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Some Ecological Indices in Flemish Cap derived from the surveys conducted by EU between 1988 and 2006

by
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Abstract

Some ecological indices were calculated from the data obtained in the research surveys conducted by EU (Spain and Portugal) in Flemish Cap between the years 1988 and 2006. These indices were calculated for individual populations (intrinsic population rate of growth and mean length of catch) and for all the community (ABC curves, indices about faunal diversity, proportion of non-commercial species, mean length in community and size spectra). We use the data of twenty seven species captured in the survey year by year, included the *Pandalus borealis*. The data of the *Pandalus borealis* and the *Sebastes* juveniles have a great influence in the value of the indices, as their abundance is very high in relation to their contribution to the biomass. The indices present a general stable pattern. Despite the moratorium of the principal commercial species of the bank of Flemish Cap, it seems not to be recovery of the general community.

Introduction

In spite of the grateful necessity of the ecosystem approach to fisheries (EAF) for improved the exploited resources, (ICES, 2000; FAO, 2001) they have not still been carried out intents to performed ecological indicators in the Northwest Atlantic. Large efforts are devoted to the construction of indicators of marine capture fisheries at various levels from population to Ecosystem (García and Staples, 2000). Population and community descriptors can be used as indicators of the impact of fishing. Comparison of indicators with target and limit reference points provides decision criteria and also measures how well management performs. However, whereas reference points are rather well defined in single-stock assessment, an ecosystem approach complicates the matter for several reasons (Rochet *et al.*, 2005).

Many indicators targeting various components of Ecosystem have been developed, and used based on experience or more or less explicit assumptions, stemming from diverse ecological theories.

Moving from single-stock towards ecosystem based management mean taking note that exportation may not only modify target populations, but whole communities because fish communities are directly impacted by fishing as target species and also as by-catch and discards. For this reason our work has as objective two levels, e. g., population and community as whole. To address the impacts on both commercial and bycatch species in a comparable way, these indicators are estimated from scientific survey data. Furthermore time-series data are available on fish than the other groups, e. g. benthos.

Several studies have carried out critical revisions (Rochet and Trenkel, 2003) of the indicators of the impact of the fishing in the ecosystems. Others provide the usefulness and relevance of size based indicators (SBIs) to EAF (Yunne-Jai Shin *et al.*, 2005) and some papers present the performance in indicators derived from abundance estimates for detecting the impact of fishing on a fish community (Trenkel and Rochet, 2003).

Our aim is estimating for first time ecological indexes in the NAFO Area. Our objective is to contribute to the diagnosis of the general tendency of the communities in this area. We concentrate the analysis on Flemish Cap due to the available series of data is the longest: 1988 to 2006 from scientific bottom trawl surveys that have been conducted in Flemish Cap. On the other hand, Flemish Cap has some physical characteristics that cause a relative isolation. The Flemish Cap is an isolated bank, centred at 47 °N-45 °W, which is separated from the Grand Banks of the Newfoundland continental shelf by the deeper waters (up to 1500 m) of the Flemish Pass. The Cap is a dome-shaped feature that consists of a shallow central area (125 to 150 m). Their isolation and the relative simplicity in the biodiversity allow considering Flemish Cap a good example for studying the ecosystem level.

Multi-species bottom trawl surveys of the Flemish Cap have been conducted in July by the European Union (EU) since 1988. During 1988-2002, survey biomass indices indicated a shift in the predominant groundfish species from American plaice (*Hippoglossoides platessoides*) Atlantic cod (*Gadus morhua*) to Greenland halibut (*Reinhardtius hippoglossoides*) (Saborido and Vázquez, MS, 2003).

Up to the present mainly studies related to Flemish Cap have been published at the species level, so much of their biology (Alpoim *et al.*, 2002; Bowering and Brodie, 1994; Murua *et al.*, 2005; etc.) as of their ecology (Hendrickson and Vázquez, 2005; Paz and Casas, 1996; González *et al.*, 2006) but they have not been developed attempts in order to perform indicators at population and or community level to measure the impact of the fishing in the ecosystem as whole.

Material and methods

Material

European Union (Spain and Portugal) has conducted the summer groundfish research trawl survey series *Flemish Cap* in NAFO Division 3M since 1988. The data used in the present work correspond to the sampling results from this series between 1988 and 2006. The survey used a stratified random sampling design, with strata based on depth boundaries of 144, 181, 254, 365, 547 and 730 m (80, 100, 200, 300 and 400 fathoms) (Fig. 1). A description of the demersal sampling gear used can be found in Vázquez (2000); it was the same throughout the study period. The survey sample unit was defined as the swept area by a *Lofoten* trawl towed at a constant speed (3.5 kn) for 30 min.

In 2003 the vessel that had conducted the survey, the R/V *Cornide de Saavedra*, was replaced by the R/V *Vizconde de Eza*, both using a *Lofoten* gear. To avoid the lost of the information of the survey time series, a calibration between the two vessels was performed in years 2003 and 2004. The data (biomass and abundance at length) of the principal commercial species of the bank (*Reinhardtius hippoglossoides*, *Hippoglossoides platessoides*, *Gadus morhua*, *Sebastes* (*marinus*, *fasciatus*, *mentella*, juveniles), *Macrourus berglax* and *Pandalus borealis*) was transformed from the former vessel indices to the new vessel indices. In all cases transformation factors were near 1 (González-Troncoso and Casas, 2005). As in this work more species than the ones transformed were studied, we decided not to use the transformed data but the original data, so we used the data from the R/V *Cornide de Saavedra* in the period 1988-2002 and the data from the R/V *Vizconde de Eza* in the period 2003-2006. It is expected that the results were not too mistaken, as the gear was not changed.

In each survey the sets were allocated to strata according to area, with all strata containing at least two sets. Details of the survey are described by Vázquez (2002). Some information about the surveys is shown in Table 1.

Twenty seven species were selected in order to estimate several indices (Table 2). It was considered their importance so much in occurrence, biomass and abundance as the available data of each of them. The goal of the survey data is that they consisted of commercial and non-commercial species, but they were potentially dominant species in a given region, or potential forage for other species. The species of genus *Sebastes* have been identified every year since 1992 and three species were considered in the analysis: *Sebastes marinus*, *S. mentella* and *S. fasciatus*. In years 1989-1991, the *S. mentella* and the *S. fasciatus* were recorded together as *S. sp*. We distributed the data of the *S. sp* amongst *S. mentella* and *S. fasciatus* taking into account the proportion of the catches of these two species in years 1992-2006.

These 27 species amounted more than the 99% of the total biomass and abundance of the total period. All strata were sampled with sufficient intensity to asses their composition.

The data used for each species are biomass, abundance and numbers by length. These indices were calculated by the swept area method (Cochran, 1997) assuming catchability factor of 1 from the catches and the numbers, respectively, for each species.

Methods

Different ecological indexes have been proposed in the literature (ICES, 2005) although not all are sustained in a base theoretical white (Rochet and Trenkel, 2003).

We use indicators for species and for the community, based in the data of the 27 selected species, in order to try to measure the impact of fishing in the whole community. In Tables 3 and 4 we present a resume with all the models used and their characteristics.

Preliminary analysis indicate that *Pandalus borealis* and *Sebastes* juveniles have a great influence in the total abundance with regard to biomass. Some indices more sensitive to numbers could suffer great changes with the inclusion or not of these species in their calculation. For these indices, we made two analyses, one with all the species and another one without one or two of these species.

<u>Population indicators</u>

Intrinsic population rate of growth

The intrinsic population rate (r_i) is estimated using annual abundance estimates. The population dynamics model underlying this indicator is the following one:

$$N_i(t) = N_i(t-1)e^{r_i}$$

where $N_i(t)$ is the abundance of the species i in the year t

This model can be linearised by taking logarithms of both sides (Table 3, eq. 1):

$$\log(N_i(t)) = \delta_i + r_i t + \varepsilon_{i,t}$$

As the log-transformation is also applied to abundance estimates, the transformation stabilizes variances and justifies the use of standard regression techniques for estimating r as the slope. For our study we use as estimation model a simple linear regression. Taking r=0 as the reference point assumes that without any noticeable impact of fishing the population would be stable although randomly varying between years.

Mean length of catch

With the aim of know the health of each species, we analyse the progress of the mean length of catch, L_{mean}. A linear regression was adjusted to the data to know if a variation in the length distribution has occurred (Table 3, eq. 2). If the cero is among the 95% confidence interval, it is assumed that without any noticeable impact of fishing the population would be stable although randomly varying between years.

<u>Community indicators</u>

ABC curves

Abundance biomass comparison (ABC) curves is an indicator very used in the marine ecology literature (Warwick, 1986). Although at a first attempt we included the shrimp, at last we decide not to included it in the analysis because the high abundance with regard to biomass of this species could distort the results. A similar case is the *Sebastes* juveniles. So, we included in the analysis 25 species in total, except for the year 1989, where the *Lycodes valhii* was no present, and the 2000, where the *Synaphobranchus kaupi* was no present. And in the year 1988 only twenty two species are present, so although we include this year in the analysis, it must be not representative.

ABC curves are the combined k-dominance curves for species biomass and numbers. They have a theoretical background in classical evolutionary theory of r- and k-selection. In undisturbed states, the community is supposed to be dominated by k-selected species (slow-growing, large, late maturity), and the biomass curve lies above the abundance curve. With increasing disturbance, slow-growing species can not survive, and the system is increasingly dominated by r-selected species (fast-growing, small, opportunistic), and the biomass curve will be below the abundance curve (Blanchard *et al.*, 2004, Yemane *et al.*, 2005). The difference between the two curves is given by the W-statistics, which represents the area between them and take the following form:

$$W = \frac{\sum_{i=1}^{S}\left(\sum_{j=1}^{i} b_j - \sum_{j=1}^{i} a_j\right)}{50(S-1)}$$

where

b_j is the biomass of the species j, so $\sum_{j=1}^{i} b_j$ is the cumulative biomass

a_j is the abundance of the species j, so $\sum_{j=1}^{i} a_j$ is the cumulative abundance

S is the total number of species

In order to make the calculation, the species were ranked in decreasing order of abundance.

