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Distribution and Density of Carnivorous Fish Species Around Lanzarote and Fuerteventura, Canary Islands

by

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**Abstract**

The distribution patterns of the fish species around Lanzarote and Fuerteventura (Canary Islands, NE Atlantic) was investigated from 223 longline stations from 0 to 1200 m. Seventy-three species and a total of 1885 individuals were caught. The full data set was stratified according to the depth distribution of stations. The accuracy of the stratification was investigated from multivariate analysis and study of indicator species. The multivariate analysis reveal no geographical pattern in the species distribution around these islands.

Poisson's and Exponential probability distributions were fitted to the number of species and individuals caught per longline station. The probability distributions fitted well the data. This knowledge of the probability distribution of the number of species and individuals caught per station allowed to compare the density and diversity per strata because parametric confidence intervals could be estimated. The mean number of species per station, which was both the mean and variance of the Poisson's distribution was used as an index of the small-scale diversity that can be used in complement of the usual Shannon diversity index. The interest of this method for ecological studies of the fish assemblage in the context of not-trawlable grounds, in particular along the slope and other deep areas is discussed, in particular with regards to the small scale diversity.

Keywords: Longline; demersal fishes; Poisson distribution; exponential distribution; density; diversity; Canary islands.

**Introduction**

Most ecological studies of deepwater fish assemblages addressing the depth and geographical distributions of species, their density and diversity, and the effect of exploitation have been based on trawl sampling. Such studies have been much less advanced in the context of non-trawlable grounds, such as the waters surrounding oceanic islands, seamounts, or ridges, as well as continental slope areas like several ones in the eastern North Atlantic off Ireland, France, Spain, and Portugal which are partly of high interest to deep-water fisheries. In such areas, fisheries exploitation and scientific investigation can only rely on fixed gears. At great depths, areas with longstanding fixed gear fisheries, such as the longline fishery for the black scabbard fish (*Aphanopus carbo*) in Madeira (Leite, 1988) as well as unexploited and newly exploited areas exist and comparison between these areas should be of help to assess the sustainability of current or developing fisheries. Due to the bottom roughness of several areas, exploitation relies partly or exclusively on longlining (Anonymous, 2000; Iglesias and Paz, 1995; Magnusson *et al.*,

1997; Martins and Ferreira, 1995; Piñeiro *et al.*, 2001), etc. In addition to the slope context, rough bottoms and ecosystems sensitive to trawling extend over most of the tropical coastal waters. In all these areas, the deepwater as well as the shelf species may be exploited by longlines and gillnets and these gears may provide the only data available for assessment of the exploited stocks.

Although they are recognized as the only gear that can be used on some rocky or sloping bottoms, longlines are not often used for stock assessment (Hovgard and Riget, 1992) probably because they have clear limitations due to their selectivity (Lokkeborg and Bjordal, 1992) and their fixed nature (Hovgard and Riget, 1992)]. Recent methodological developments for stock assessment purposes have taken into account the gear saturation in the Catch Per Unit Effort (CPUE) (Somerton and Kikkawa, 1995) or compared their reliability to other sampling methods (Ellis and Demartini, 1995). In the deep waters, most assessment studies and management based on longlines deal with CPUE and selectivity (Anonymous, 2000; Erzini *et al.*, 2001; Hareide, 1995; Hareide and Garnes, 2001; Huse *et al.*, 1999; Jorgensen, 1995; Woll *et al.*, 2001) but, to our knowledge, their use for ecological purposes is still rather restricted. However, for the same reasons as above, this method may be the only one to monitor, compare, or predict possible changes due to fishing pressure properly. Hence, it should be an important tool for assessing the sustainability of a particular fishery, it can also be operated from small and simple vessels.

The present paper is an attempt to widen the usefulness of longlining data considering them as a sampling gear for the guild of predators. The data from a series of bottom-longlining cruises around Lanzarote and Fuerteventura, Canary Islands (Uiblein *et al.*, 1996; Uiblein *et al.*, 1998) are analysed to address the following questions: (i) how can data from longline surveys be analysed in terms of density and diversity to allow for comparison between different areas or ecosystems? (ii) can longline data be used for investigating possible changes in fish assemblages due to fishery exploitation?

To answer these questions distinct depth strata were objectively identified from the data set irrespective of the field sampling scheme. For each depth stratum geographical patterns in the distribution of species were investigated from multivariate analysis, the distributions of the number of species and individual per station were fitted to Poisson and Exponential probability distributions. The potential for increasing the accuracy of the stratification and hence of the parameters of the probability distributions was further assessed from indicator species. The advantage of these new techniques and their extensions will be discussed.

