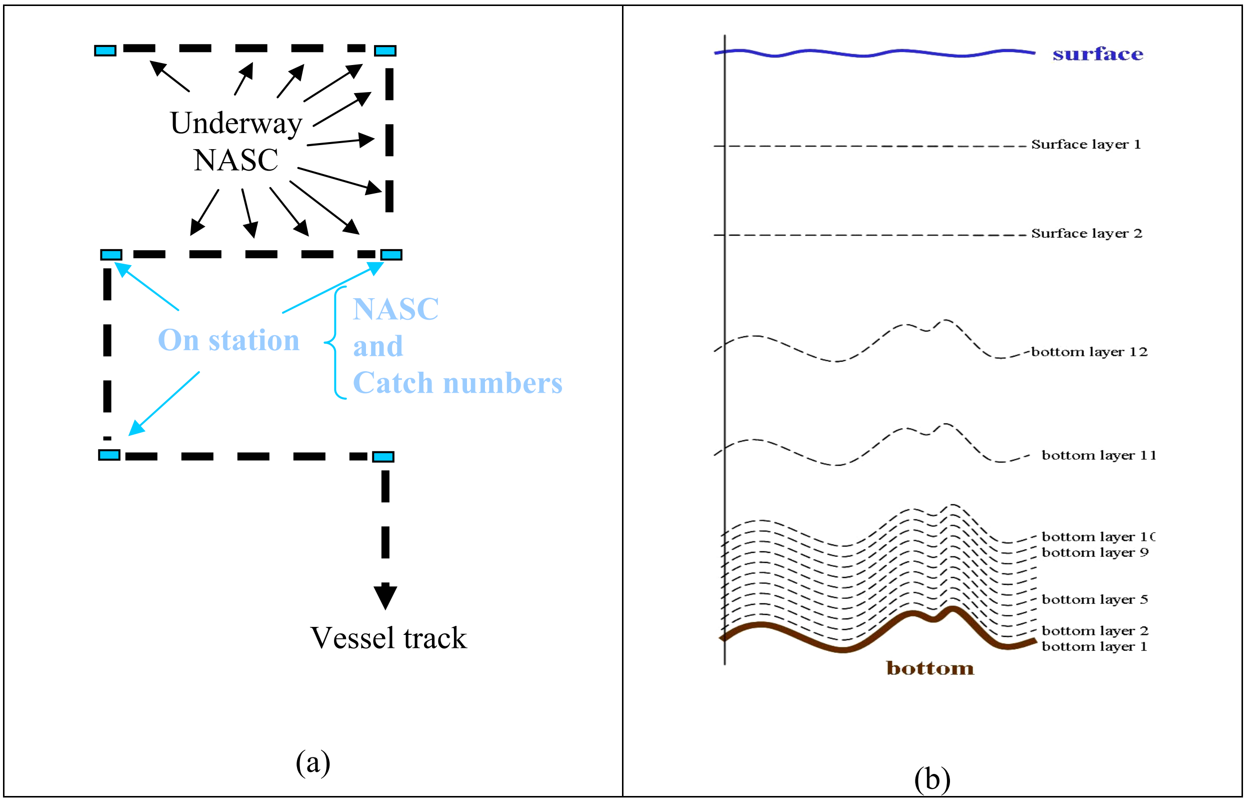


Figure 1. Sampling characteristics. (a) Relative locations of on station and underway variables. (b) Depth layers bottom or surface referenced depth layers used for the acoustic.

Table 1 summaries the main characteristics of each survey.

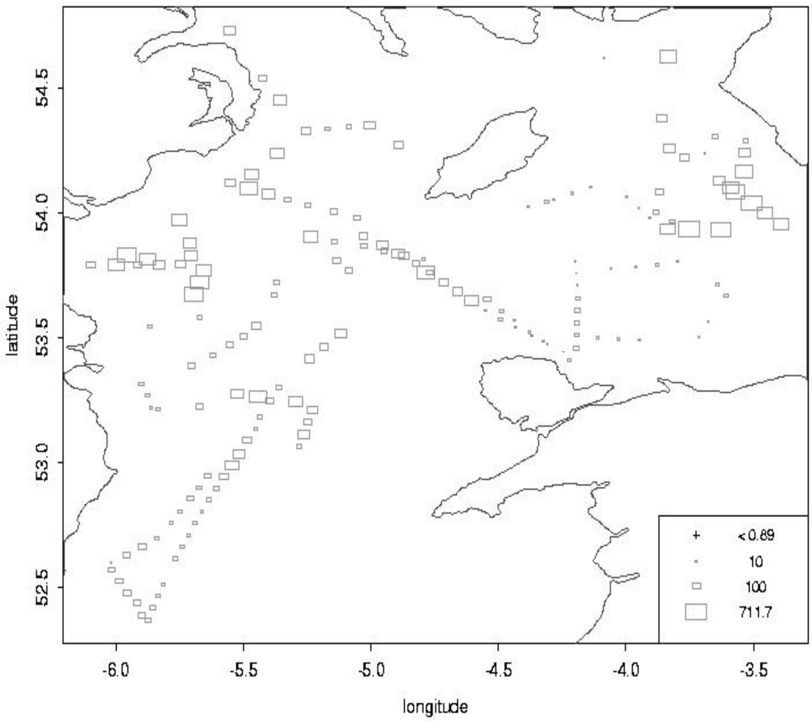
In the Irish Sea, the surveys are often small (20 or 30 hauls). They follow a random sampling design (Fig. 2), stratified by depth. Depth varies between 25 and 150 m, with most species concentrated on the continental shelf. Four surveys are available: autumn 1997, winter 2000, autumn 2001 and winter 2002. The proportion of pelagic fish is higher than the proportion of demersal fish which corresponds to the overall decline of the demersal biomass, such as cod biomass, observed during recent decades (ICES Cooperative Research Report No. 255).

In the North Sea (Fig. 3), IBTS surveys follow a random stratified sampling (data are not collected during the night). The surveys are available in 1999, 2000 and 2002 for Scotland, 2000, 2001 and 2002 for England and 2002-2003 for France. Each survey gets between 60 and 80 hauls. The general context of this area is that biomass of many demersal species has decreased during the past 10 years. In the meantime, the pelagic stocks have been fluctuating considerably between years (ICES Cooperative Research Report No. 255). In the present dataset, the pelagic numbers change greatly between Scottish, English and French catches. On the other hand, demersal catches are homogeneous between the three countries. In 2000, demersal catches have been more important. The North Sea is the area where distributions of NASC values are the most asymmetrical, with many low values and few extremely high values. For French data for instance, 65 % of the total energy collected on-stations are concentrated in 3 % of the stations. Catch numbers are, however, less skew (26 % of the total pelagic catches are in 3% of the stations).

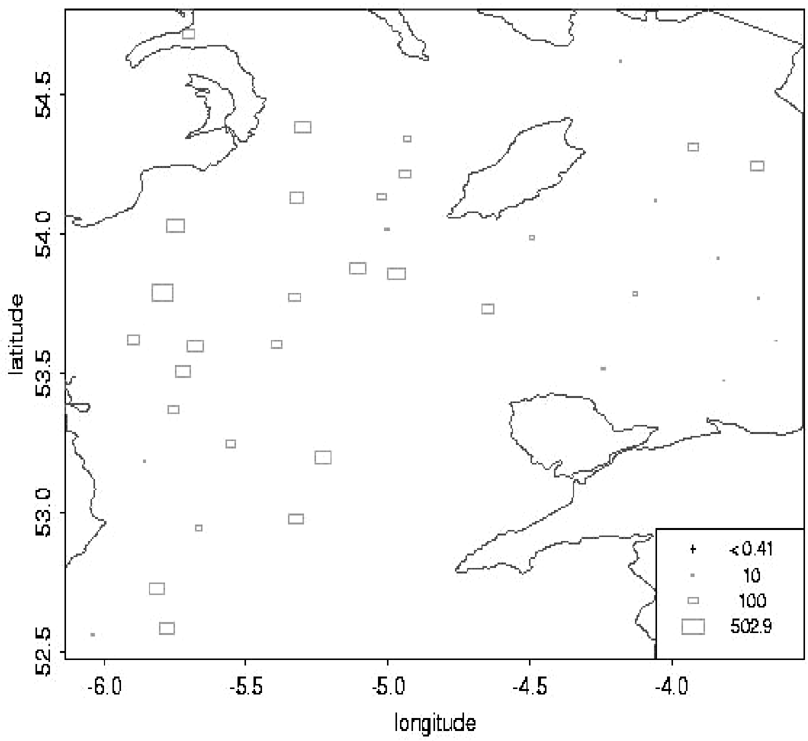
In the Barents Sea (Fig. 4), sampling is targetting a regular grid with a haul every 20 n.mi. Sampling size is quite large as urveys get between 200 and 300 hauls. Available surveys are 1997, 1998, 1999, 2000, 2001 and 2002. The proportion of demersal fish is higher than the proportion of pelagic fish and biomass seems to have been quite stable since 1997, except for some fluctuations of demersal numbers. Pelagic catches are strongly skew (3% of the hauls explain 60% of the total catches in 5 out of the 6 available surveys). However, large concentrations of fish tend to occur where the surface temperature is below zero, because of the polar front effect. Since outliers typically have a large impact on the results, this part of the data needs particular attention. As a first step we have chosen to exclude trawl stations with surface temperature below zero from the analysis.