Faunal diversity

Species diversity is classically assessed with the species richness S, the Shannon-Wiener diversity index H and the Pielou evenness index J, calculated as follow (Blanchard *et al.*, 2004):

S is the number of species

$H = -\sum_{i=1}^{S} p_i \log p_i$, where p_i is the abundance or biomass ratio of the species i

$$J = \frac{H}{\log S}$$

The diversity indices N of Hill (1973) and D of Simpson were also assessed. The first is less sensitive to dominant species and the second to the sampling effort that the previous indices:

$$N = \exp(H)$$

$$D = \frac{1}{\sum_{i=1}^{S} p_i^2}$$

This indices were calculated with abundance data and with biomass data.

Another reasonable index of ecological stress, derived in this case of the idea of the ABC curves of comparing abundance and biomass, is the Shannon-Wiener evenness proportion $\left(SEP\right)$ index, calculated as McManus and Pauly (1990):

$$SEP = \frac{J_{biomass}}{J_{abundance}} = \frac{H_{biomass}}{H_{abundance}}$$

Warwick (1986) stays that under severe stress, community biomass will be more evenly distributed among species that numbers of individual are. So, in the case of non-stressed communities, the SEP index will have no trend along the time.

Proportion of non-commercial species

The relative importance of non-commercial species in the community is expressed in terms of either abundance or biomass (Table 4, eq. 1):

$$\frac{\hat{B}_n(t)}{\hat{B}(t)}, \frac{\hat{N}_n(t)}{\hat{N}(t)}$$

where

$\hat{B}_n(t)$ is the estimated biomass of all non-commercial species

$\hat{B}(t)$ is the estimated biomass of all commercial species

$\hat{N}_n(t)$ is the estimated abundance of all non-commercial species

$\hat{N}(t)$ is the estimated abundance of all non-commercial species

Under the impact of fishing, this proportion is expected to increase. The relationship of the proportion of non-commercial species with time is modelled by logistic regression (general linear model (GLM) with binomial distribution and logit-link function), where time is the explanatory variable. A positive slope is taken to suggest a significant impact of fishing (Trenkel and Rochet, 2003)

Mean length in community

We calculated the mean length in the community by confounding the lengths of all the species except *Pandalus borealis* (Table 4, eq. 2). Fishing is expected to shift the distribution to smaller lengths. As in the community there are species with different growth, and in order to avoid the influence of recruitment and outlier lengths, we use only the lengths between the 5^{th} and the 95^{th} percentile for each species to calculate the mean.

Size spectra

To calculated the size spectrum, we used abundance estimates at length in 5-cm length classes, with all the species confounded. These classes were used as a compromise between the desired precision of abundance estimates and the number of length classes available to fit the relationship (Trenkel and Rochet, 2003). The size spectrum is usually represented as a relationship between natural log of abundance numbers versus natural log of the mid-length of each length class. The inspection of the scatter points suggested that the quadratic models were appropriate to represent the annual size spectra across the whole observed length ranges (Table 4, eq. 3):

$$\ln(N_{i,t}) = \alpha_t + \beta_t l_i + \gamma_t l_i^2 + \varepsilon_i$$

Results

Population indicators

Intrinsic population rate of growth

Growth rate estimates for eleven species indicated that there was no evidence to reject the null hypothesis of a zero growth rate, whereas twelve populations were significantly increasing and four species were significantly decreasing (*Gadus morhua*, *Hippoglossoidess platessoides*, *Lycodes vahlii* and *Notacanthus chemnitzi*). Note that, between the four species on decreasing, two of them have a high commercial interest and are under moratorium (*Gadus morhua* and *Hippoglossoidess platessoides*) (Table 5).

Mean length of catch

The mean of the length remains significantly stable along the years for seventeen species of the seventy seven. For eight species, the mean decreases, and increases only for two species, the *Hippoglossoides platessodies* and the *Notacantus chemnitzi*. It is interesting to note that this two species have a decreasing intrinsic population rate (Table 6).

<u>Community indicators</u>

ABC curves

We present the results for all the species except the *Pandalus borealis* and for all species except the *Pandalus borealis* and the *Sebastes* juveniles. In all cases, the abundance curve lies above the biomass curve, so the W statistic is negative, but in general its absolute value is not too high. Without *Pandalus borealis* and *Sebastes* juveniles the W-statistics has no trend along the years, so the community is not improving, is not deteriorating. When we introduce the *Sebastes* juveniles in the equation the trend of the W statistics is positive, but because the W in the first years is smaller. So although it seems to be a improving in the community, it is no true, because in general the W is smaller each year (Figures 2a, 2b and 3).

Note that in the second case, when we do not introduce the *Sebastes* juveniles, it seems to be three-year ascending cycles in the W-statistics since 1995 (Figure 3).

Faunal diversity

Table 7 (a and b) shows the results of the diversity indices calculated. In this case, we calculated the indices with all the species, and the indices without the *Pandalus borealis* and the *Sebastes* juveniles, in order to know the impact that these two species have in the community. In general, the impact of this two species is not too high, less in biomass that in abundance. Generally, the diversity is higher for biomass and lower in abundance when we use all the species, but the trend is the same in all the cases, with a slight decrease in the indices along the years.

The results of the index SEP can be seen in Figure 4. As we can see, the influence of the *Pandalus borealis* and *Sebastes* juveniles is highly marked in some years. Without the data of these two species, the SEP shows no trends along the years.

Proportion of non-commercial species

A list of the species considered commercial or no commercial is in table 2. We made the analysis for all the species and without the *Pandalus borealis*, due to its increase in last years could overestimated the ratio of commercial species.

The ratio of non commercial species in abundance and biomass decrease in the last years (Figure 5). It must be due to the increase in the biomass and abundance of the species of the genus *Sebastes* (Tables 8 and 9).

Mean length in community

The mean population length has decreased in the period studied. It could indicate that fishing shift the distribution to smaller lengths (Figure 6).

Size spectra

The smallest length class observed and used for the annual size spectra was 0-5 cm, except for 1989 size spectrum which consisted of fish at least 6 cm long. The largest length class was 155-160 cm. All size spectra showed regular decreasing patterns generally indicative of high fish numbers in smaller sizes and viceversa in large sizes (Shin, 2000, Munyandorero, 2006) (Figure 7). They were rather curvilinear and well fitted by quadratic functions, with R^2 varying between 0.91 and 0.98.

Changes in the curvature term respond to fishing. They usually decrease with increasing fishing pressure and removals of large fish (Shin, 2000; Munyandorero, 2006). But the linear trends have not yet been given any fishery or biological interpretation. In the other hand, changes in the intercept followed variations in total abundance and biomass (Trenkel and Rochet, 2003). In our case all curvature terms were negative, meanwhile the linear parameters are all positive. But in general, no one of the parameters have a trend over the years (Figure 8). This could indicated a stability in the community.

It must be noted in the graph that, if we consider only the larger sizes, the scatter points seem to fit a linear line. The size spectra is usually described by a decreasing linear function, but irregularities may occur, particularly among the smaller sizes, causing a curvature in the spectrum (Munyandorero, 2006).

Discussion

There are many studies that trying to explicate the effect of fishing in individual populations or, more and more, in communities, trying to contribute to the development if an ecosystem approach in the evaluation of fisheries. But it must be noted that the majority of the ecosystem indicators are sensitive but not specific to fishing impacts (Shin *et al.*, 2005). It has been shown that the relationships between diversity, stability and stress are far very complex and difficult to explain.

The presence of species that have a high abundance in regards to their biomass, as *Pandalus borealis* and *Sebastes juveniles*, have a strong influence in some of the indices performed, as the ABC curves and the SEP index, that difficult the test of the commercial species. It would be necessary to perform a deeper sensitive analysis with and without this two species. Note that this two species make up an important part of the diet of the *Gadus morhua* and the *Sebastes*.

From the above analysis we can conclude that the performed indices seem to be more or less in accordance. In the case of individual indices, the mean length and the intrinsic population rate, the vision in general is that the community, except for some species, remain rather stable. The community indices are in general in accordance that the community is stable or a bit improving, although the fishing affect the populations, as we can see in the decrease of the mean population length, for example, in the case of the *Gadus morhua* or of the *Hippoglossoides platessoides*, two very important commercial species of the North Atlantic.

More of the indices point a stable vision of the Flemish Cap bank, as the mean length of the catch, the ABC curves and the size spectra. Some of then could be indicate a slight improve, as the intrinsic population rate that is stable for 11 species and increases for another 12 and the proportion of non-commercial species, that decreases along the years, although it must be due to the increase in the abundance and biomass of the species of genus *Sebastes*. The faunal diversity indices present in general a decrease, as the mean length in the community, but the decrease is very slight.

In general, it seems that the community in Flemish Cap is not recovered although the principal commercial species have been under moratorium since several years ago, as the *Gadus morhua* since 1999 or the *Hippoglossoides platessoides* since 1996.

It is clear that not only the fishing affects a marine community. It can be another more factors such as environment ones, predation, migration... In addition, in this work we do not study all the community of the Flemish Cap, only twenty seven species, of which twenty six are fishes. Surely, there are more interactions between another species, fishes and not fishes, that we are not being studied in the present paper.

