Cryptobenthic Fish Assemblages

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Abstract
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Image: *Aidablennius sphynx* by Jordi Regàs

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Effect of the 2008 Sant Esteve's extreme storm on the small cryptobenthic fish assemblages of the upper sublittoral zone along the northern Catalan coast

By

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Resumen

El posible efecto de la tormenta de Sant Esteve (2008) en la comunidad de peces criptobentónicos de Port de la Selva, Illes Medes y Blanes, fue analizado mediante recuentos directos de individuos a lo largo de transectos entre 0 y 1.5m de profundidad. A lo sumo, sólo se observaron pequeñas variaciones en la densidad de algunas especies moduladas por la situación geográfica de cada localidad. Blanes y Medes fueron las más afectadas, mientras que Port de la Selva no presentó cambios significativos entre los años estudiados. Puede concluirse que las poblaciones de peces criptobentónicos de la zona sublittoral superior de la costa Catalana resistieron notablemente bien el impacto del temporal.

Abstract

The possible effect of an extreme storm on cryptobenthic fish assemblages in Port de la Selva, Medes Islands and Blanes, was assessed by direct counting the individuals along transects between the surface and 1.5 m of depth. At most, just slight variations in density were observed for some species. These variations have been modulated by the geographic situation of each locality. Blanes and Medes seemed more affected than Port de la Selva, where there were no remarkable changes among years in total densities. As a whole, it can be concluded that the population of cryptobenthic fishes from the upper sublittoral zone studied, remarkably resisted the impact of the storm all along the Catalan coast.

Introduction

The Mediterranean upper sublittoral zone (≈-1m) is populated by quite a characteristic and diverse assemblage of blennioid fish. The assemblage mainly consists of blennies related strictly to this area, plus an invasive three fin blennioid species (*Tripterygion tripteronotus*), and some other blennies which are relatively common in deeper waters (i.e. *Parablennius gattoruggine*, *P. incognitus*). All these fish are sedentary and remain on the bottom, rarely separating from it, swimming for only short distances and spending very little time in open water (Gibson, 1969; Thompson, 1983). Habitat features, such as exposure to water motion, bottom slope, substratum complexity and heterogeneity, and the dominant benthic community play an important role in determining the distribution patterns of the species in