Table 1. Main characteristics of the various survey used in the analyses.
ESDU : Elementary Sampling Distance Unit

Area	Source	year	month	Number of stations	Number of Underway-ESDU (after regularization)	Mean towed distance (n.mi.)	depth range	Mean demersal catch numbers	Mean pelagic catch numbers
Barents Sea	IMR	1997	02- 03	176	5209	1.50	143 – 699	1 434	97
Barents Sea	IMR	1998	02	198	5135	1.53	63 – 720	745	227
Barents Sea	IMR	1999	01- 02	223	5567	1.49	104 – 480	1 382	606
Barents Sea	IMR	2000	01- 02	302	7680	1.42	58 – 550	845	452
Barents Sea	IMR	2001	01- 03	300	7666	1.49	55 – 487	1 299	414
Barents Sea	IMR	2002	01- 03	287	7383	1.44	63 – 542	698	215
North Sea	FRS	1999	01- 02	44	468	1.8	45-150	2 440	400
North Sea	FRS	2000	01- 02	46	351	2.01	48 – 144	6 625	525
North Sea	CEFAS	2000	08- 09	71	1038	1.98	24-178	7 049	4 637
North Sea	CEFAS	2001	08- 09	70	883	2.01	24 - 211	3 597	2 656
North Sea	CEFAS	2002	02	23	1140	1.98	24 – 84	994	3 496
North Sea	FRS	2002	01- 02	47	430	1.98	49 – 150	2 512	598
North Sea	IFREMER	2002	02	77	440	1.83	9 – 88	1 078	5 861
North Sea	IFREMER	2003	02	82	722	1.89	14- 90	883	4 562
Irish Sea	QUB	1997	10	13	84	3.00	25 – 103	14 357	7 506
Irish Sea	QUB	2000	3	37	110	2.90	26 – 106	3 990	6 139
Irish Sea	QUB	2001	3	20	Not used	3.00	30 – 103	Not used	Not used
Irish Sea	QUB	2001	10	34	236	2.70	23 – 90	12 927	21 392
Irish Sea	QUB	2002	3	41	173	2.85	24 – 102	3 975	6 314

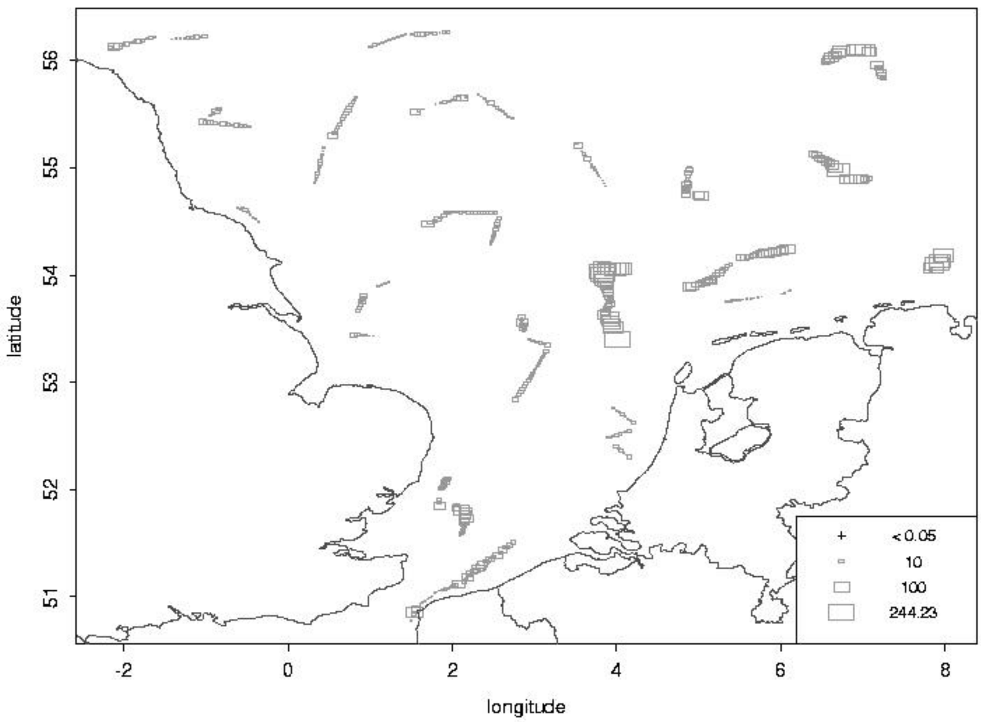


(a) “underway”acoustic data regularised to 3 n.mi .

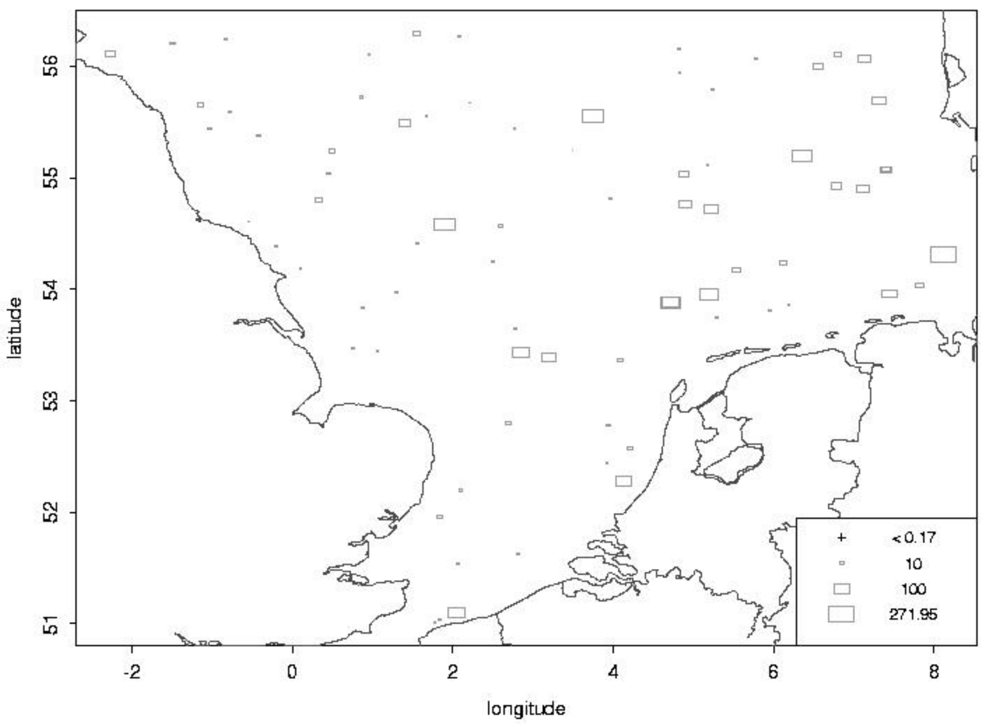


(b) “on station”acoustic data..