The stability of more of the indices in a long period of years suggest a new state of equilibrium in Flemish Cap, due to the collapse of the *Gadus morhua*, the present dominance of the species of genus

Sebastes and the increase of the presence of *Pandalus borealis* (González Troncoso *et al.*, 2006). The shift in the abundance and biomass of these species can be due to the collapse of the Atlantic cod, that is the more direct competitor as predator in the community for *Sebastes* and the principal predator of the *Pandalus borealis*. It can be a problem for the *Gadus morhua*, as the community has remained stable last almost 20 years, as in an equilibrium point, and it seem not to be important changes in the community and the factors than affect it (fishing pressure, environmental processes…) that could change this equilibrium. This can make difficult the recover of the Atlantic cod and the community to the previous stage.

It would be interesting to open new ways of investigation in the area of indicators, taking into account another parameters not using here, as can be oceanographic parameters or feeding parameters.

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Table 1.- Number of trips and hauls made during *Flemish Cap* EU bottom trawl surveys on NAFO Division 3M on R/V *Cornide de Saavedra* (1988-2002) and the R/V *Vizconde de Eza* (2003-2006).

Year	Valid hauls	Depth range
1988	115	126-710
1989	116	139-749
1990	113	128-723
1991	117	129-708
1992	117	129-725
1993	101	132-730
1994	116	135-721
1995	121	126-721
1996	117	135-701
1997	117	133-720
1998	119	140-712
1999	117	133-718
2000	120	135-704
2001	120	132-719
2002	120	130-740
2003	114	80-683
2004	124	136-1378
2005	117	132-1438
2006	115	134-1457
Total	2216	80-1457

Table 2.- Species included in the analysis

Main fish species	Common name	Status	Depth range
Anarhichas denticulatus	Northern wolffish	No commercial	129-1295
Anarhichas lupus	Wolf-fish	No commercial	80-752
Anarhichas minor	Spotted wolffish	No commercial	126-1100
Antimora rostrata	Blue antimora	No commercial	171-1457
Bathyraja spinicauda	Spinetail ray	No commercial	148-1277
Chauliodus sloani	Sloane´s viperfish	No commercial	252-1457
Gadus morhua	Atlantic cod	Commercial	126-749
Glyptocephalus cynoglossus	Witch flounder	Commercial	126-730
Hippoglossoides platessoides	American plaice	Commercial	126-715
Lycodes esmarki	Greater eelpout	No commercial	218-863
Lycodes reticulatus	Artic eelpout	No commercial	155-1311
Lycodes vahlii	Vahl´s eelpout	No commercial	251-1438
Macrourus berglax	Roughhead grenadier	Commercial	227-1457
Nezumia bairdi	Marlin-spike grenadier	No commercial	141-1438
Notacanthus chemnitzi	Spiny eel	No commercial	221-1457
Onogadus ensis	Threadfin rockling	No commercial	194-1457
Pandalus borealis	Northern shrimp	Commercial	80-1316
Raja radiata	Thorny skate	Commercial	80-1334
Reinhardtius hippoglossoides	Greenland halibut	Commercial	80-1457
Sebastes (juveniles)	Juveniles redfish	No commercial	80-972
Sebastes fasciatus	Acadian redfish	Commercial	80-1089
Sebastes marinus	Ocean perch	Commercial	80-690
Sebastes mentella	Deepwater redfish	Commercial	80-1274
Serrivomer beani	Bean´s sawtoothed eel	No commercial	307-1457
Stomias boa	Scaly dragonfish	No commercial	141-1457
Synaphobranchus kaupi	Kaup´s arrowtooth eel	No commercial	201-1457
Urophycis chesteri	Longfin hake	No commercial	141-771

Table 3.- Indicators for measuring the impact of fishing on population i

Indicator	Description	Required information	Model	Estimation method	Null hypothesis H_0	Hypothesis test method
r_i (1)	Intrinsic population growth rate	$N_i(t)$	$N_i(t) = N_i(t-1)e^{r_i}$	$\log(N_i(t)) = \delta_i + r_i t + \varepsilon_{i,t}$	$r_i = 0$	0 within 95% CI of $\hat{r}_i$
L_{mean_i} (2)	Mean length of catch	$C_{l,i}$	$L_{mean_i} = \frac{1}{C_i}\sum_{l=1}^{L} C_{l,i} l_l$	$\hat{L}_{mean_i} = \frac{1}{\hat{C}_i}\sum_{l=1}^{L} \hat{C}_{l,i} l_l$ $\hat{L}_{mean_i} = a_i + b_i t + \varepsilon_{i,t}$	$b_{ii} = 0$	0 within 95% CI of $\hat{b}_i$

Table 4.- Indicators and their data requirements for measuring the impact of fishing on a community consisting of S species (i=1,…,S).

Indicator	Name of indicator	Estimator	Method to obtain indicator distribution	Null hypothesis	Alternative hypothesis	Hypothesis test method
$\frac{B_n(t)}{B(t)}, \frac{N_n(t)}{N(t)}$ (1)	Proportion of non-commercial species	$\frac{\hat{B}_n(t)}{\hat{B}(t)}, \frac{\hat{N}_n(t)}{\hat{N}(t)}$	Linear regression	$\frac{\hat{N}_n(t)}{\hat{N}(t)} = a + ct$, $c = 0$ no trend	Increase in proportion of non-commercial species, $c > 0$	0 within 95% CI of $\hat{c}$
$\overline{L} = \frac{1}{C}\sum_{l=1}^{L} C_l l_l$ (2)	Mean length in community	$\hat{\overline{L}} = \frac{1}{C}\sum_{l=1}^{L} C_l l_l$		No change	SLOPE=0	0 within 95% CI of $\hat{c}$
$slope_{l_s}$, int_{l_s} (3)	Curvature term and intercept of length spectra	Quadratic regression: $\ln(N_{i,t}) = \alpha_t + \beta_t l_i + \gamma_t l_i^2 + \varepsilon_i$	Unknown	$\alpha_t = 0$ $\gamma_t = 0$	$\alpha_t \neq 0$ $\gamma_t \neq 0$	Visual (trend of the points)

Table 5.- Intrinsic population growth for all the species

Main fish species	r	Std(r)	Confidence interval (95%)	Test
Anarhichas denticulatus	0.0630	0.0161	0.0290 - 0.0970	Up
Anarhichas lupus	-0.0108	0.0251	-0.0638 - 0.0422	r=0
Anarhichas minor	0.0133	0.0269	-0.0434 - 0.0701	r=0
Antimora rostrata	0.0235	0.0160	-0.0103 - 0.0573	r=0
Bathyraja spinicauda	-0.0270	0.0129	-0.0542 - 0.0003	r=0
Chauliodus sloani	0.0402	0.0205	-0.0031 - 0.0835	r=0
Gadus morhua	-0.2461	0.0510	-0.3537 - -0.1384	Down
Glyptocephalus cynoglossus	0.0062	0.0254	-0.0472 - 0.0597	r=0
Hippoglossoides platessoides	-0.1421	0.0184	-0.1808 - -0.1033	Down
Lycodes esmarki	0.0174	0.0332	-0.0530 - 0.0878	r=0
Lycodes reticulatus	0.1794	0.0464	0.0815 - 0.2771	Up
Lycodes vahlii	-0.1299	0.0325	-0.1991 - -0.0606	Down
Macrourus berglax	0.0430	0.0175	0.0060 - 0.0798	Up
Nezumia bairdi	0.0553	0.0181	0.0169 - 0.0935	Up
Notacanthus chemnitzi	-0.1053	0.0260	-0.1601 - -0.0505	Down
Onogadus ensis	0.1302	0.0215	0.0848 - 0.1755	Up
Pandalus borealis	0.1916	0.0253	0.1382 - 0.2448	Up
Raja radiata	0.0276	0.0224	-0.0196 - 0.0748	r=0
Reinhardtius hippoglossoides	0.0708	0.0223	0.0237 - 0.1178	Up
Sebastes (juveniles)	0.0980	0.0848	-0.0827 - 0.2786	r=0
Sebastes fasciatus	0.1059	0.0487	0.0031 - 0.2086	Up
Sebastes marinus	0.1602	0.0489	0.0570 - 0.2633	Up
Sebastes mentella	0.0653	0.0241	0.0144 - 0.1161	Up
Serrivomer beani	0.0418	0.0206	-0.0016 - 0.0852	r=0
Stomias boa	0.1462	0.0430	0.0549 - 0.2373	Up
Synaphobranchus kaupi	-0.0190	0.0720	-0.1716 - 0.1335	r=0
Urophycis chesteri	0.1192	0.0276	0.0608 - 0.1774	Up