## **Material and Method**

Abundance and distribution data of carnivorous fishes around Lanzarote and Fuerteventura, two islands of the Canarian archipelago, Eastern Central Atlantic, from 223 longline stations were analysed. Two hundred stations were distributed over 21 radials perpendicular to the coastline and 23 extra stations, mainly deeper than 800 m were concentrated to the south-east of Fuerteventura off Gran Tarajal (see chart in Uiblein *et al.*, 1998). Details of the sampling methods can be found in Uiblein *et al.* (1996, 1998) and Rico *et al.* (1999) (Rico *et al.*, 1999). The distribution of the samples around the Islands allow to consider these data as a systematic sampling of the islands slopes except for the deeper stations.

### **Stratification**

In a former analysis, the diversity and catch rates were estimated with respect to 200 m depth strata (Uiblein, *et al.*, 1996). The field sampling scheme aimed at sampling contiguous depth zones: 0-60; 60-150; 150-250; 250-350; 350-500; 500-650 and >650 fathoms (Bordes *et al.*, 1995). However, here the strata were defined according to the depth distribution of all the stations. Gaps in the mid-depths of longlines hauls were used as strata boundaries. All values of mid-depth were sorted and then plotted according to their rank. When the mid-depth increased rapidly (which may be due to gaps in the data or to topography) the depth strata were separated. The diversity, density, species composition of the catch in each stratum was further investigated from multivariate analysis, trial fits of probability distribution functions, diversity index and indicator species.

## Multivariate Analysis

Binary Correspondence Analysis (CA) was carried out for the whole data set and for the depth strata where the number of fish was sufficient. This analysis mainly aimed at investigating the geographical distribution of species around the islands. Station without any catch were not taken into account here (and would be of no effect in such analysis). CA was considered as the most adequate multivariate method because the two entries of the data matrix (here species and stations) are treated in the same way allowing for direct correspondence of species and stations in the factorial space (Dazy and Le Barzic, 1996; Lebart *et al.*, 1982). Moreover, zero value, that are numerous in our data, make no problem in CA, which is frequently used for analysing species composition data.

## Probability Distributions

The number of species and individual caught per station were adjusted to known probability distribution functions. Contrarily to the multivariate analysis, the null stations where included in the fit as station catching no fish were expected to participate to the overall statistical distribution of the catch.

The catch of one distinct species in one longline haul can be envisaged as a rare event that should follow the Poisson distribution. For the catch of individuals, this variable can be treated as continuous and we use an Exponential distribution to fit this variable in each stratum.

The Poisson distribution is the distribution of a discrete random variable  $k$  with individual probabilities expressed as :

$$P(k) = e^{-\lambda} \frac{\lambda^k}{k!} \quad k = 0, 1, 2, \dots, \infty$$

A Poisson distribution has the following characteristics:

$$\text{Mode } M_0 \quad \text{integer such as } \lambda - 1 < M_0 < \lambda$$

$$\text{Mean } E(k) = \lambda$$

$$\text{Variance } Var(k) = \lambda$$

The density function of the Exponential distribution is:

$$f(x) = \mu e^{-\mu x} \quad \text{where } 0 \leq x < \infty$$

For both Poisson and Exponential distributions the fits were adjusted from the maximum likelihood estimator of parameters using MATLAB software. The  $\lambda$  and  $\mu$  parameters are respectively the arithmetic mean numbers of species and individuals caught per station taking into account all stations (i.e. including unsuccessful stations).

## Diversity Index

For comparison with the number of species per station, the classical Shannon index of diversity was computed for each strata. The Shannon index ( $H'$ ) in a given strata  $s$  expresses as:

$$H' = - \sum_{i=1}^s \frac{N_i}{N} \cdot \log_2 \frac{N_i}{N}$$

Where  $N_i$  is the number of individuals of species  $i$  and  $N$  is the total number of individuals.

## Indicator Species

The indicator value index proposed by Dufrene and Legendre (1997)(Dufrene and Legendre, 1997) was used to identify the indicator species for each depth stratum.

The specificity and fidelity of each species  $s$  to each stratum  $j$  can be measured by the values  $SP_{j,s}$  and  $FI_{j,s}$ , respectively:

$$\begin{cases} SP_{j,s} = NI_{j,s} / NI_{+j} \\ FI_{j,s} = NS_{j,s} / NS_{j+} \end{cases}$$

where  $NI_{j,s}$  is the mean abundance of species  $s$  across the stations of stratum  $S_j$ .  
 $NI_{+j}$  is the sum of the mean abundances of species  $s$  within all the strata.  
 $NS_{j,s}$  is the number of stations of  $S_j$  where the species  $s$  is present  
 $NS_{j+}$  is the total number of stations in that depth stratum.