Figure 2 Sampling scheme and proportional representation of the sum of the first 5 acoustic layers (layer1-5). North Irish Bottom trawl survey 2001. Data larger than 200 $m^2 \cdot n.mi.^{-2}$ removed for lisibility.

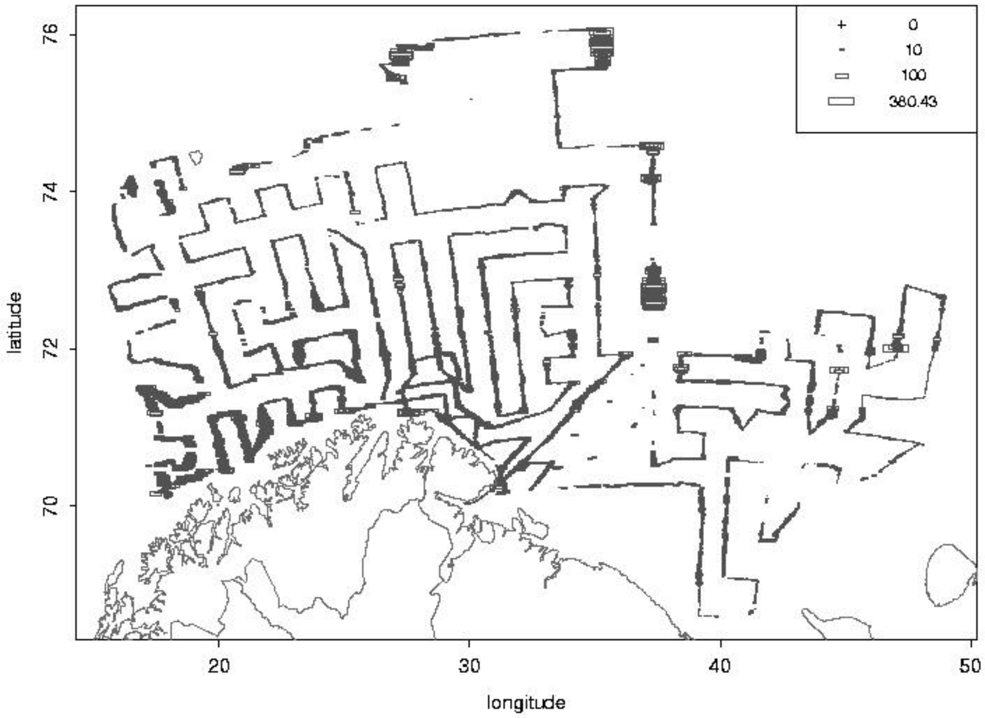


(a) “underway”acoustic data regularised to 1.8 n.mi .

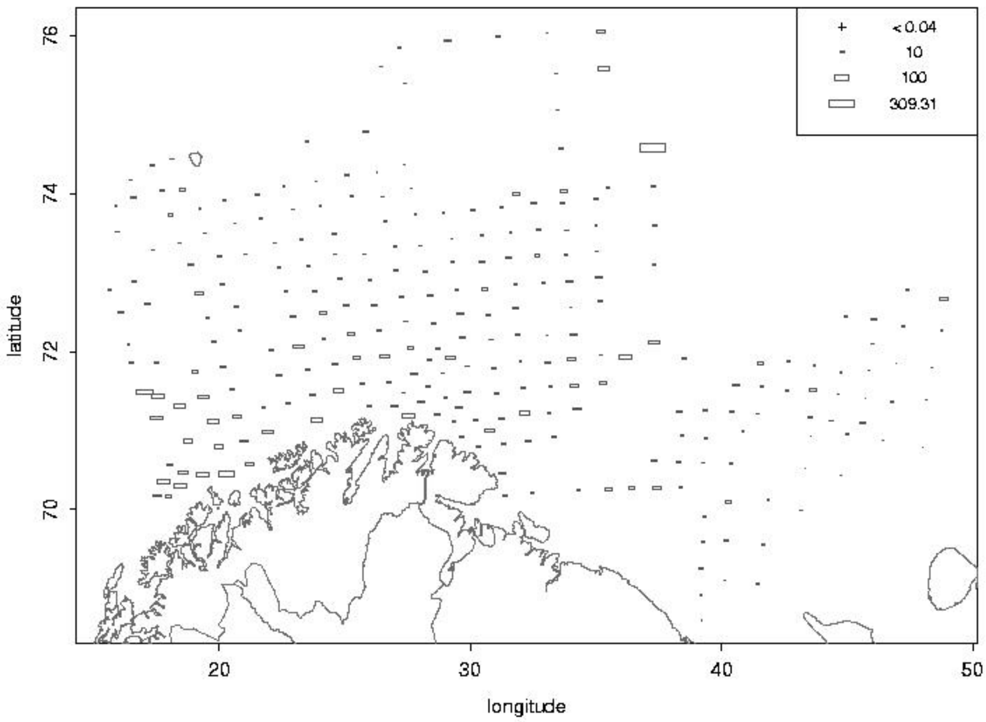


(b) “on station”acoustic data.

Figure 3 Sampling scheme and proportional representation of the sum of the first 5 acoustic layers (layer1-5). IBTS 2002. French leg. Data larger than 200 $m^2 \cdot n.mi.^{-2}$ removed for lisibility.



(a) “underway” acoustic data.



(b) “on station” acoustic data.

Figure 4. Sampling scheme and proportional representation of the sum of the first 5 acoustic layers (layer1-5). Norway 2001. Data larger than 100 $m^2 \cdot n.mi.^{-2}$ removed for lisibility.

Methods

In geostatistics, fish distribution is considered as one possible outcome of a random function usually denoted Z(x), x being a point in the study space. When two variables are considered, say acoustic and trawl catches, they are denotes $Z_1(x)$ and $Z_2(x)$. The main geostatistical tools used for studying spatial structures in the present communication are briefly recalled.

The variogram :

$$\gamma(h) = \frac{1}{2}\operatorname{var}\left[Z(x) - Z(x+h)\right]$$

measures the mean square differences between two points distant of h (the distance h is expressed in nautical miles after the coordinates have been properly projected in a one to one reference system). The increments of Z(x) are assumed to be zero on average.The variogram starts at 0, increases more or less quickly with h to the total variance of Z(x), if Z(x) is stationary. The range of $\gamma(h)$ is the minimal distance such that total variance is reached. Two points more apart than the range are no longer correlated. The slope at the origin is linked to the spatial regularity of Z(x). The nugget effect is the discontinuity of the variogram at the origin: higher is the nugget effect, less Z(x) is spatially structured. Variograms estimations are made with omnidirectional distance classes. For underway NASC, distance lag equal the ESDU size. For catch numbers (demersal or pelagic groups), distance lag equal the average distance between neighbouring samples.

The cross variogram:

$$\gamma_{12}(h) = \frac{1}{2}E\left[\left(Z_1(x) - Z_1(x+h)\right)\left(Z_2(x) - Z_2(x+h)\right)\right]$$

quantifies parts of the structures of Z_1 and Z_2 that are common.The increments of Z_1 and Z_2 have to be stationary. Its estimation requires to know both variables at any sampling point. In the present case, it can only be used to compute cross structures between on station variables. Distance lags used for the estiamtion are then equal to the inter samples distance. Cross variograms start at 0, and can be negative if the increase of one variable over a given distance is associated on average with the decrease of the other variable for the same distance.