Table 6.- Mean length of each species

Main fish species	Slope	Confidence interval (95%)	Tendency
Anarhichas denticulatus	-0.3140	-0.8673 - 0.2392	Stable
Anarhichas lupus	-0.5439	-0.7697 - -0.3179	Down
Anarhichas minor	0.0728	-0.7295 - 0.8751	Stable
Antimora rostrata	0.2158	-0.1092 - 0.5408	Stable
Bathyraja spinicauda	-0.0877	-1.2077 - 1.0322	Stable
Chauliodus sloani	0.0474	-0.0306 - 0.1253	Stable
Gadus morhua	0.3579	-0.7310 - 1.4468	Stable
Glyptocephalus cynoglossus	0.1211	-0.0146 - 0.2567	Stable
Hippoglossoides platessoides	0.3965	0.1695 - 0.6233	Up
Lycodes esmarki	-0.0810	-0.3192 - 0.1572	Stable
Lycodes reticulatus	-0.4386	-0.6398 - -0.2373	Down
Lycodes vahlii	0.1275	-0.2450 - 0.4999	Stable
Macrourus berglax	-0.1000	-0.2768 - 0.0768	Stable
Nezumia bairdi	0.0456	-0.0057 - 0.0969	Stable
Notacanthus chemnitzi	1.8386	0.9281 - 2.7490	Up
Onogadus ensis	0.1509	-0.2752 - 0.5770	Stable
Pandalus borealis	-0.5193	-0.6771 - -0.3614	Down
Raja radiata	-0.4193	-0.6450 - -0.1935	Down
Reinhardtius hippoglossoides	-0.4632	-0.7246 - -0.2016	Down
Sebastes (juveniles)	-0.0686	-0.3241 - 0.1869	Stable
Sebastes fasciatus	-0.3982	-0.5416 - -0.2548	Down
Sebastes marinus	-0.2912	-0.6512 - 0.0688	Stable
Sebastes mentella	-0.1667	-0.4479 - 0.1146	Stable
Serrivomer beani	0.1351	-0.0636 - 0.3338	Stable
Stomias boa	-0.2394	-0.4523 - -0.0264	Down
Synaphobranchus kaupi	0.0006	-0.7135 - 0.7147	Stable
Urophycis chesteri	-0.2368	-0.4453 - -0.0283	Down

Table 7.- Diversity index for the years 1988-2006

a)Abundance

A) With all the species

Year	H	J	N	D
1988	1.6828273	0.54442064	5.38074746	4.2060117
1989	1.79453166	0.5575026	6.0166562	4.94847752
1990	1.88529281	0.57202249	6.58828329	4.98127116
1991	1.69391809	0.5139569	5.44075635	3.79170369
1992	1.31838041	0.40001385	3.73736347	2.7560456
1993	1.36858049	0.41524522	3.9297684	2.79910198
1994	1.62130713	0.49192578	5.05969967	3.24789988
1995	1.43166147	0.43438481	4.18564775	2.81084732
1996	1.54070683	0.4674706	4.66788852	3.14654349
1997	1.58849776	0.48197099	4.89638784	3.3815867
1998	0.59009964	0.17904395	1.80416817	1.28443656
1999	0.81802435	0.24819928	2.26601855	1.56552305
2000	0.97476822	0.29918334	2.65055278	1.75501621
2001	0.94158265	0.28568849	2.56403618	1.70349908
2002	0.9517414	0.28877078	2.59021633	1.81863438
2003	1.28688624	0.39045811	3.62149252	2.30892017
2004	1.32864206	0.40312737	3.77591245	2.64790205
2005	1.34650364	0.40854681	3.84396212	2.56651664
2006	1.5537058	0.47141466	4.72896236	4.08027894

B) Without the *Pandalus borealis* and *Sebastes* juveniles

Year	H	J	N	D
1988	1.48797291	0.48873771	4.42811025	3.4088182
1989	1.6153932	0.50829636	5.0298653	4.04757287
1990	1.84479983	0.57311929	6.32683323	4.58990879
1991	1.75624323	0.54560764	5.79064236	4.15927515
1992	1.50829332	0.46857767	4.5190117	2.87754057
1993	1.88042822	0.58418787	6.5563118	3.51083863
1994	1.94607632	0.6045826	7.00116328	4.42778964
1995	1.38522186	0.43034337	3.99571231	2.16100494
1996	1.30023903	0.40394197	3.67017386	2.0763861
1997	1.56202786	0.48527124	4.76848128	3.22086972
1998	1.72461172	0.53578076	5.61034224	3.07783809
1999	1.2814742	0.39811235	3.60194582	2.05821168
2000	1.33630411	0.42047875	3.8049548	2.32126039
2001	1.64051048	0.50965323	5.15780177	3.02234478
2002	1.42107635	0.44148219	4.14157584	2.9174913
2003	1.54895644	0.48121038	4.70655606	3.70467232
2004	1.48147835	0.46024713	4.3994448	3.42281174
2005	1.49113983	0.46324863	4.44215593	3.88705893
2006	1.10045926	0.34187689	3.00554604	2.47130625

b)Biomass

A) With all the species

Year	H	J	N	D
1988	1.83568178	0.59387142	6.26940705	4.40492068
1989	1.7017545	0.52867976	5.48355988	3.97847166
1990	2.05113459	0.62234106	7.77671952	5.63042813
1991	1.95244093	0.59239611	7.04586507	4.27265342
1992	1.89981011	0.57642723	6.68462496	3.97236544
1993	2.20364093	0.66861347	9.05793287	5.53698523
1994	2.22428881	0.67487831	9.24690413	6.63821597
1995	2.06440664	0.62636797	7.88062044	4.32298722
1996	1.91738364	0.58175927	6.80313569	3.66889554
1997	1.9174735	0.58178653	6.8037471	4.55847966
1998	2.10554194	0.63884896	8.21155196	5.16846986
1999	1.78282013	0.54093094	5.94660299	3.47853393
2000	1.65118606	0.5067947	5.21315928	3.38035022
2001	2.18841002	0.66399222	8.92101762	5.67126699
2002	2.08252773	0.63186614	8.02472768	5.98382873
2003	1.93435245	0.58690783	6.91956183	4.96703232
2004	2.07007793	0.62808871	7.92544073	5.7508315
2005	1.86858852	0.56695419	6.47914479	5.02864439
2006	1.52717915	0.46336612	4.605168	3.38855636

B) Without the *Pandalus borealis* and *Sebastes juvenil*

Year	H	J	N	D
1988	1.79885558	0.59084984	6.04272809	4.32268394
1989	1.67028884	0.52556971	5.31370239	3.92031329
1990	1.87812597	0.58347264	6.54123488	4.77862107
1991	1.79223797	0.55679003	6.00287169	3.79559503
1992	1.61044023	0.50031139	5.0050141	2.96609246
1993	2.00519024	0.62294737	7.42750678	4.06044086
1994	2.16191641	0.6716371	8.68777108	6.1855637
1995	1.96463384	0.61034782	7.13230058	3.99195121
1996	1.80887438	0.56195842	6.10357325	3.37840794
1997	1.82362694	0.56654156	6.19428404	4.29600794
1998	1.93946469	0.60252858	6.9550269	4.19620022
1999	1.61205824	0.50081405	5.01311883	2.9338111
2000	1.48155104	0.46618186	4.39976458	3.00063147
2001	1.96746554	0.61122754	7.15252569	4.31937608
2002	1.80534292	0.56086131	6.08205676	4.04745047
2003	1.68165839	0.52243655	5.37446156	3.92268027
2004	1.80816339	0.56173754	6.09923521	4.26764837
2005	1.55989289	0.48460797	4.75831155	3.63851228
2006	1.32222257	0.41077154	3.75175066	2.95262521