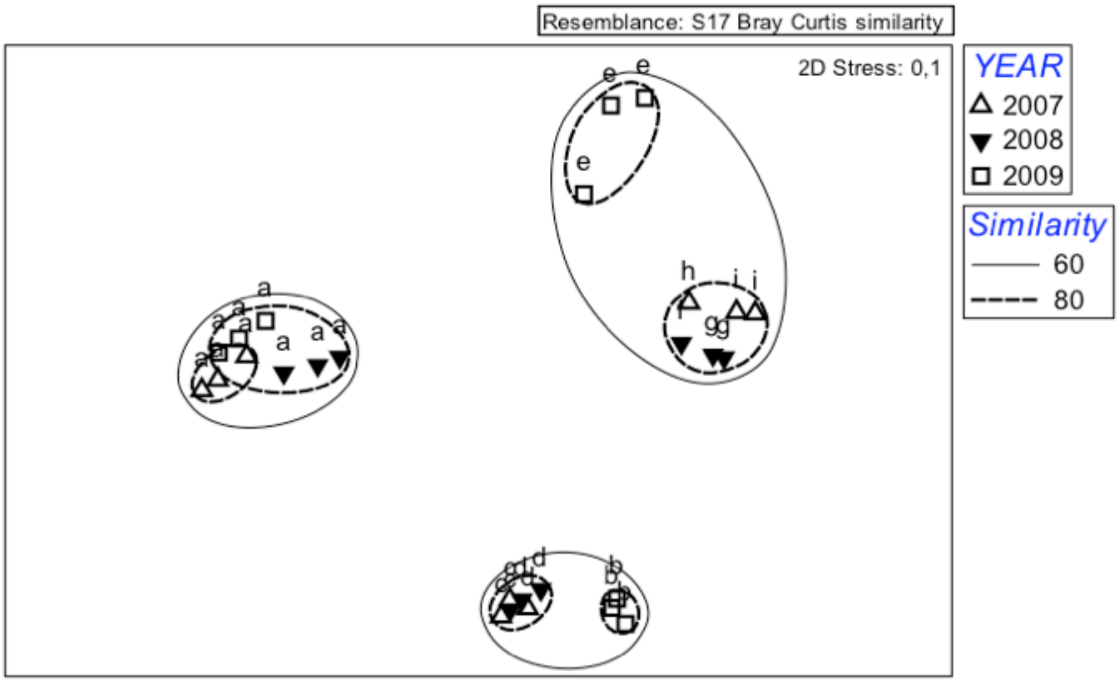

Figure 1. nMDS plots of samples coming from different zones (left: Port de la Selva; up right: Blanes; down right: Medes) and years grouped according the projected cluster SIMPROF results (different letters denoted significant differences).

this blennioid guild (Abel, 1962; Zander, 1972; Illich & Kotrschal, 1990; Macpherson, 1994; Syms, 1995; Patzner, 1999; Nieder et al., 2000; Townsend & Tibbetts, 2000). Aggregation or exclusion is not uncommon among species depending on the affinities of each species with certain habitat features (Macpherson, 1994). Since most of these species are short-lived (with a lifespan ranging from only 1 to 3 years), interannual variations in their abundances depend greatly on yearly recruitment success (Macpherson & Zica, 1999).

Their small body size and the ability to use holes and crevices as a shelter, enable these benthic fish to avoid the turbulence associated with wave action. However, and given the shallow depths they inhabit, we could expect that they would be highly vulnerable to violent wave action associated with severe unusual storm events. The degree of resistance to wave action may differ among different species as there are marked differences in the qualitative and quantitative composition of the blennioid guilds depending on whether the area is sheltered or exposed to normal wave action (Santin & Willis, 2007). The objective of this work was to determine the possible effects of the storm of 28 December 2008 on the blennioid guild in the upper sublittoral zone. To do so, the results of two years prior to the storm (2007 and 2008) were compared with the year immediately following the storm (2009), not only taking into account the total population, but also the adults and the young of the year (YOY) which were recruited after the storm.

Materials and Methods

Sampling sites

Port de la Selva, the Medes Islands and Blanes, which are roughly 50 km apart, were the sample locations. Data was collected along rocky walls, following transects between the surface and 1.5 m depth, during September and October at the end of the recruitment season.

Observations were made in the selected areas by divers snorkelling in Port de la Selva (totalling 109 m^2), the Medes Islands (52 m^2), and Blanes (69 m^2).

Field work

Three dives were carried out at each location at the end of the settlement season (September-October). The observer swam very slowly along each transect and individuals of all species were counted and their sizes recorded. Young of the year (YOY), with a total length of about 1.0 to 1.5 cm, which were easily distinguished from each other, were also counted and differentiated from adults.

Data treatment

We calculated the density (no. ind. m^{-2}) of the adults, YOY and total population. The total density matrix was subjected to a hierarchical management analysis (cluster) based on the quantitative index of Bray-Curtis similarity between locations, using the averaging group clustering algorithm along with a SIMPROF analysis that differentiated among significantly different groups. On this similarity matrix we applied a non-metric multidimensional scaling analysis (nMDS), on which the clusters obtained at the different aggregation levels were projected. In order to determine the magnitude of the differences between areas and years, we applied a two-factor (location and year) analysis of similarities (ANOSIM), followed by a two way crossed similarity percentage analysis (SIMPER) to determine which species were most responsible for the differences observed between years and locations. All these tests were performed using the statistical package PRIMER 6 ©.