The cross correlogram:

$$\rho_{12}(h) = Correlation\left[Z_1(x), Z_2(x+h)\right] = \frac{Cov\left[Z_1(x), Z_2(x+h)\right]}{\sigma\left[Z_1(x)\right] . \sigma\left[Z_2(x)\right]}$$

gives the correlation between $Z_1(x)$ and $Z_2(x+h)$ as a function of the distance h. The correlation between $Z_1(x)$ and $Z_2(x+h)$ has to be stationary, i.e. independent on x. This is a stronger assumption than the one required when using cross variogram. However, $Z_1(x)$ and $Z_2(x)$ can be known for different sampling points. Cross correlograms are then used to study the correlation between underway NASC values denoted $Z_1(x)$, and on station variables denoted $Z_2(x)$ at fine scale, i.e. for distances of the order of magnitude of inter sample distance. When $Z_2(x)$ are the on-station NASC values, results are referred to as "acoustic cross correlogram". When $Z_2(x)$ are the catch (demersal or pelagic) numbers, results are referred to as "acoustic-catch cross correlogram". The cross correlogram is more convenient than the cross covariance because the two variables are not observed with the same sampling density : few tens for on-station variables and few hundreds for underway NASC. Given the skewness of the distributions, the levels of variability of each variable might be largely different only because they do not concern the same populations of sampling points. The standardisation reduces this problem. Cross correlograms are non symmetrical tool and are used to analyse the variation of the correlation between the on-station data and the acoustic collected close to this station, distinguishing the acoustic collected before and after the haul.

Results

Choice of the number of layers

To simplify the modelling the study has been focussed on a post-processed acoustic variable: the sum of acoustic layers from the bottom such that the correlation coefficient with catch data was maximal (Fig 5).

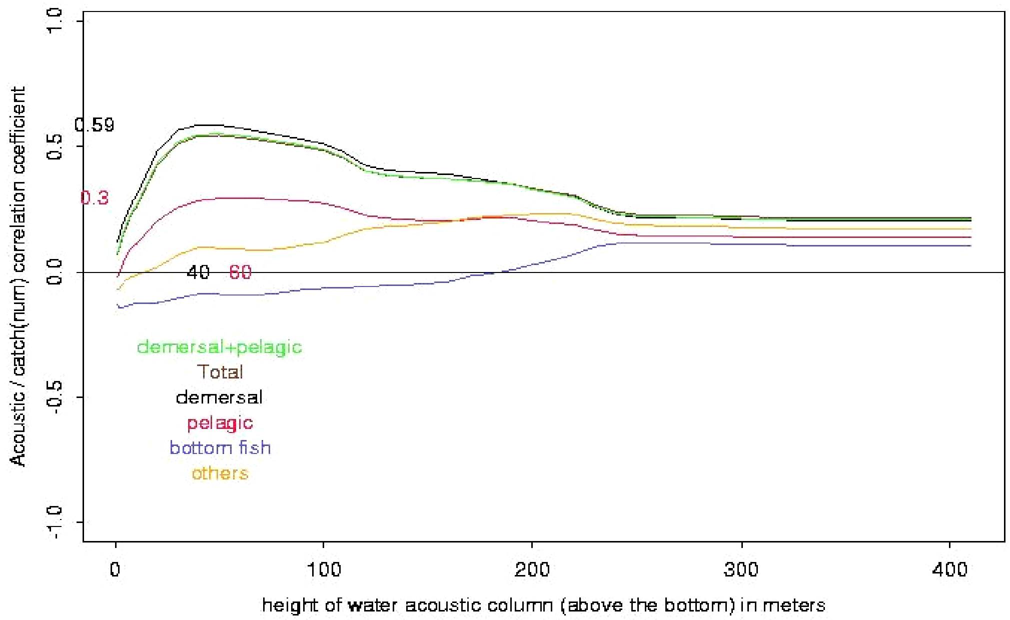


Figure 5. Variation of the correlation coefficient between the acoustic and the catches number according to the number of layers integrated (Norway On-station Data 2001). The x-axis is the height of acoustic column integrated in meters (the maximum is reached for 40m, and the correlation coefficient corresponding for the Demersal number is equal to 0.59)

Over this dataset, the average vertical distribution of the biomass increases from few meters above the bottom to the bottom (Bez *et al*., 2002). The functions of the correlation coefficient between acoustic and catch on-station according to the height of the water column are then often flat and the maximum is not always very distinct. In addition, as distributions are very asymmetrical, with some rare very high values, the correlation coefficient is very sensitive to these rare high values and is not a very good representative of the real relationship between the variables. Correlation coefficients (Table 2) are more likely giving a clue for understanding.

The optimal number of layers to integrate happens to be quite different for demersal and pelagic fish (Table 2).
For the Barents Sea (Table 2) the optimal height is on average 80m above the bottom for demersal fish and 150m above the bottom for pelagic fish. The correlation coefficients are often greater between NASC and the demersal number than between NASC and the pelagic number, except in 1998 and 2000.

Table 2 Height of the water column above the bottom (in meters) such taht the correlation between acoustic and catches is maximal. Yellow cells indicate, between demersal and pelagic group, the one with the largest correlation**.** These will be further selected for the analysis.

Survey	Demersal fish		Pelagic fish	
	height above the bottom (in meters)	correlation coefficient	height above the bottom (in meters)	correlation coefficient
Norway 1997	70	0,36	40	0,13
Norway 1998	1	0,39	150	0,68
Norway 1999	3	0,62	10	0,17
Norway 2000	300	0,72	300	0,77
Norway 2001	40	0,59	60	0,31
Norway 2002	80	0,27	310	0,17
Irland 1997	8	0,73	1	0,94
Irland 2000	3	0,07	7	0,73
Irland 2001	20	0,5	3	0,73
Irland 2002	8	0,17	4	0.92
IFREMER 2002	40	0,02	3	0,26
IFREMER 2003	0	0	0	0
CEFAS 2000	4	0,25	7	0.27
CEFAS 2001	40	0,17	10	0,14
CEFAS 2002	10	0	20	0.32
Scotland 1999	1	0,24	1	0,4
Scotland 2000	0	-0,01	20	0,73
Scotland 2002	1	0,18	30	0,27

In the Irish Sea, the coefficients are systematically greater between the acoustic and the pelagic numbers than with the demersal numbers. This could be explained by the high proportion of pelagic fish in this area. The optimal height is about the 4 meters above the bottom for the pelagic numbers and about 8 or 9 meters for the demersal.

For the North Sea, the correlations are much lower. For English surveys, the correlation is also better with pelagic numbers, particularly in 2000 and 2002. For Scotland, the correlations are also systematically greater with pelagic numbers, even though for Scottish surveys demersal catches are higher. For the French surveys the correlations between acoustic and catches are almost zero, whatever the height of the acoustic column integrated.

Comparison between spatial structures of the different surveys

For each survey, the following results concern the group of species (i.e., demersal or pelagic) where the correlation coefficient with acoustic was maximal (Table 2), the group selected is shown in yellow.

In the Barents Sea, the variograms often have a linear slope with a high nugget effect (Fig. 6). This drift is consistent through time and is highly visible for the NASC values. More fluctuations are observed for the catch data but the linear trend is still present. This drift is due to the observation of large values at the eastern border of the sampling area or on shelf near the norwegian coast. Because variograms are not pure nugget effects, two stations 20 n.mi apart will not be totally independent. They will be all the more correlated that the value of the variogram for a distance equal to 20 will be low. The acoustic cross correlograms (Fig. 7) show short range structures between 10 n.mi. (1998) and 25 n.mi (2002), and are reasonnably symmetrical (except may be in 1998). The acoustic-catch cross correlograms changes between years. In 1997, the demersal number has a correlation almost constant with the acoustic 20 n.mi before and after the station. In 1998, the pelagic number has a very high correlation with the acoustic of the 6 n.mi before the station and the 2 n.mi after. In 2000, the pelagic number is correlated with acoustic only on stations. In 2001 and 2002 the demersal number is correlated with the 15 n.mi before the station, but only with the 6 or 7 n.mi after. But no systematical effect "before or after station" is visible.

In the Irish Sea, in 2000, 2001 and 2002, the variograms show a very short range structure around 5 or 10 n.mi and, in 2002, a medium range structure of about 20 n.mi (Fig. 8). The acoustic cross correlograms are quite symmetrical (Fig. 9), they have structures with a shorter range than in the Barents Sea, about 5 n.mi in 2000 and 2002 and a medium range structure of about 20 n.mi in 2001. The catch-acoustic cross correlograms are quite similar to the simple correlogram of the acoustics.