Table 8.- Abundance (,000000) by species and total per year

Species	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Anarhichas denticulatus	0.276	0.204	0.151	0.299	0.424	0.437	0.723	0.755	0.657	0.456	0.538	0.336	0.261	0.449	0.709	0.649	0.781	0.858	0.884	9.571
Anarhichas lupus	8.994	8.857	8.127	11.529	8.62	21.044	12.777	25.989	43.679	15.219	12.483	5.147	4.772	9.479	3.786	16.934	15.293	9.618	10.304	243.657
Anarhichas minor	1.206	0.938	1.167	2.607	1.791	2.591	5.09	5.434	6.604	6.04	4.577	2.018	1.502	1.201	1.071	1.579	3.046	2.686	2.663	52.605
Antimora rostrata	4.312	3.734	2.885	4.928	7.517	3.103	4.65	1.807	3.255	2.682	4.112	3.313	3.775	7.727	3.632	4.411	8.75	6.422	4.889	81.592
Bathyraja spinicauda	0.238	0.182	0.288	0.224	0.185	0.339	0.188	0.127	0.171	0.108	0.098	0.176	0.115	0.186	0.103	0.188	0.187	0.185	0.141	3.191
Chauliodus sloani	0.74	0.202	0.662	0.542	0.912	1.186	0.789	0.324	0.845	1.245	0.549	1.353	1.52	0.51	0.683	0.586	1.471	0.959	1.266	15.604
Gadus morhua	129.048	192.649	53.976	195.344	128.247	169.032	36.777	19.578	12.426	9.052	2.987	1.391	1.312	2.55	1.976	1.555	4.303	8.732	25.876	867.763
Glyptocephalus cynoglossus	2.354	0.631	0.915	1.683	1.919	2.418	1.983	1.495	0.999	0.599	0.56	0.971	0.864	0.996	0.454	1.546	3.022	3.21	1.76	26.025
Hippoglossoides platessoides	25.222	21.834	16.674	14.601	10.563	9.307	8.514	7.185	4.38	2.901	2.892	2.06	1.624	2.365	1.489	2.999	4.109	2.831	2.139	118.467
Lycodes esmarki	0	0.252	0.303	1.025	0.286	1.621	0.317	0.885	1.536	1.177	2.198	1.007	0.762	1.168	0.207	1.023	0.715	0.659	0.373	15.514
Lycodes reticulatus	0.318	6.039	5.732	10.089	5.766	4.873	8.294	10.733	9.913	10.888	24.015	7.515	8.366	14.049	10.413	23.694	35.898	1156.917	15.26	1368.454
Lycodes vahlii	0	0	0.25	0.503	0.627	0.963	0.826	0.802	1.203	0.589	0.513	0.184	0.129	0.374	0.083	0.228	0.217	0.066	0.091	7.648
Macrourus berglax	4.695	1.964	1.823	2.956	3.324	7.038	4.015	4.243	3.467	2.952	4.413	3.135	2.54	4.996	3.025	9.215	11.051	4.361	6.027	80.545
Nezumia bairdi	0	5.414	4.114	16.831	9.187	19.025	14.697	13.638	13.198	14.163	16.416	10.375	12.203	12.684	12.003	32.585	25.616	14.964	18.751	265.864
Notacanthus chemnitzi	0.81	0.291	0.107	0.522	0.534	0.784	0.604	0.498	0.215	0.312	0.31	0.098	0.1	0.149	0.122	0.055	0.248	0.094	0.078	5.121
Onogadus ensis	0.204	0.115	0.081	0.219	0.221	0.318	0.139	0.337	0.421	0.375	0.997	0.24	0.238	0.522	0.427	1.683	1.681	1.1	1.155	10.269
Pandalus borealis	147.148	127.451	182.253	679.336	1550.143	907.847	261.267	590.707	428.447	623.509	3514.731	1869.984	1758.975	2385.96	3031.864	2772.297	4443.552	6896.874	3738.488	35763.685
Raja radiata	1.047	0.608	0.8	1.49	1.272	2.058	1.471	0.944	0.686	0.735	0.874	0.608	0.534	0.936	0.693	3.338	3.318	1.499	1.557	23.421
Reinhardtius hippoglossoides	7.565	3.791	5.725	9.327	10.529	9.133	11.626	21.763	22.733	31.091	43.217	35.941	26.956	23.548	19.177	10.587	25.32	16.285	15.676	342.425
Sebastes (juveniles)	0	0	242.638	284.169	841.257	601.456	653.717	9.285	16.478	27.389	35.517	20.905	63.923	369.927	675.993	339.699	1552.25	1359.611	1498.605	8592.819
Sebastes fasciatus	352.6684	233.705	103.773	142.0545	71.86761	19.16	47.378	33.273	66.698	97.344	48.821	49.534	70.217	85.84	191.84	373.9108	684.5279	886.45	3218.257	5752.674
Sebastes marinus	60.873	62.903	29.431	14.025	10.754	11.93	73.053	50.616	53.187	165.28	22.996	22.786	63.806	16.877	27.723	370.522	596.407	634.949	1497.113	3724.358
Sebastes mentella	340.347	225.5399	100.1474	137.0859	316.641	47.509	162.105	408.934	531.611	340.657	240.863	332.937	352.996	216.683	217.637	372.1031	389.5662	561.661	936.308	5242.485
Serrivomer beani	0.079	0.127	0.142	0.146	0.329	0.487	0.151	0.217	0.214	0.324	0.613	0.404	0.493	0.276	0.235	0.36	0.297	0.171	0.214	5.2
Stomias boa	0	0.138	0.11	0.24	0.414	0.205	0.173	0.249	0.012	0.589	0.961	1.007	1.231	0.976	0.938	0.979	0.943	0.668	1.431	11.264
Synaphobranchus kaupi	1.471	0.722	0.257	0.609	0.553	0.431	0.034	0.056	0.017	0.042	0.273	0.007	0	0.125	0.027	0.389	0.722	0.424	2.652	7.34
Urophycis chesteri	1.493	1.078	1.249	1.416	1.194	2.409	2.579	1.27	1.64	0.619	7.323	4.733	2.683	5.796	1.301	13.124	13.357	8.933	6.238	76.942
Total	1091.108	913.153	770.161	1542.185	2987.907	1846.704	1313.979	1211.144	1224.692	1356.345	3993.904	2378.165	2381.897	3166.373	4207.701	4362.223	7829.808	11581.22	11008.498	64076.061

Table 9.- Biomass (thousand of tons) by species and total per year

Species	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Anarhichas denticulatus	877	1401	751	1022	1379	1701	2120	2567	2298	1398	1450	1045	648	1197	1659	1306	2072	1513	2224	27751
Anarhichas lupus	4815	4676	4942	6015	4614	8117	6290	8817	9990	4464	3429	1502	1378	2205	1116	2707	4196	2701	3063	80221
Anarhichas minor	2174	1411	2445	3060	3130	3691	7228	7923	8271	8173	6108	3036	2495	2460	2450	1864	4310	3496	3696	75246
Antimora rostrata	392	302	286	560	720	510	799	195	186	235	488	292	263	665	348	309	1157	814	948	9077
Bathyraja spinicauda	1991	676	1154	995	1111	1315	1009	453	830	601	451	656	296	874	604	371	1113	924	725	14158
Chauliodus sloani	29	9	19	16	35	43	26	13	29	45	18	43	50	20	22	19	51	32	41	530
Gadus morhua	37133	103795	53977	36597	25389	55431	24062	9072	8196	9063	4532	2596	2782	2451	2270	1593	4070	4928	12254	363056
Glyptocephalus cynoglossus	914	335	419	769	836	1037	788	715	509	319	240	379	412	462	211	841	1565	1547	869	12251
Hippoglossoides platessoides	12029	10533	8986	7565	6594	5896	6169	5201	3073	2268	2577	1940	1204	1803	1536	2298	3512	2366	1649	75171
Lycodes esmarki		98	86	275	100	591	90	229	310	268	323	179	142	204	55	198	155	138	82	3523
Lycodes reticulatus	69	975	1010	1598	1114	827	1565	1745	1179	1366	1662	676	619	992	743	1735	3502	2319	1662	25289
Lycodes vahlii			34	104	133	280	218	163	213	97	69	47	16	51	11	26	25	9	13	1509
Macrourus berglax	2390	1037	1014	1587	1865	3595	2350	1838	1619	1425	2014	1488	1249	2473	1440	2295	3593	1841	3498	36221
Nezumia bairdi		314	227	653	606	909	874	738	738	863	807	830	577	590	602	1275	1185	722	963	13471
Notacanthus chemnitzi	501	408	65	478	449	652	455	344	180	287	169	62	100	107	65	25	139	49	90	4124
Onogadus ensis	51	13	17	38	50	84	40	39	33	62	104	50	43	104	55	150	272	156	270	1579
Pandalus borealis	2164	1973	2160	8211	16531	8059	3338	5323	6502	5096	16620	12430	9720	14110	18134	20697	20040	24599	16049	209593
Raja radiata	1885	1051	1617	2965	2438	3608	2445	1719	1182	1173	1509	940	832	1321	925	3891	4929	2413	2620	37577
Reinhardtius hippoglossoides	6818	4399	5708	8038	8567	6428	7910	10577	11324	15820	23849	20986	16751	14143	11912	6127	12785	9169	11054	205547
Sebastes (juveniles)			16127	4001	23237	28647	49262	235	329	830	1100	255	2045	5156	23070	9823	43060	63743	41811	312732
Sebastes fasciatus	52279	41661	26562	26059	33290	4352	7823	5024	11025	17471	6436	7926	12915	11530	23173	52477	79555	100657	309657	646245
Sebastes marinus	15326	22962	14086	4093	4227	4026	33225	9062	11293	64847	6422	9429	44888	8610	9798	69049	85384	122159	290805	814365
Sebastes mentella	83687	66690	42520	82693	114633	17852	35727	58662	77897	56093	45358	65281	89365	38617	40999	48236	51431	84182	105496	911471
Serrivomer beani	13	18	15	12	28	38	12	19	19	30	51	30	46	36	25	26	30	13	20	467
Stomias boa		7	4	6	10	4	6	6	2	12	17	16	21	17	16	16	14	14	19	206
Synaphobranchus kaupi	219	88	44	77	70	65	8	16	3	11	37	1		23	4	26	105	56	490	1125
Urophycis chesteri	187	143	151	147	69	126	214	82	81	33	229	246	151	368	102	528	643	581	553	4446
Total	225943	270598	188275	200392	254966	157883	194085	130776	157309	192355	126128	132360	189008	110608	141424	229479	329983	431185	810915	4247730

Figure 1. Chart showing the positions of some bottom trawl stations on Flemish Cap area between years 1988 and 2006 with the approximate isobaths.