The degree of assemblage among adults and YOY, according to the adults and YOY affinity matrices, were compared using the RELATE routine (PRIMER 6 ©) by calculating the Spearman correlation coefficient (ρ) between all elements of the respective similarity matrices (Mantel coefficients). Pearson's correlation coefficients among adults and YOY for each species were calculated using the statistical program Statistica 6.0 © to test the role of annual recruitment and temporal variations in the populations of the species studied.

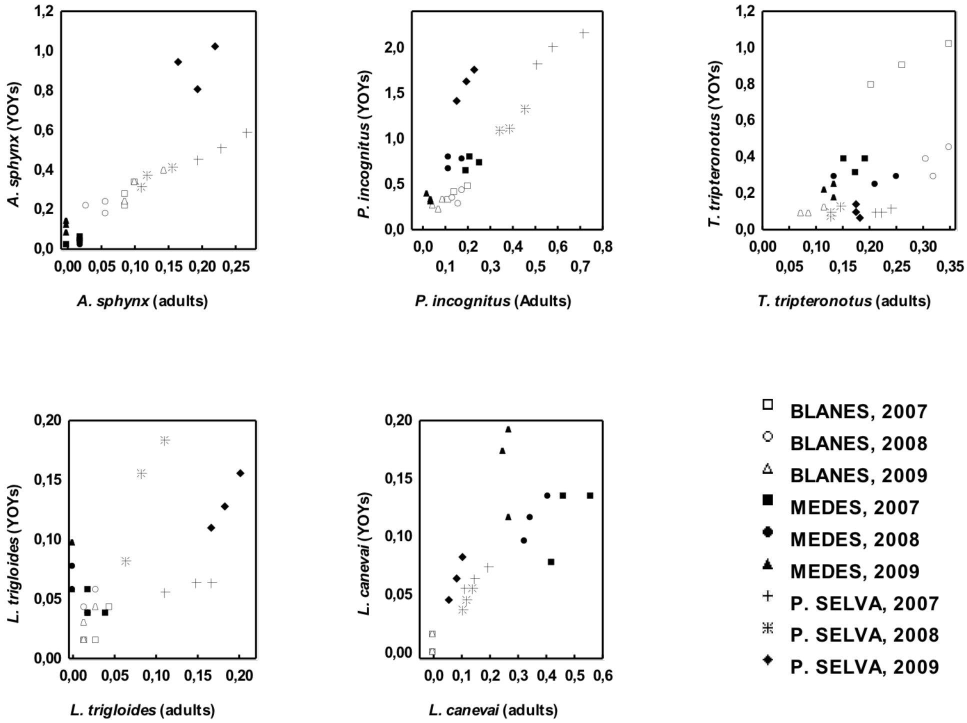

Figure 2. Correlations among adults and YOYs of the five more abundant species.

Results

The three areas along the Costa Brava showed remarkable uniformity in the qualitative species composition. Except for *Coryphoblennius galerita*, which was totally absent in Blanes, all the species were represented consistently in all areas (Annex 1). The spatial differences among the zones were quantitative, as shown by the nMDS results (Figure 1). The similarity percentage analysis (SIMPER) showed that the main difference was between Port de la Selva and both the Medes Islands and Blanes due to variations in the density of *Parablennius incognitus*, which was higher in Port de la Selva than in Blanes and the Medes Islands (Table 1). Between Blanes and Medes most of the dissimilarity was due to *Lipophrys canevai*, which was quite abundant in the Medes Islands and merely present in Blanes, and *Tripterygion tripteronotus*, which was the dominant species in Blanes but less abundant in the Medes Islands, where the dominant species was *Parablennius incognitus*. The differences among locations were significant according to the results of the analysis of similarity (ANOSIM).