In North Sea, no structure is really observed in the variograms (Fig. 10). The acoustic cross correlograms (Fig. 11) show very short structures of about 4 n.mi. The catch-acoustic cross correlograms are very disturbed. These fluctuations are attributed to the strong patchiness of the biomass. Some very large pelagic schools (of herring or sprat) seem randomly distributed in the area and hide every kind of spatial structure. To avoid repetition of figures that show the same kind of results, we only presents structures obtained with CEFAS (England) data are.

For most surveys, the acoustic cross correlograms and the acoustic-catch cross correlograms are quite symmetrical (up to some statistical fluctuations) or, in any case, no systematical difference between before and after the station is visible and no trawl effect can be detected, globally speaking. It could have been expected that the trawl had an impact on the fish behaviour both in terms of local abundance and vertical distribution. But, we do not observe such phenomom. Correlation between the catch numbers and the underway NASC is also higher near the station and quite similar before or after the haul (except in North Sea where correlograms have too large fluctuations).

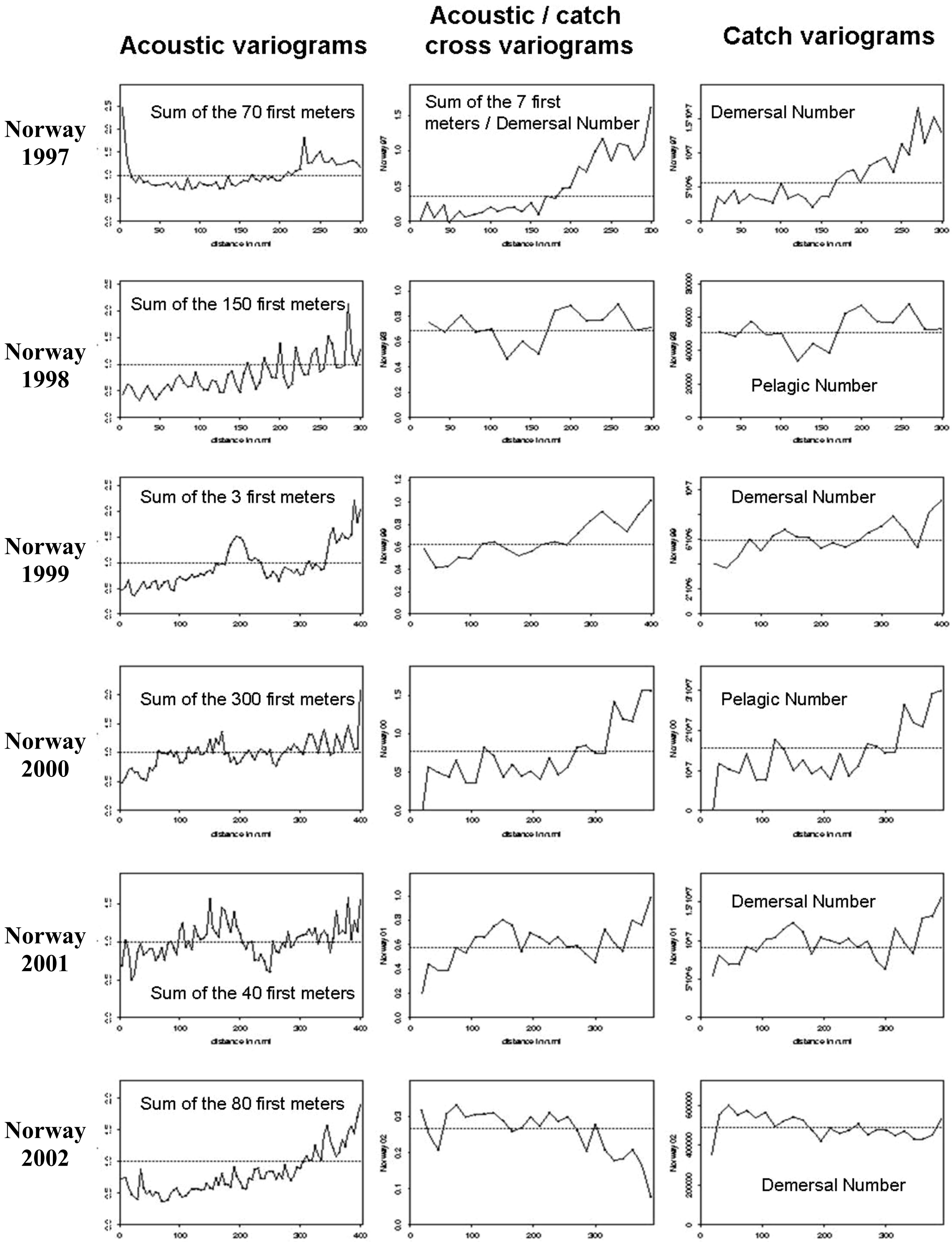


Figure 6. left column: between-stations acoustic normalised variograms. Medium column: acoustic-catch cross variograms between the variables of the first and the third column calculated with the on-station data. Right column: catch variograms, for Norwegian surveys. Distances are in n.mi. The graphics have plotted only for the demersal fish in 1997, 1999, 2001 and 2002, and only for pelagic fish in 1998 and 2000 (see 1. Choice of the number of layer)