The specificity value ( $SP_{j,s}$ ) is maximum when species  $s$  is present in depth stratum  $S_j$  only, whereas the fidelity value ( $FI_{j,s}$ ) is maximum when species  $s$  is present at all sites of  $S_j$ .

The specificity and fidelity represent information independently from one another, their product multiplied by 100 produces a percentage of the indicator value  $IV_{j,s}$ :

$$IV_{j,s} = 100SP_{j,s}FI_{j,s}$$

## Results

### Stratification

The mid-depths of stations show gaps, which represent poorly sampled depths. These gaps were used as boundaries to define 5 depth strata labelled S1 to S5 from the shallowest to the deepest (Figure 1). The depth range of station sampled in strata S1 to S5 were respectively: 22-224 m, 278-437m, 495-594m, 656-777m and 816-1208m.

### Distribution of the Species Around the Islands (CA)

The CA on the whole data set showed a few singularities like one species caught in one single station, where no common species was caught. These results are usual in CA and were set as illustrative elements. The deeper stations were strongly opposed to all others as they were associated to four species (*Mora moro*, *Trachyrincus trachyrincus*, *Synauphobranchus kaupi* and *Aphanopus carbo*) that were not caught shallower. Setting these stations as illustrative elements the contributions to the first axis were reasonably balanced (i.e. the structuring species were also the major species in terms of total abundance). Expectedly, the first axis remained strongly correlated to depths (Figure 2a).

For the subsets of stations of each depth stratum, there was a remaining depth effect in S1 (Figure 2b), and, to a lesser extend in S2 (Figure 2c). In S1, two extra subsets of stations were analysed, from below and beyond 100 m depth. In these sub-matrices no more depth effect was visible. No spatial structure could be revealed by CA in the two sub-strata of S1 nor in S2. In the 3 deeper strata the number of stations, species and individuals caught (Table 1) were too low for the multivariate approach to be of interest. The locations of species caught in small numbers in the factorial space had no signification and results are not provided here.

### Probability Distribution

The fits of the Poisson density function to the number of species per tow per strata were very good (Table 1). There was a consistent trend of declining  $\lambda$  from S1 to S4 and  $\lambda$  increased again in S5. The confidence intervals of  $\lambda$  clearly show that the changes with depth are statistically significant. Taking all the stations from all the strata, the fit was slightly poorer than in any individual stratum except for S3.

The fits of the exponential distribution to the number of individuals per station and strata were slightly less good. The cumulative distributions were however in agreement with the observations (Table 2), and  $R^2$  values were high except in the strata S1 and S5. The  $R^2$  for the entire data set was higher than the average of the strata. In the strata the  $\mu$  parameter of the exponential distribution varied like the  $\lambda$  parameter of the Poisson distribution: it declined from S1 to S4 and increased in S5, the changes from one stratum to the next were significant except between S1 and S2.

### Shannon Diversity Index

$H'$  calculated for the whole data set and for each of the 5 strata showed the same declining trend with depth (Table 3) as formerly obtained by Uiblein *et al.* (1996) using 200 m depth strata. The dataset used here was slightly larger than that of Uiblein, *et al.* (1996), due to further cruises. The globally higher value in  $H'$  in the present study than in Uiblein *et al.* (1996) is due to the use of base 2 logarithm here and natural logarithm in Uiblein *et al.* (1996). Comparing  $H'$  to  $\lambda$ , they decreased similarly with depth from S1 to S4. But  $H'$  continued the decrease from S4 to S5 while  $\lambda$  increased.

### Indicator Species

There were few indicator species. Four species were indicators of S1, 2 of S2 and 3 of S5. The intermediate strata S3 and S4 had no indicator species (Table 4). Indicator species of S1 were all specific to this stratum, *Pagrus pagrus* had the highest indicator value due to a high stratum fidelity. The two indicator species of stratum S2 had an extended depth range and moderate fidelities resulting in quite low indicator values. Indicator species of S5 were almost completely restricted to S5. However, with the exception of *Mora moro*, they had low indicator values indicating low fidelities.

## Discussion

### Choice of Stratification

The strata defined here, from an a *posteriori* procedure were to a large extent consistent with the field sampling scheme, however the distinction between the two shallowest field strata did not appear as a gap in the depth distribution of stations and the deeper end of the stations' depth distributions was also re-arranged. All stations and fish species caught were processed including stations with zero catches and a small proportion of pelagic species (Uiblein, *et al.*, 1996).