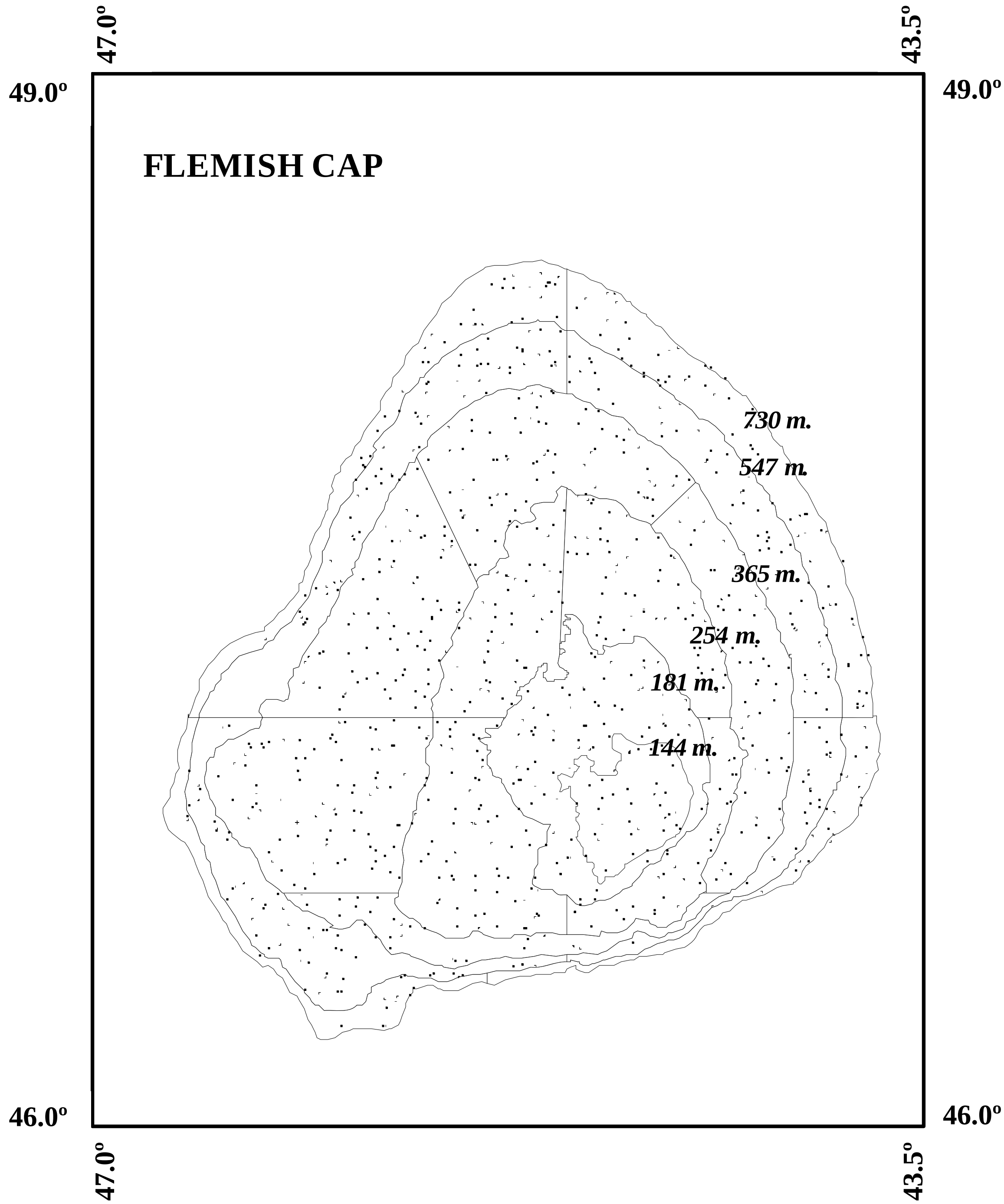


Figure 2a. ABC curves for all the species except the shrimp (*Pandalus borealis*)

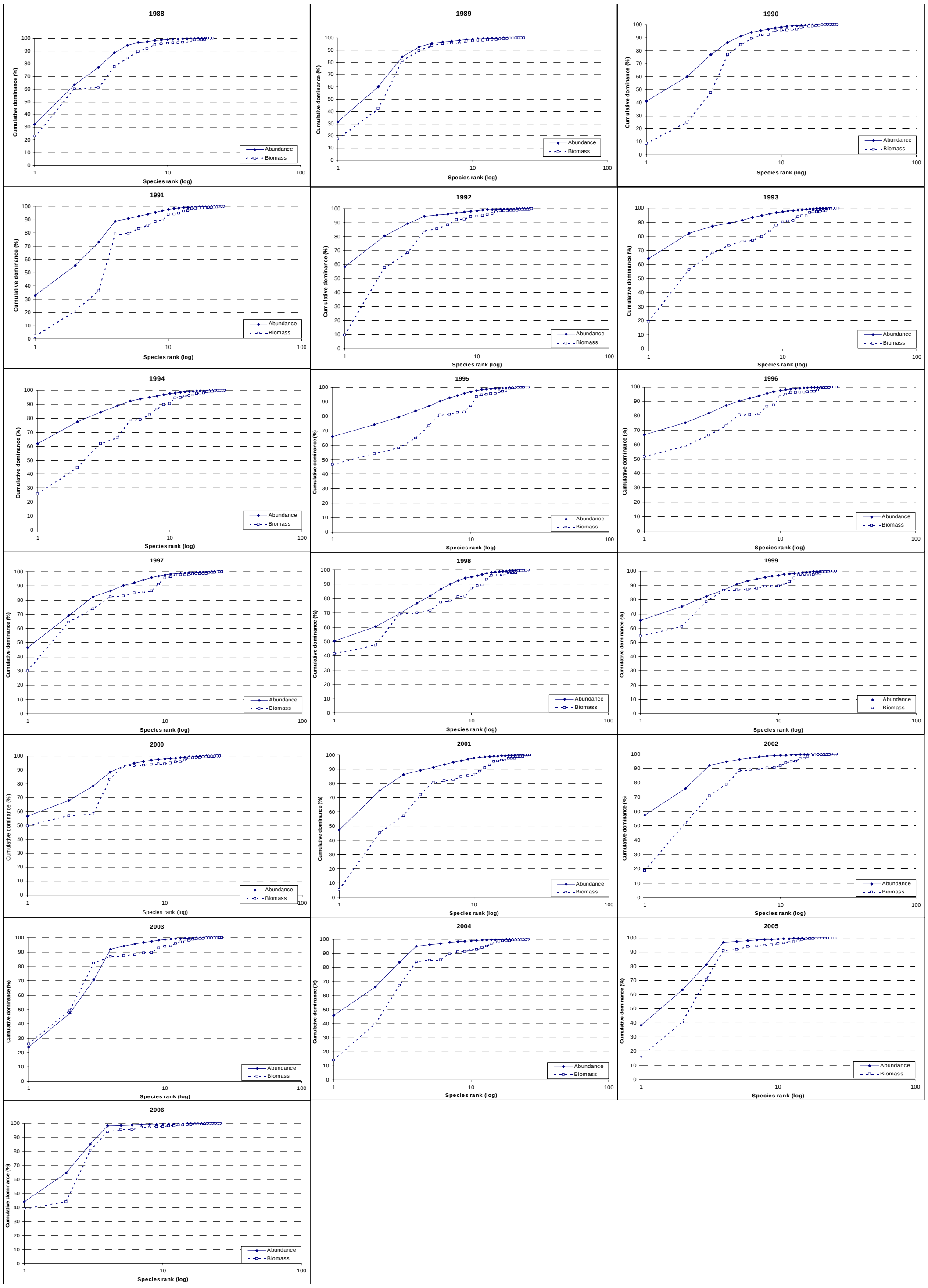


Figure 2b. ABC curves for all the species except the shrimp (*Pandalus borealis*) and the *Sebastes* juveniles

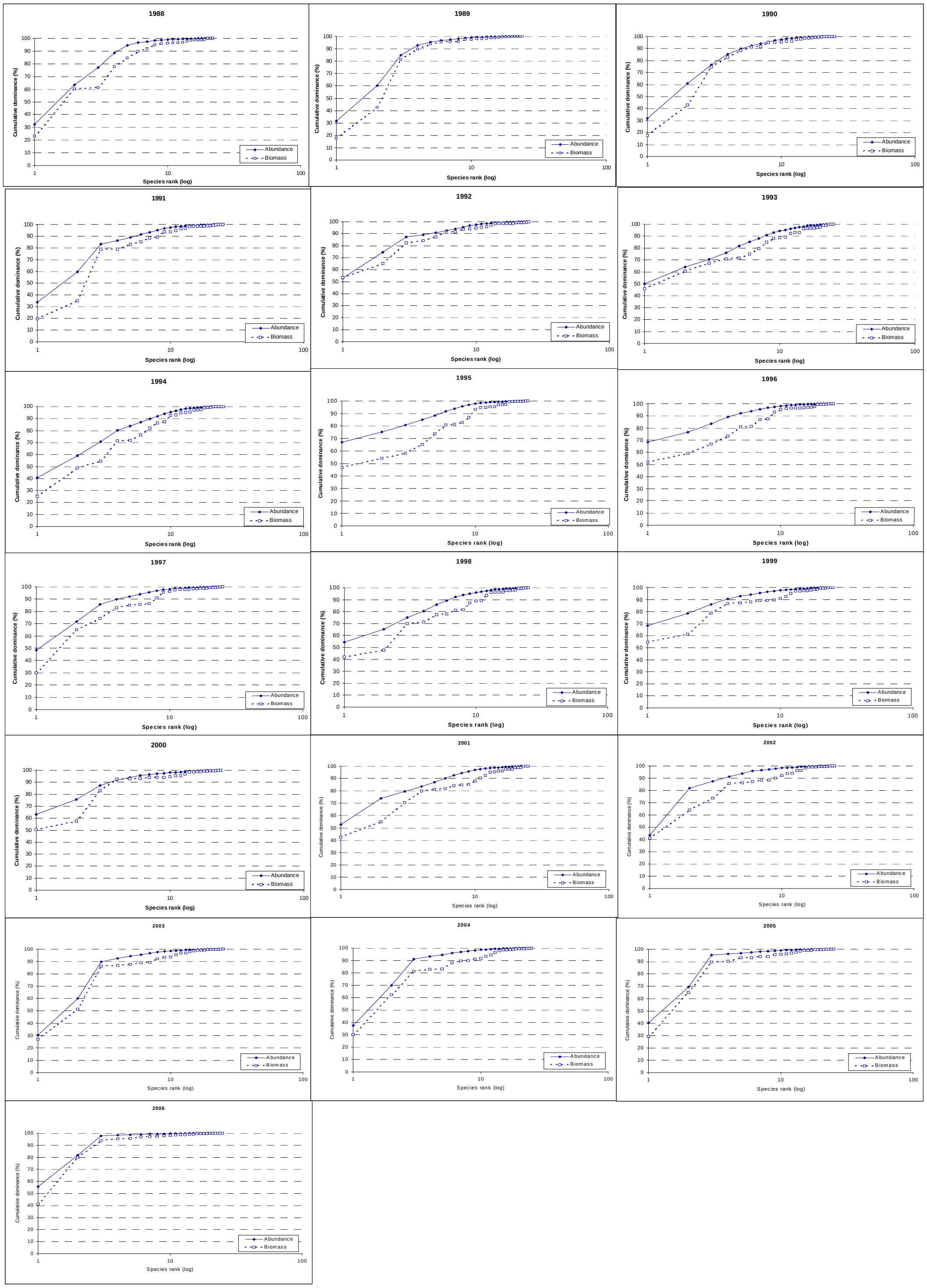
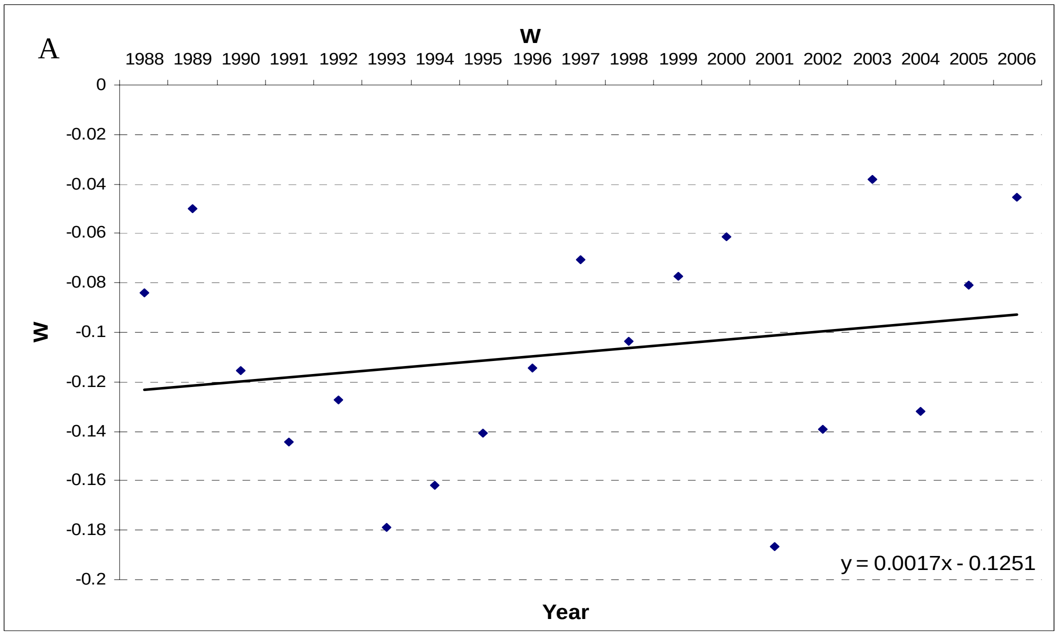