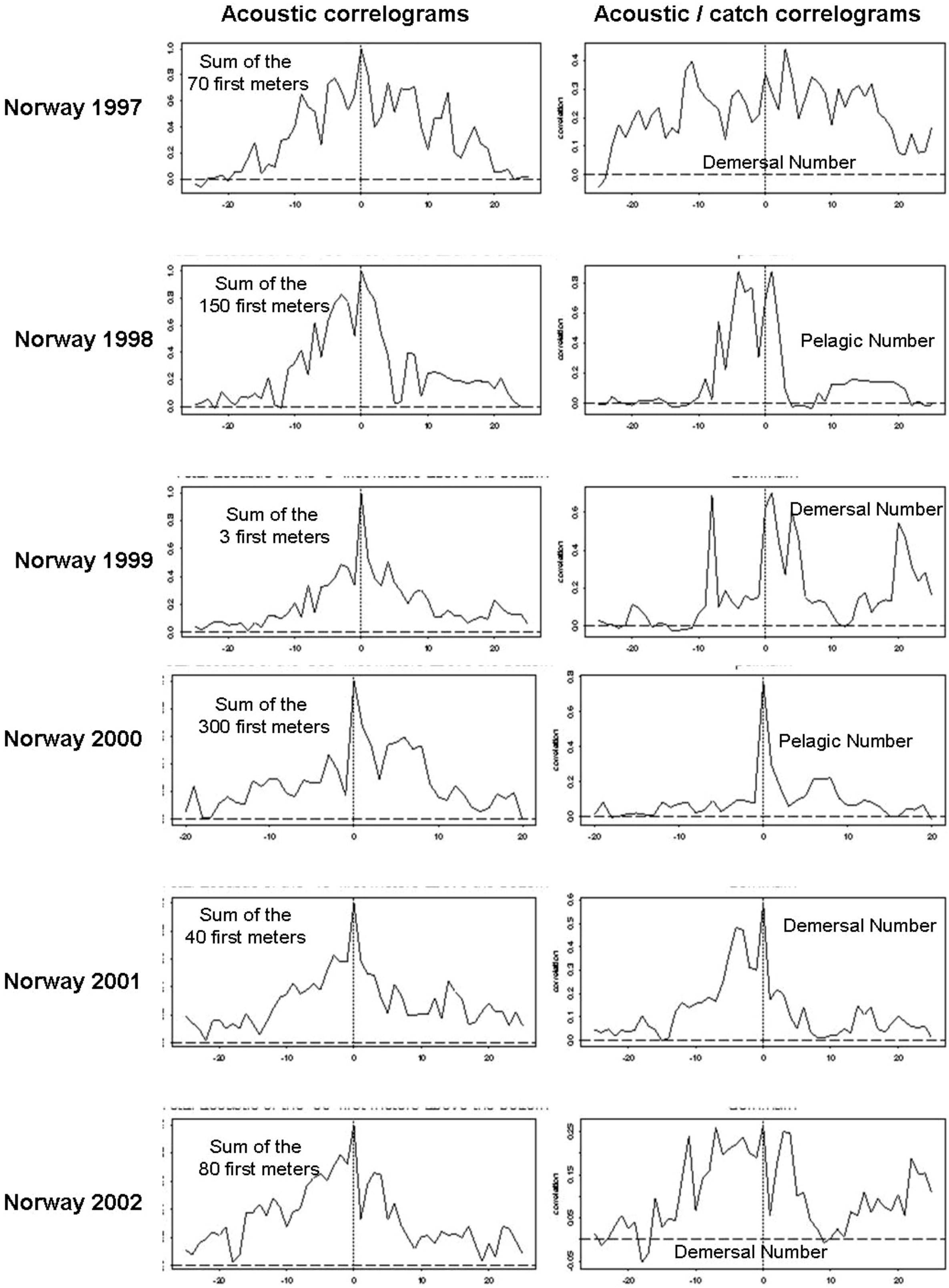


Figure 7. Acoustic correlograms (left) and acoustic-catch cross correlogram (right), calculated along the transects, for Norway surveys. On each graph, zero distance corresponds to the on-station position (vertical line), on its left the correlogram with the acoustic collected BEFORE the station and on its right this one collected AFTER the station. Distances are in n.mi.

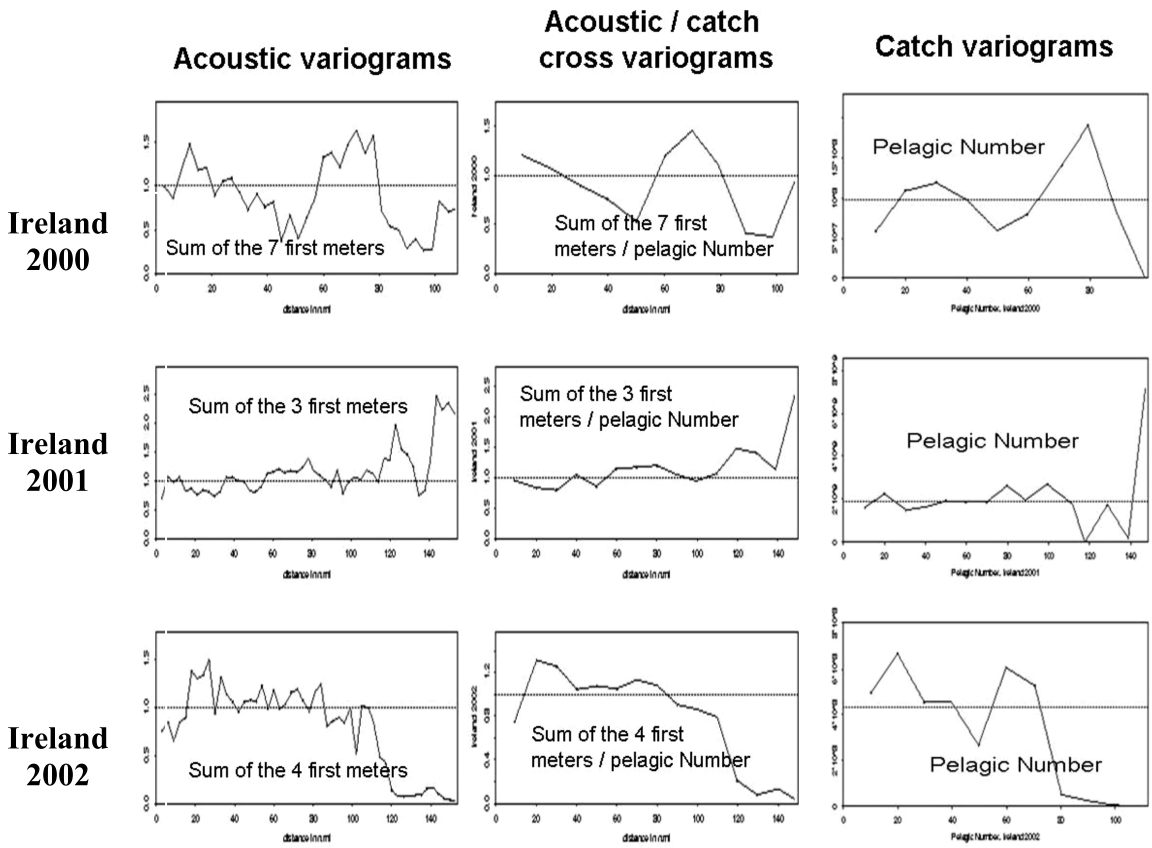


Figure 8. Acoustic-catch simples and cross variograms. Irland surveys. Distances are in n.mi

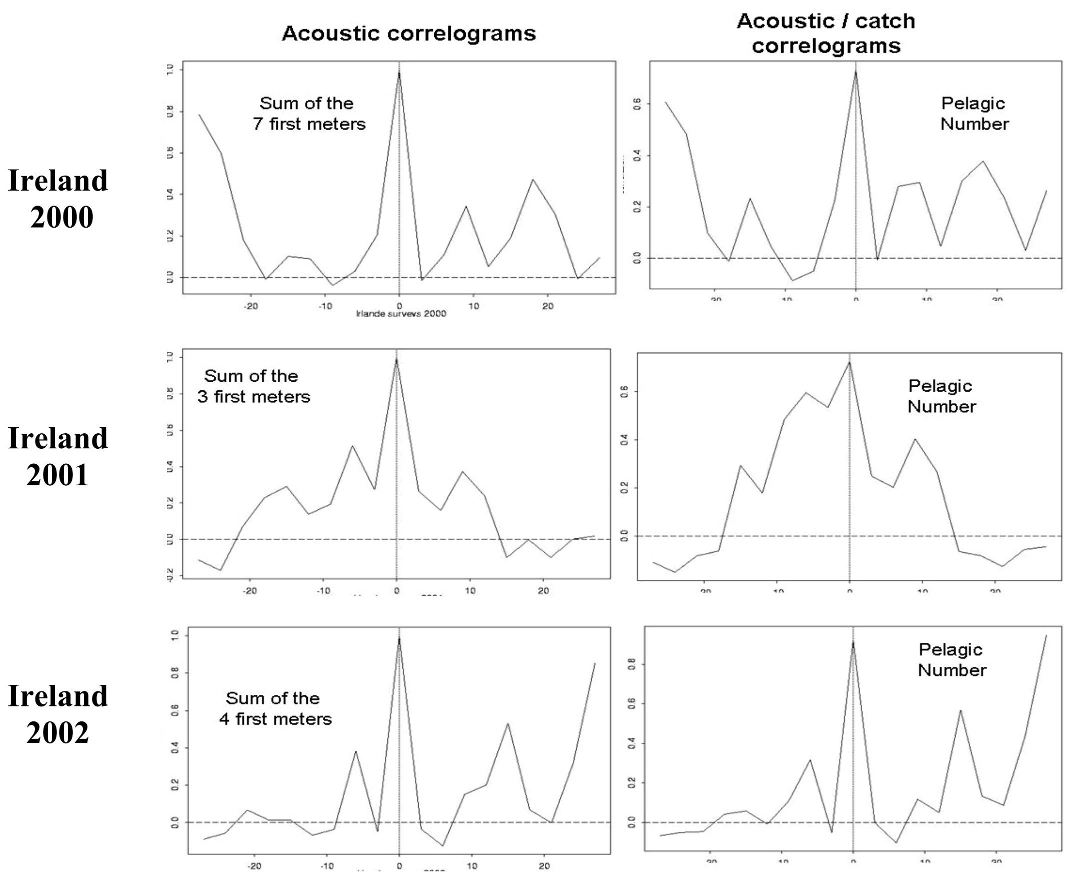


Figure 9. Acoustic-catch covariances around stations. Irland surveys. Distances are in n.mi