### Factorial Analysis

Working out all the stations, finding a depth pattern in the species composition of the catch is a trivial result. Indeed, systematic changes in the faunal composition across the vertical range in altitude are evident worldwide (Merrett and Haedrich, 1997). The stratification process was an attempt to define strata within which the depth effect is reduced enough to allow for investigation of other possible pattern (e.g. geographical).

Within the strata defined, the CA detected some remaining depth effect in S1 and to a lesser extent in S2. In S1 this effect was no longer visible with a thinner stratification. It should however be noted that the shelf fish community usually change within smaller depth range or in relation to the distance to the coast. The present work dealing primarily with the deep-water this will not be further discussed here. We will just note that due to the narrowness of the islands shelf these depth or distance to coast effects may be less clear than over large continental shelves, also the input of terrestrial material and freshwater is obviously much more reduced in such an island context, probably keeping some oceanic conditions up to the coast. However, further investigations of these questions around the studied islands would require a higher sampling intensity.

These depth effects were not large enough to hide other possible structure in the data matrix analysed in the CA and no geographical pattern appeared. However, the fishery around the two islands displays some geographical pattern with major efforts directed to the SW of Fuerteventura and the east of both Fuerteventura and Lanzarote, which may suggest some pattern in the distribution or density of the target species. The distribution of the fishing effort may

also be due to the location of convenient landings ports. Lastly, the fishing in the Canaries is only moderately developed and the absence of difference between the more and less frequented areas may reflect an overall pristine state of the whole area with respect to the demersal assemblage species composition.

In the deep waters, several species have very large geographical distributions. The deep-water fish assemblage is structured in depth longitude and latitude (Koslow, 1993). The depth structure clearly appeared in the present study like in former analysis in the same area (Uiblein *et al.*, 1996, 1998). No latitudinal or longitudinal gradient appeared. It is indeed not astonishing to find no geographical pattern at the scale of this study (the North-South and East-West extensions of the sampling area are both about 190 km, which is small compared to the scale of the species geographical distributions and to that of the deep-water environmental changes). Several former studies at local scale only revealed the depth gradients or changes in the species composition (Bergstad *et al.*, 1999; Gordon and Duncan, 1985a; Gordon and Bergstad, 1992; Lorance, 1998; Merrett *et al.*, 1991; Snelgrove and Haedrich, 1985) while when areas distant from several hundreds of kilometres are compared, geographical patterns were found (Gordon *et al.*, 1996; Koslow, 1993; Williams *et al.*, 2001).

### **Fitting of Probability Distributions**

Although at least the deeper stratum was poorly sampled both in terms of number of stations and of their geographical distribution, the fits were good for both the numbers of species and individuals in all the strata suggesting that applying probability distributions to such data is a quite robust approach.

In S1 the fit of the Poisson distribution to the number of species was very good but the fit of the exponential distribution to the number of individuals was poorer. This may reflect the heterogeneity of this stratum where the CA showed a depth effect in term of species composition and which corresponds to the full range of the shelf zone. The fit of the exponential distribution to the number of individuals was poor also in S5, probably as a result of individual hauls being relevant of the fish density in and out of the spawning aggregation.

Then it is likely that when both the Poisson and the exponential distributions properly fit respectively the number of species and individuals caught per station, the sampling area or the stratum can be considered as enough homogeneous without physical or biological pattern resulting in strong patchiness in the fish distribution or in different fish assemblage occupying different habitats. However, this later case would not appear as a deviation from the probability distributions if different species select different habitat with similar density patterns. Nevertheless, when the probability distribution apply, the mean number of species and individuals per station can be considered as parameters of the fish assemblage.

### **Using $\lambda$ as a Diversity Index, Comparison of $H'$ and $\lambda$ ,**

$\lambda$  is the mean number of species per strata, although generally consistent with  $H'$  (Figure 3, Tables 1 and 3), it contains another information, which appears here in S5. The total number of species caught in this stratum was very low (Table 1), however, on average more species were caught in one station in S5 than in S3 and S4.  $H'$  computed on the species composition cumulated over stations does not account for this, which is important as an index of the diversity at small scale.

In spite of the additive property of the Poisson distribution, the fit to all the 223 stations, was slightly less good due to the within strata heterogeneity in term of local diversity. A diversity index like  $H'$  provides no clue to detect such deviations. When working out more heterogeneous stations,  $H'$  tends to increase as more species are taken into account. Here,  $H'$  for the all data set was very high (Table 3). This property does not apply to  $\lambda$  which remains the average number of species per station and  $\lambda$  for the whole data set appears as a weighted average of the means per strata (Table 1). Lastly, the small-scale diversity includes a density component: although the species richness is lower in S5, there is a higher probability to observe several species within a small area in S5 than in S3 and S4 due to higher total density.