Figure 3. Trend of the W-statistic for (A) all the species except the *Pandalus borealis* and (B) all species except *Pandalus borealis* and *Sebastes* juveniles



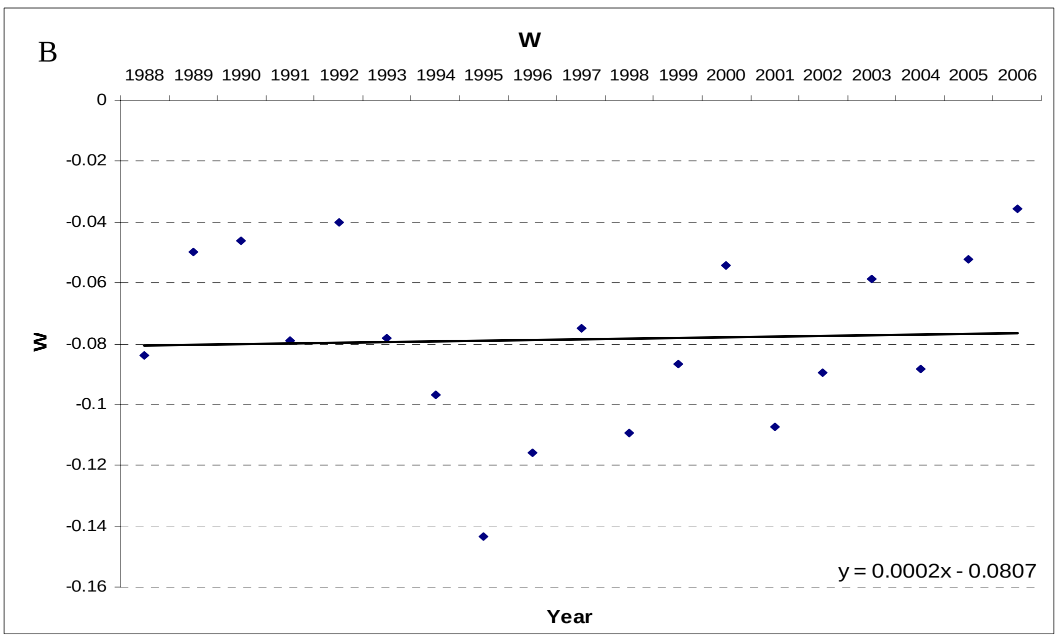
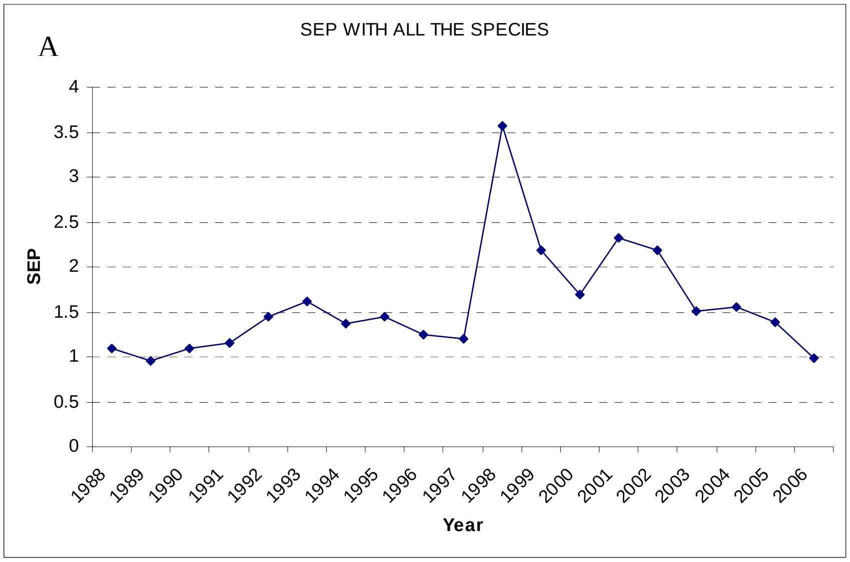


Figure 4. Trend of the SEP-statistic for (A) all the species and (B) all species except *Pandalus borealis* and *Sebastes juveniles*



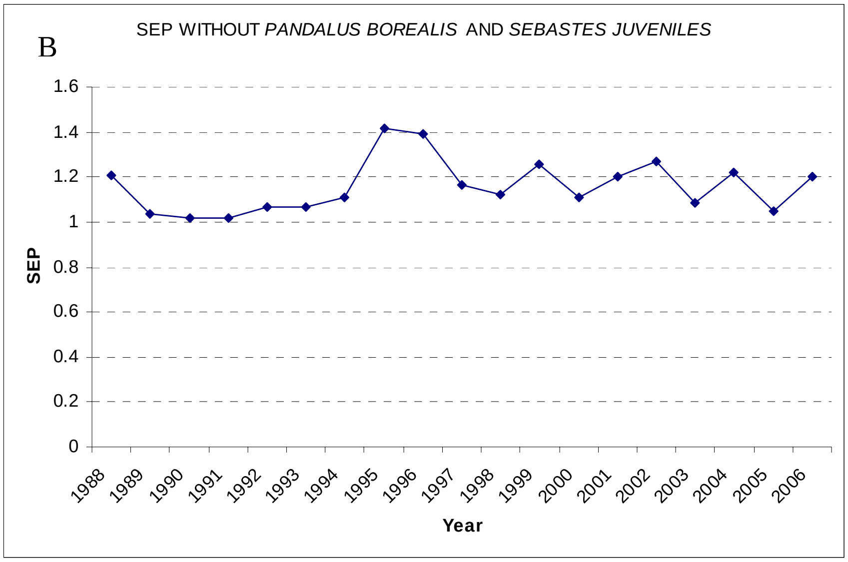
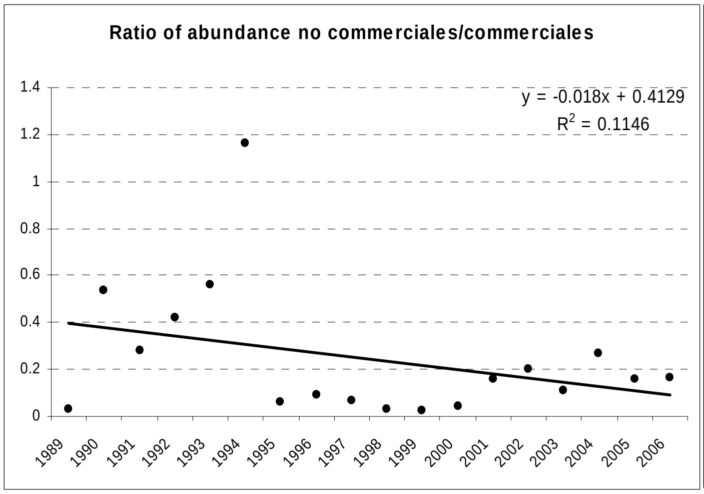
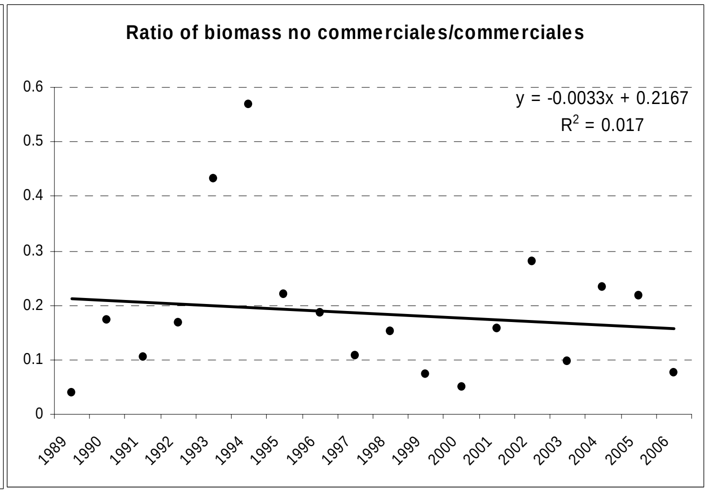