The SIMPROF analysis associated with the cluster and projected onto the results of the NMDS demonstrated the high homogeneity among the samples from Port de la Selva, where no significant differences between different years were observed. In Blanes the heterogeneity among samples was greater, with significant differences even among samples of the same year, and the samples from 2009 were clearly separated from those of the other years. In Medes there were significant differences between years and, as in Blanes, the samples from 2009 were clearly separated from the other years (Figure 1).

The temporal variations were also mainly quantitative, and according to the analysis of similarity (ANOSIM) differences were significant among years, especially from 2009 to 2007 and 2008 (Annex 2). Overall, there was a progressive decrease in *Parablennius incognitus* and *Tripterygion tripteronotus*, whose densities decreased from 2007 to 2008 and especially in 2009 (see SIMPER results, Annex 2). The decline in these two species was especially remarkable in Blanes from 2008 to 2009, but also occurred to a lesser extent in Medes. In Port de la Selva, the annual densities of *P. incognitus* remained at similar levels in 2008 and 2009, but were considerably lower than the density observed in 2007 (Annex 1). *Aidablennius sphynx* was the only species that increased in 2009 from the two previous years in Blanes and especially in Port de la Selva.

Recruitment plays a very important role in explaining the interannual variations in abundance of these species, and there was a strong relationship between the density of recruits and adults, which explained a high correlation in the adult and YOY affinity matrices according to the RELATE results ($\rho = 0.619$, $p < 0.001$). In fact, a large fraction of the populations was integrated by the YOY, which basically maintained the same qualitative and quantitative structure as the adults. However, there were large interannual differences in YOY densities both among regions and between species. All the most abundant species, *P. icognitus*, *A. sphynx*, *T. tripteronotus*, *Lipophrys trigloides* and *L. canevai*, showed positive significant correlations between adult and YOY densities, with some annual variations. In the case of *A. sphynx*, the positive correlation was evident and significant ($r = 0.86$, $p < 0.001$), but in Medes, where the species was very scarce, the entire population was only integrated by YOY in 2009 (Figure 2a). In Blanes the correlation between adults and juveniles was very high regardless of the year. In Port de la Selva, however, while the density of adults declined only slightly, the number of YOY increased appreciably in 2009. In the case of *P. icognitus* ($r = 0.83$, $p < 0.001$) the adult population decreased markedly in 2009 compared to previous years that coincided with a small decrease in the density of YOY, except in Port de la Selva, where in spite of the decline in adult density the number of YOY was higher than expected given the density of adults (Figure 2b). *T. tripteronotus* showed a lower correlation among YOY and adults than the previous two species ($r = 0.58$, $p < 0.01$) and the relationship was only apparent when all the samples from all areas were compared. In Port de la Selva the YOY density appeared to be independent of the adult density, while in Medes and Blanes the correlation was somewhat more pronounced. In these last two areas, and especially in Blanes where the YOY density was higher, the lowest YOY density coincided with a decline in the adult population (Figure 2c). *L. trigloides* had the lowest density of both adults and YOY in Blanes and Medes, in contrast to the high values recorded in Port de la Selva, including the high YOY density in 2008 even though the number of adults was the lowest in the three years. *L. canevai* showed a good correlation between adults and YOY in Medes and Port de la Selva ($r = 0.82$, $p < 0.001$) where the species was more abundant. In both areas the relationship between YOY density and adult density was notably higher in 2009, which corresponded with a decrease in the adult density. This was especially marked in Medes, where the density was clearly higher than in Port de la Selva (Figure 2d).