The clear changes of the  $\lambda$  parameter with depth reflect a decline in the small scale diversity. In S5 this diversity increases due to local particular conditions. Then the approach used here allows for comparison of assemblage structures with depth. It is quite obvious that the same could be also applied to different areas. The mean number of species per station can then be used as a diversity index. The fit of the Poisson distribution provides a confidence

interval of this index so that the significance of differences are easily handled while diversity indices are most often computed without indication of variance (however such a variance is accessible through bootstrap methods).

In the same way, the fit of the exponential distribution provides a confidence interval of the number of individuals per station. The fit to the whole data set was good as a result of a stronger statistically additive effect than for the Poisson distribution. Lastly, the combination of  $\lambda$  and  $\mu$  allows to analyse the link between the local diversity and the density (Figure 4). From S1 to S4 the density and the diversity both decline and the relationship between the two is kept. In S5 the density is high in respect to the diversity and the confidence intervals are wide due to small sample size. The relationship between the two parameters for the whole data set is the same as for strata S1-S4.

### Indicator Species

Few species were indicator of each stratum and their indicator values were low except for *Pagrus pagrus* and *Mora moro*. The former is clearly a shelf-dwelling species while the latter is a mid-slope inhabitant. To the west of the British Isles, the depth range of *M. moro* does not seem to extend deeper than about 1300 m (Gordon and Duncan, 1985b; Haedrich and Merrett, 1988; Merrett, *et al.*, 1991) so that its specificity to S5 in the present study is probably not a sampling artefact. Other indicator species all have high specificities except in S2. In addition to this, the absence of indicator species in S3 and S4 is probably due to the large depth range of many species from the upper and mid-slope in this area (Uiblein, *et al.*, 1998) and elsewhere (Gordon and Duncan, 1985a; Haedrich and Merrett, 1988; Merrett and Marshall, 1981; Merrett, *et al.*, 1991; Merrett and Haedrich, 1997) making it unlikely that an increased sampling intensity would allow to define a much thinner depth stratification, except in S1 and, to a lesser extent, S2, where the CA detected some depth effect. It is worth noting that although these strata had no indicator species, and that they had quite restricted depth ranges S3 and S4 were clearly different in terms of diversity and density. Although the number of stations at these depths was quite low (36 and 34 stations), this cannot be a sampling artefact as the stations were well distributed around the islands. Lastly the high specificity of *Synaphobranchus kaupi* and *Aphanopus carbo* in S5 are due to the truncation of the sampling at about 1200 m as both these species extend much deeper (Haedrich and Merrett, 1988; Merrett and Domanski, 1985; Merrett, *et al.*, 1991).

With the exception of *M. moro* and *P. pagrus* the indicator species had quite low fidelities. This is related to the size of the experimental units (one longline had 300 hooks) and the relatively short exposure time. With experimental units of this size and duration, the probability of the main species to be caught in a given station is relatively small in particular in deeper zones where densities generally are lower. Fidelities from trawl data, where hundreds of fish are caught at each station, may be much higher (Merrett, *et al.*, 1991).

### Availability of Longlining Data, Selectivity and Potential use of the Proposed Approach

The species richness observed from longline sampling is reduced compared to that obtained from trawl sampling (Connolly and Kelly, 1996; Hareide, 1995; Reinert, 1995). This is probably the main reason why longline data are poorly used for ecological purposes. However, any kind of trawl is selective too and it was clearly shown along the slope that analyses relying on one single gear could provide only little ecologically relevant information (Gordon, 1986; Gordon and Bergstad, 1992; Gordon, *et al.*, 1996; Merrett, *et al.*, 1991). Moreover, in addition to their usefulness on rough bottom, longlines can provide complementary data in areas accessible to trawling. Lastly, where exploitation relies primarily upon longlining, dominant species, those able to frighten others (Godo *et al.*, 1997), and the largest individuals (Hareide, 1995; Hovgard and Riget, 1992; Lokkeborg and Bjordal, 1992; Reinert, 1995), better competing for bait, would undergo a higher fishing mortality. As those would also be the less available to trawl sampling, due to avoidance capabilities of larger more mobile fishes, changes in the fish assemblage due to longlining (disappearance of larger fish) would hardly be observed from trawl sampling. However, the size distribution of longline catches may depend both upon the size composition of the population and its density (Engås *et al.*, 1996).