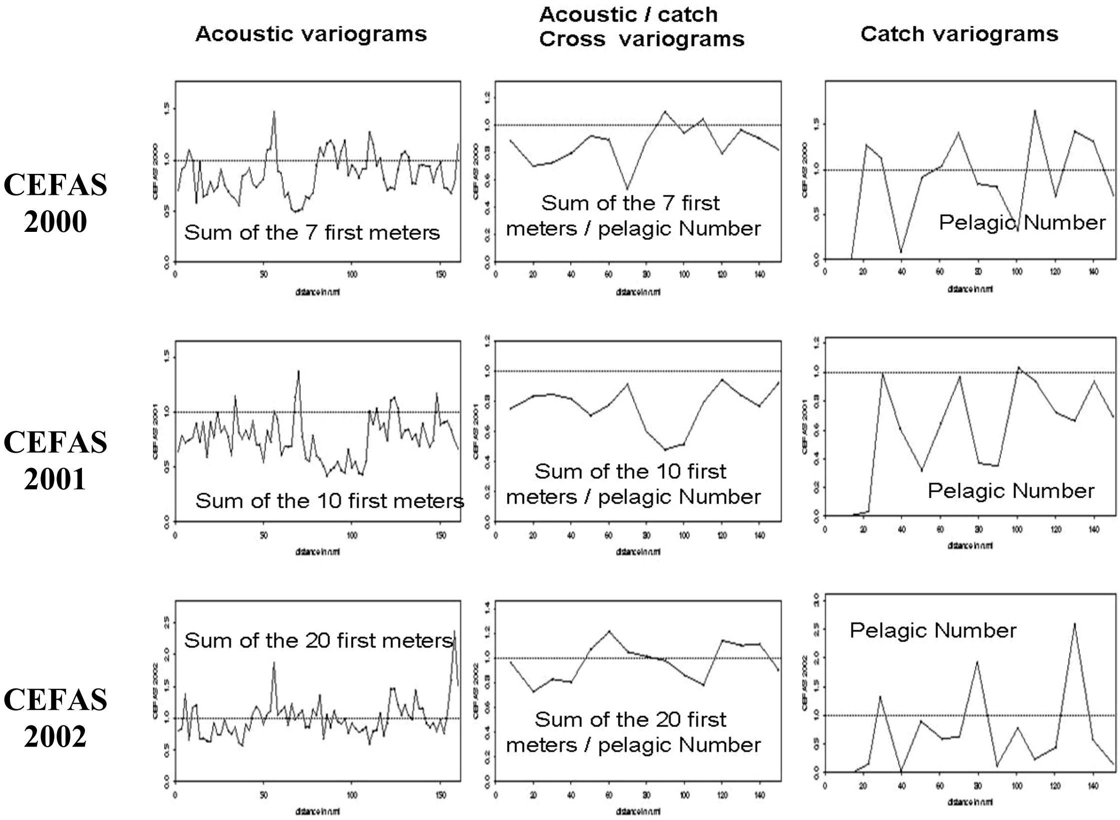


Figure 10. Acoustic-catch simples and cross variograms. English surveys. Distances are in n.mi

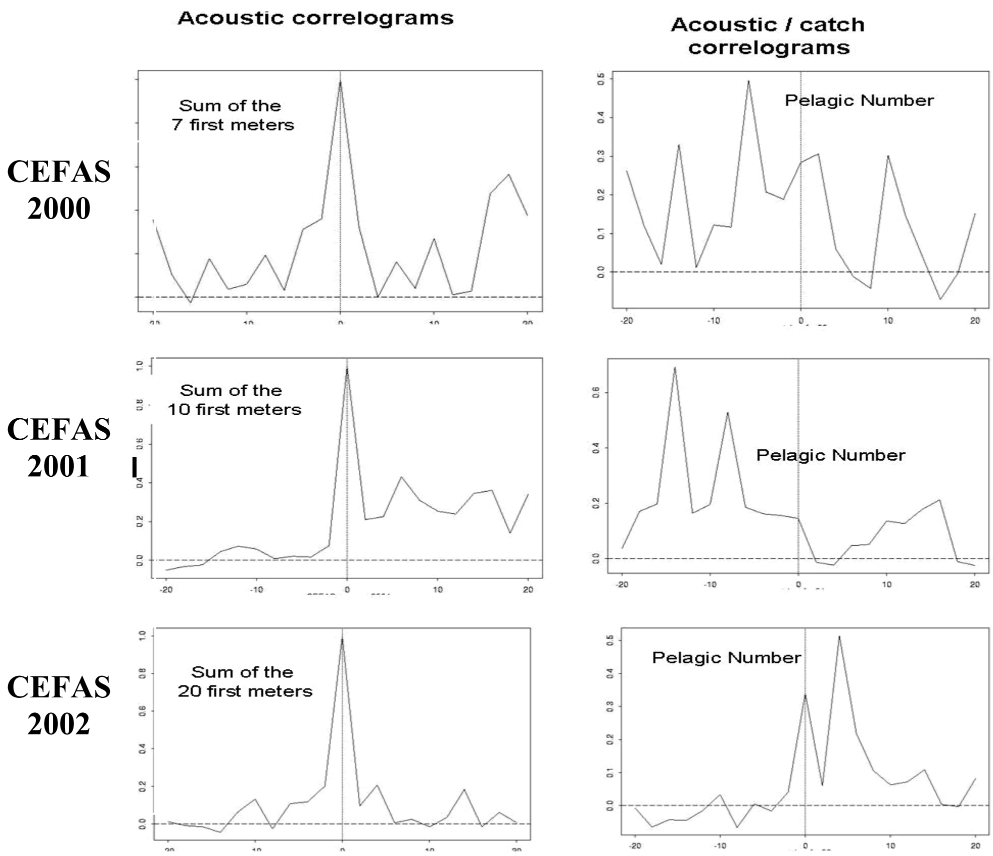


Figure 11 Acoustic-catch covariances around stations. English surveys. Distances are in n.mi

Describing spatial pattern when the variograms are lacking structure

Due to the extreme spatial patchiness of biomass distribution, particularly in the North Sea, the classical geostatistical tools are of no use. Measuring the square of the difference between fish densities, the experimental variograms are very sensitive to isolated large values. They tend to hide the more regular structure of the low values. One possible solution is to cut up the variables into different classes: a first class corresponding to small value, a few classes corresponding to medium values and a class corresponding to the largest values. The variable Z(x) is then transformed into some indicator variables equal to 0 or 1. This conversion allows understanding of the spatial arrangements between the sets of high and low values (Rivoirard, 1994). This method has very little been used (Petitgas, 1993). An example of the kind of analyses this approach offers is given with CEFAS data in 2000.

Let Z(x), the sum of NASC values for the 40 first meters above the bottom, be cut into four classes:

$$I_1 = 1_{Z(x)\geq 50}$$
$$I_2 = 1_{Z(x)\geq 100}$$
$$I_3 = 1_{Z(x)\geq 200}$$
$$I_4 = 1_{Z(x)\geq 400}$$

Because we are using indicator variables, the expected values get the meaning of probabilities. The variogram of the first class I_1 is then equal (in the stationary case) to the probability

$$\gamma_{I_1} = P\left[Z(x) \geq 50, Z(x+h) < 50\right]$$

The cross variogram of two classes I_1 and I_2 is equal to the probability:

$$\gamma_{I_1 I_2} = P\left[\mathrm{Z(x)} \geq 50,\ \mathrm{Z(x+h)} \geq 100\right]$$

Finally, the ratio between the cross variogram of the two indictor variables and the simple variogram of the first one is equal to the probability:

$$\frac{\gamma_{I_1 I_2}}{\gamma_{I_1}} = P\left[\mathrm{Z(x+h)} \geq 100 \middle| Z(x) < 50, Z(x+h) \geq 50\right]$$

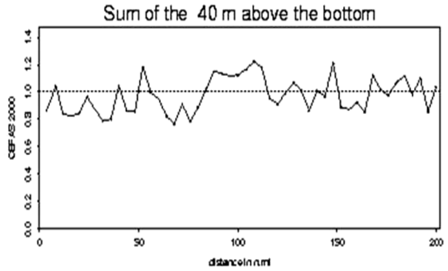


Figure 12. Example. The noised variogram of Z(x)