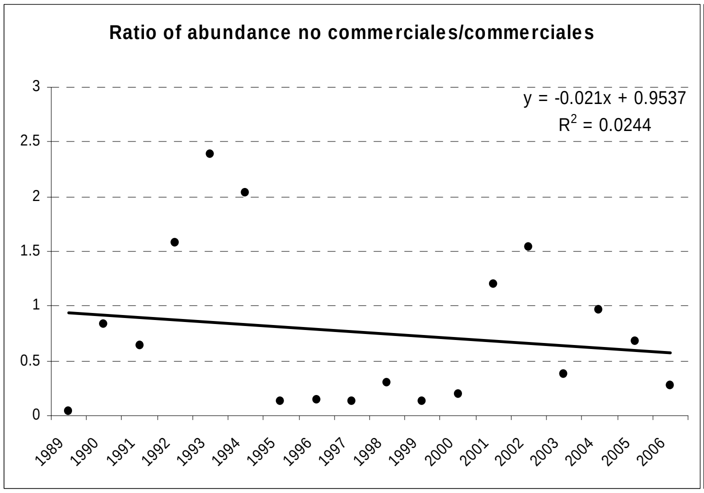
Figure 5. Ratio of abundance and biomass of no commercial/commercial species. A) With all the species. B) Without *Pandalus borealis*

A)





B)



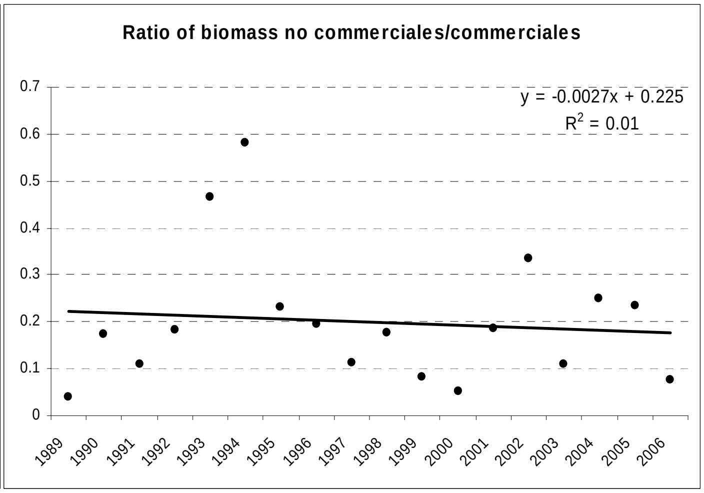


Figure 6. Mean length in community

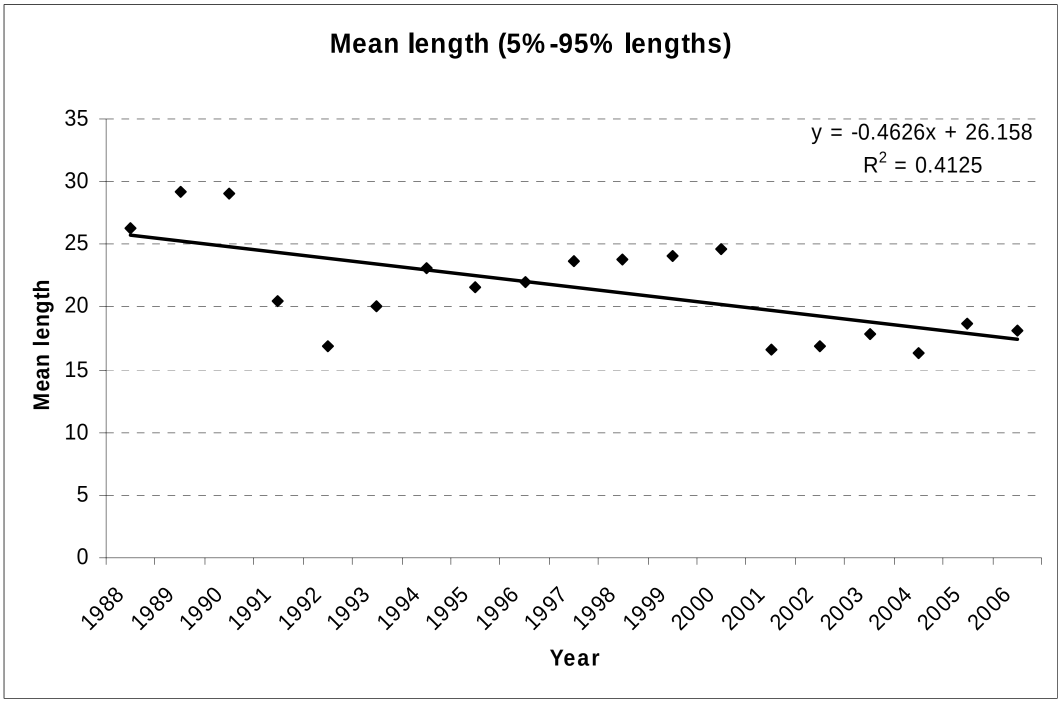


Figure 7. Scatter plots for the size spectra year by year

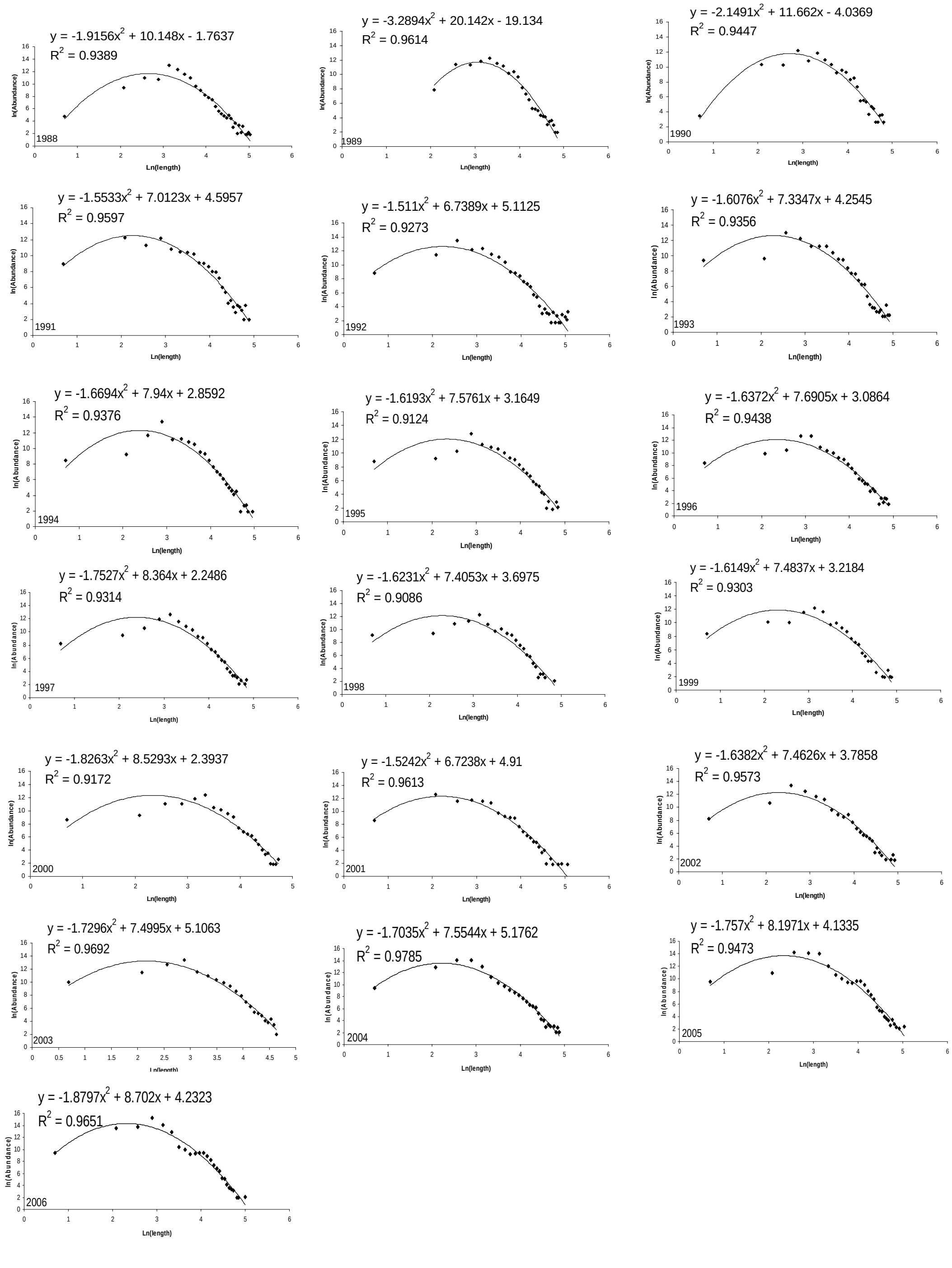


Figure 8. Trend of the parameters of the size spectra