Along the slope, the species caught are large predators such as chondrichthyans and several large gadiform, scorpaeniform and trichiurid species. The abundant deep-sea scavenger, *S. kaupi*, is also caught while the large predator *Hoplostethus atlanticus* and the abundant North Atlantic, *Coryphaenoides rupestris* hardly take any bait. Longlines clearly are more species selective than trawls. However, the species caught are the target species... of longlining and may also be that of trawling or gillnetting or their by-catch. In both cases, the time trends for these

species, in term of density and diversity, and possible changes in their probability distributions, would reflect ecosystem changes under exploitation. The top predator species caught on longlines are often the most long lived in a given ecosystem and they also often represent the most valuable fishery-exploited species. The combination of the two characters make these species highly sensitive to exploitation in particular in the case of the deep waters and hence more attention should be paid to this valuable but most vulnerable component of the fish assemblage. Over trawlable grounds, the use of trawl sampling allows to collect data more relevant to the whole fish assemblage. Even in this case, longlining remains of interest for comparison to non-trawlable areas, small scale diversity and habitat selection as well as studying long lived or large sized species.

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Table 1. Number of stations, species and individuals per strata and parameter, bounds of confidence interval and determination coefficient of the Poisson's probability distribution fitted to the number of species per station in each depth strata.

Strata	stations	Number of species	individuals	$\lambda$	Confidence interval	R <sup>2</sup>
All	223	73	1885	2.73	2.51 - 2.95	0.68
S1	94	53	1236	4.31	3.89 - 4.73	0.95
S2	41	28	333	2.51	2.03 - 3.00	0.75
S3	36	15	105	1.42	1.05 - 1.86	0.63
S4	34	9	34	0.56	0.34 - 0.87	0.96
S5	18	5	177	1.72	1.17 - 2.44	0.84

Table 2. Parameter, bounds of confidence interval and determination coefficient of the Exponential distribution fitted to the number of individuals per station in each depth strata.

Strata	Number of stations	Maximum number of individuals per station	$\mu$	Confidence interval	R <sup>2</sup>
All	223	67	8.45	7.38 - 9.60	0.79
S1	94	67	13.15	10.63 - 15.94	0.47
S2	41	37	8.12	5.83 - 10.79	0.69
S3	36	15	2.92	2.04 - 3.94	0.84
S4	34	9	1.00	0.69 - 1.36	0.99
S5	18	56	9.83	5.83 - 14.87	0.44

Table 3. Shannon diversity index ( $H'$ ) per strata.

Strata	All	S1	S2	S3	S4	S5
<b>H'</b>	4.43	3.78	3.36	3.09	2.68	0.87

Table 4. Indicator species per strata.

Depth Stratum	Species	Indicator Value	Specificity	Fidelity
S1	<b><i>Muraena helena</i></b>	21.3	1	0.22
	<i>Serranus atricauda</i>	44.7	1	0.45
	<i>Pagrus pagrus</i>	80.9	1	0.81
	<i>Trachinus radiatus</i>	27.7	1	0.28
S2	<i>Lepidopus caudatus</i>	20.3	0.64	0.32
	<i>Helicolenus dactylopterus</i>	43.6	0.78	0.56
S5	<i>Mora moro</i>	71.7	0.99	0.72
	<i>Aphanopus carbo</i>	38.9	1	0.39
	<i>Synphobranchius kaupi</i>	44.4	1	0.44