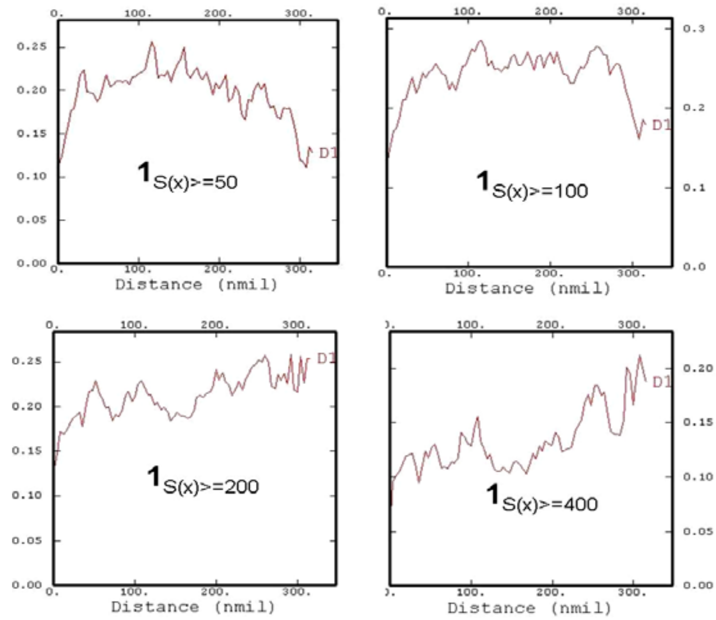


Figure 13. Variograms of the four indicators variables I_1, I_2, I_3 and I_4

The cut-off (50, 100, 200 and 400) have been chosen to have a similar number of data into each class. A medium scale structure of 100 n.mi appears on the variogram of the second indicator (Fig. 13). The last indicator is less structured has its experimental variogram present a slope with no range. These indicator variograms can be compared with the variogram of the variable which happens to be completely noised (Fig. 12). It means that the values under 100 are spatially structured, but that large densities above 400 are randomly distributed and disturb the overall spatial structure. So, dividing the variable into classes allows the extraction of the specific structure of each grade.

The points where the sum of the 40 first meters above the bottom is greater than 100 represent 50 % of the data but 90% of the acoustic biomass. The spatial distribution of the indicator I_2 summarizes the location of the biomass.
After kriging the indicator variable I_2 ($1_{Z(x)>=100}$), an area of low probability to exceed 100 can be discerned in the centre of the North Sea. On the contrary, this probability is quite large in south eastern part of North Sea (Fig. 14). This estimation allows to define the outline of the rich area. Then, inside this eastern area, it can be asked if the highest values are or not, independently positioned from the other values The cross variograms between indicators allows the assessment of the conditional probability of largest values occurring in this rich area.

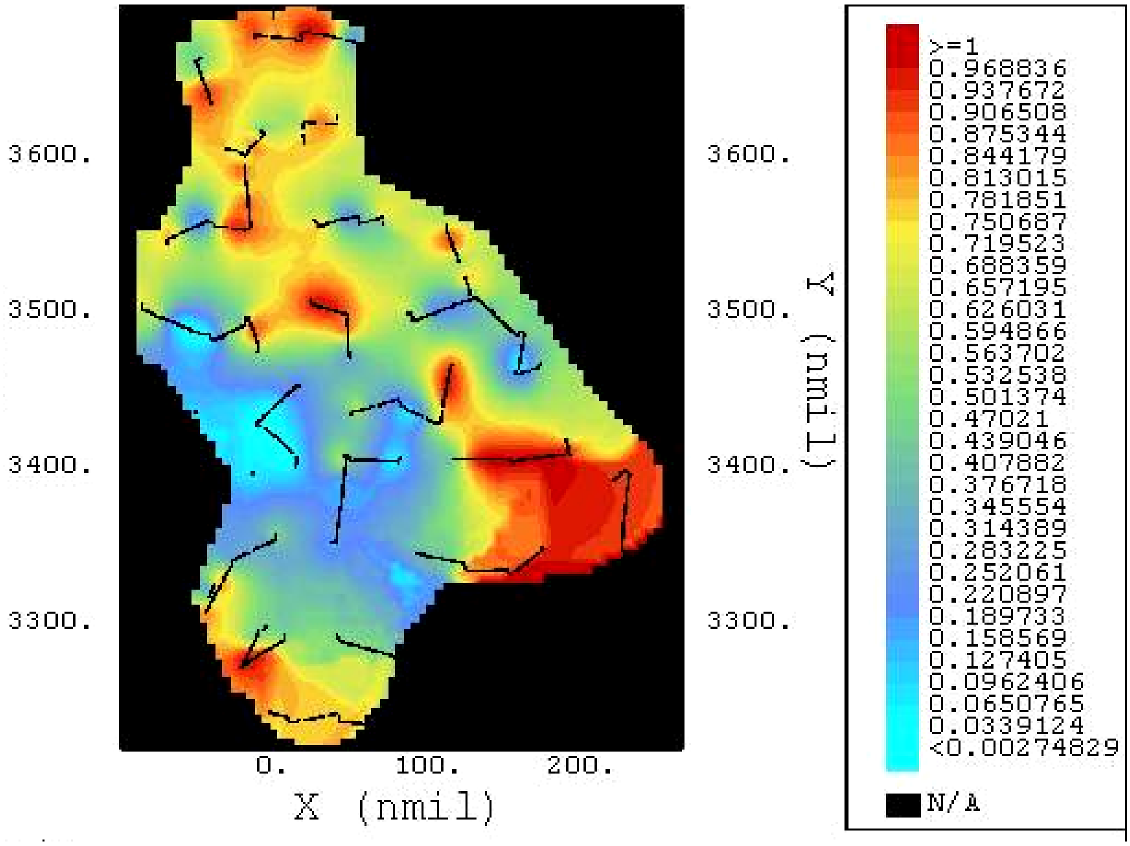


Figure 14. Kriging map of the indicator I_2. Coordinates are in n.mi (converted using a cosine projection). Data points are superimposed in black. The kriging was calculated with a moving neighbourhood (circular with a 80 n.mi radius). The variogram model is exponential (scale = 60 n.mi, sill=0.13) and a nugget effect (sill=0.12). CEFAS Data 2000.

The aim of the approach is to study how the high values are spatially related to the other values and to see if they have to be treated separately in the estimations. In the CATEFA project context, it is may be advisable to choice the indicators or a combination of indicators which optimize the catch interpolation.

Conclusions

Spatial patterns of the three regions considered here are very different. In the Barents Sea, the NASC values contain few outliers. The NASC variograms often have a short range structure of about 20 n.mi and a large scale structure of about 300 or 400 n.mi consistent through time. The acoustic seems more correlated with demersal fish than pelagic fish. In the Irish Sea, very short structures of about 6 n.mi emerge. The cross structures display that the acoustic is more able to represent the pelagic number than the demersal number. At least, in the North Sea, the acoustic variables are extremely asymmetric with some very rare and very large values. The corresponding variograms present high variations and lack structure. These results indicate that acoustic data are potentially useful, in Barents Sea like in Irish Sea, to help interpolation procedure between trawl stations because the ranges observed are often smaller than the inter-station distance.

For most surveys, the shapes of the acoustic cross correlograms and the corresponding acoustic-catch cross correlograms (same survey and same height of water integrated) are similar. This observation is very important as it makes possible the use of a very simple bivariate model $Z_2(x) = aZ_1(x) + b + R(x)$ where the catch number $Z_2(x)$ is modelled by a simple linear regression of NASC values $Z_1(x)$ with a residual spatially independent from $Z_1(x)$. This model, based on the experimental cross structures, will simplify the combination of acoustic and trawl catch.

This communication suggests an alternative method when the acoustic variables are too asymmetrical to help catch interpolation. This approach consists in dividing the acoustic variable into different classes to examine the specific spatial structures of each class and its arrangement with the neighbouring classes. For CEFAS surveys, the values under 100 present a structure of about 80-100 n.mi, when the higher values present a linear trend. These non-linear geostatistical tools allow to determine areas where large values have a high occurrence probability and then, to improve the knowledge of the total biomass structures.

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