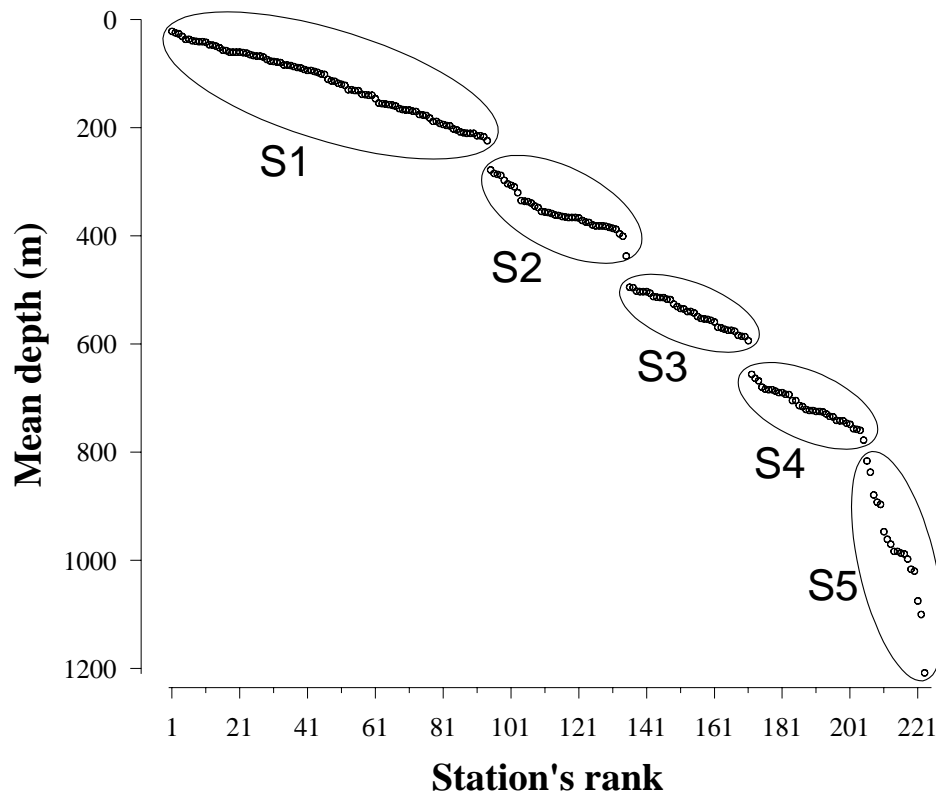
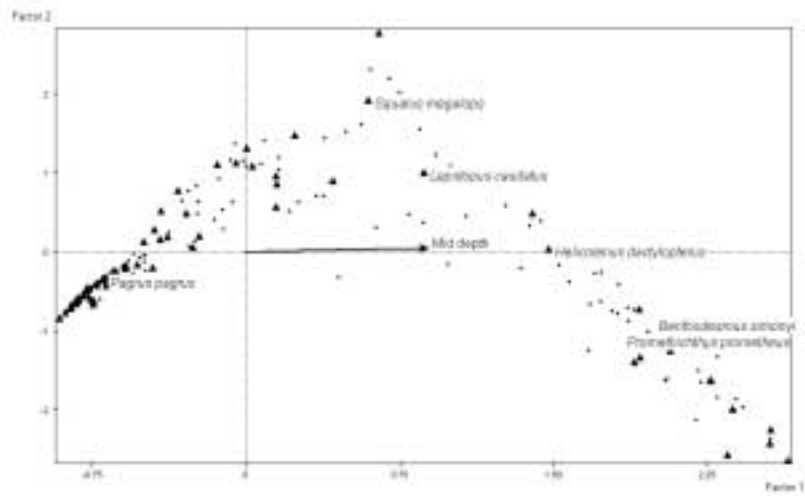
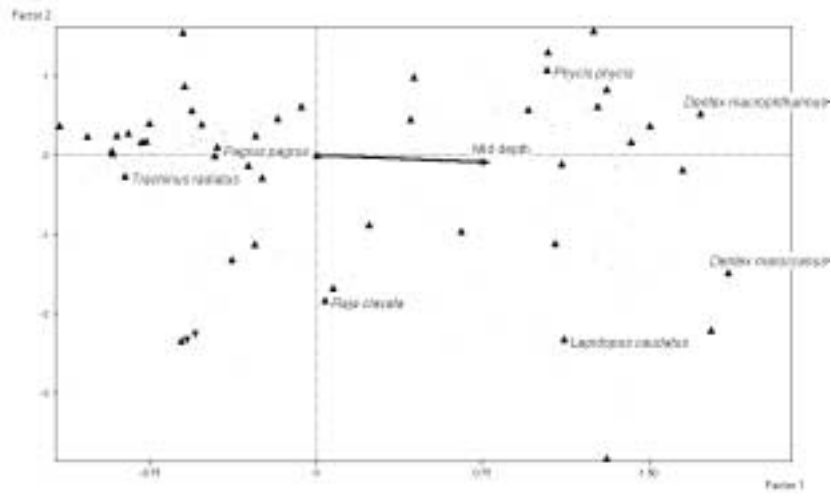


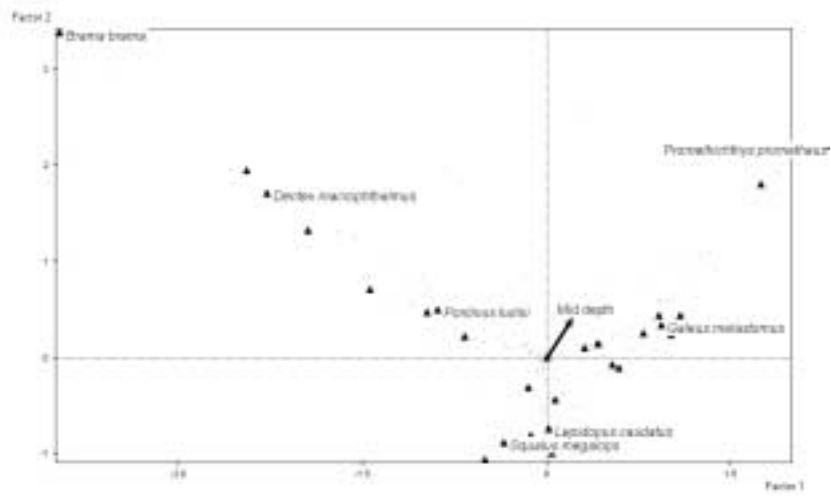
Figure 1. Representation of mid-sounding distribution of samples arranged sequentially in sounding order and indication of the grouping of stations per depth strata.



a)



b)



c)

Figure 2. First factorial plane of the CA for: a) the whole data set, b) S1 and c) S2.

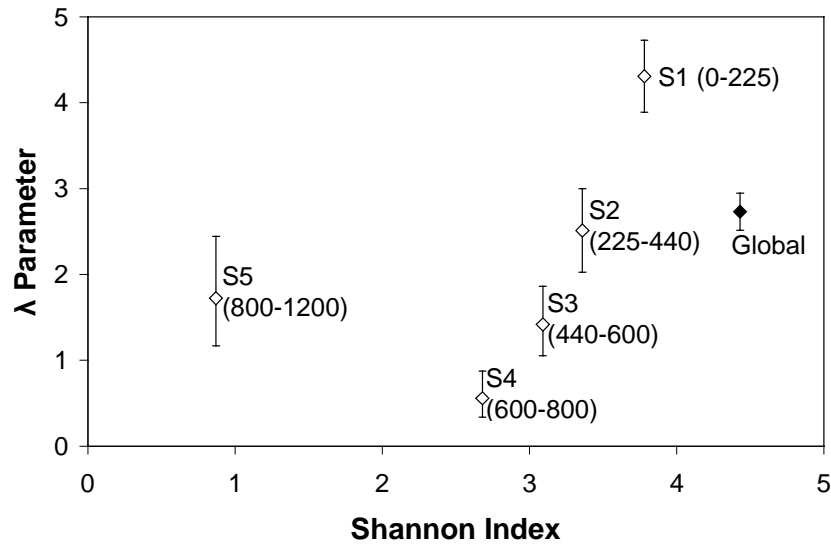


Figure 3. Relationship between the mean number of species per station and the Shannon index of diversity ( $H'$ ), the mean number of species is represented together with a confidence interval from the fit of the Poisson probability distribution.

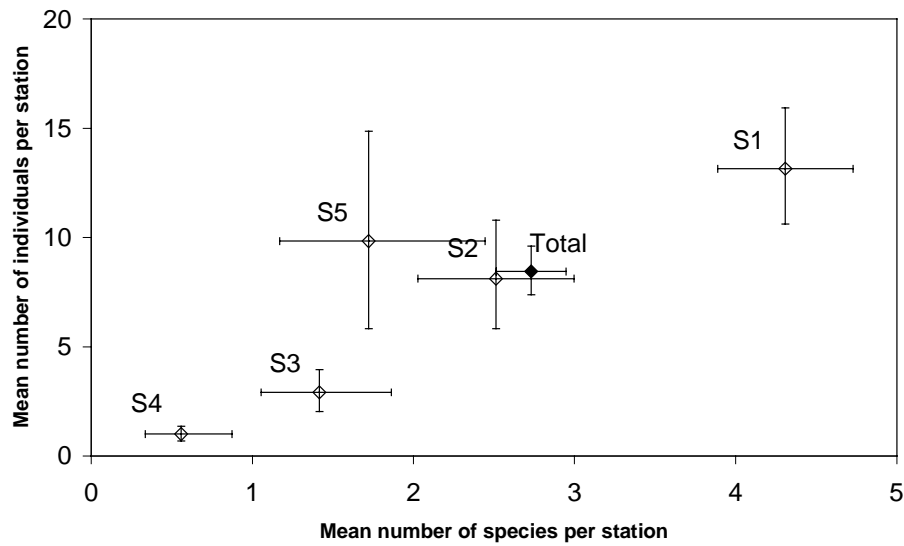


Figure 4. Relationship between the mean of the probability distributions of the number of species (adjusted to the Poisson Law) and individuals (adjusted to the exponential law) caught per station.