Discussion

According to the results, the main conclusion is that the upper sublittoral blennioid assemblage has withstood the damaging effects of the storm well, which highlights the remarkable adaptation of these fish to the shallow environments in which they live. The severe storm of 26 December 2008 did not cause large changes but rather, and even in the worst case, variations in density that were modulated by the geographic situation of each location. Blanes and Medes both seem to have been more affected than Port de la Selva, where there were no remarkable changes in total densities among years. General changes affected the quantitatively most dominant species, which were quite well represented in all locations. Overall, there was a decrease in *Parablennius incognitus*, *Tripterygion tripteronotus* and a slight increase in *Aidablennius sphynx*. *P. incognitus* seems to have been declining gradually since 2007 to 2009 in Blanes and Medes, while in Port de la Selva the main decrease in this species occurred between 2007 and 2008, which makes it difficult to attribute these changes to the impact of the storm. The decrease in *T. tripteronotus* was especially pronounced in Blanes but only slightly marked in Medes and it did not decrease at all in Port de la Selva, where the species density even increased slightly from 2008 to 2009. In contrast, *A. sphynx* densities increased in all areas from 2008 to 2009, while the changes between 2007 and 2008 were of different signs: the density dropped slightly in Blanes and Port de la Selva and did not vary in Medes.

The short lifespan of these species makes annual recruitment very important for explaining temporal variations. There was usually a good correlation between the density of

YOY and adult populations, with the general rule that any variations in the adults were reflected in the YOY. This relationship is probably due to a common affinity for the same habitats because no connection between annual recruitment and the adult population of the next year was found, although the scarcity of data may also have influenced this result. Broadly speaking, the decrease in the density of *P. incognitus* and *T. tripteronotus* affected both adults and YOY, which was also the case of the increase in *A. sphynx*. However, there were some variations to this rule that could have been caused by the storm: the decrease in density of adults of *P. incognitus* in Port de la Selva, and *L. canevai* in Medes and, to a lesser degree, in Port de la Selva, were compensated by an increase in the YOY density. The increase in *A. sphynx* in Port de la Selva in 2009 was also due to an increase in YOY density, while the adult density remained essentially unchanged.

Conclusions

As a whole, it can be concluded that the benthic fish from the upper sublittoral assemblage are more resistant than other sublittoral fish that cannot withstand the effects of strong water motion (see Chapter 15), and thus the storm that occurred in December 2008 did not have catastrophic effects on this assemblage.

Acknowledgements

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Annex 1. Average densities of total population (a) and YOYs (b) in the different areas during the three years of monitoring.

a)															
Total population		***A. sphynx***		***P. incognitus***		***T. tripteronotus***		***L. trigloides***		***L. canevae***		***C. galerita***		***P. gattorugine***		
Zone	**Year**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**N**
Total	All	0.40	0.34	1.06	0.75	0.47	0.30	0.12	0.10	0.23	0.22	0.04	0.04	0.02	0.02	27
BLANES	All	0.35	0.10	0.46	0.13	0.69	0.44	0.05	0.02	0.01	0.01	0.00	0.00	0.00	0.01	9
MEDES	All	0.07	0.04	0.73	0.28	0.45	0.10	0.07	0.01	0.50	0.10	0.06	0.03	0.00	0.01	9
P.SELVA	All	0.79	0.29	1.99	0.51	0.28	0.05	0.25	0.07	0.17	0.05	0.06	0.02	0.05	0.01	9
All	2007	0.39	0.31	1.36	0.95	0.68	0.39	0.11	0.07	0.27	0.26	0.04	0.03	0.02	0.03	9
All	2008	0.27	0.20	0.98	0.48	0.47	0.21	0.12	0.09	0.21	0.21	0.04	0.03	0.02	0.02	9
All	2009	0.55	0.45	0.83	0.73	0.27	0.07	0.14	0.13	0.19	0.18	0.05	0.04	0.01	0.02	9
BLANES	2007	0.37	0.07	0.55	0.12	1.17	0.18	0.05	0.03	0.01	0.01	0.00	0.00	0.00	0.01	3
BLANES	2008	0.26	0.03	0.50	0.08	0.70	0.09	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.01	3
BLANES	2009	0.43	0.11	0.33	0.06	0.19	0.04	0.05	0.02	0.01	0.01	0.00	0.00	0.00	0.00	3
MEDES	2007	0.05	0.03	0.94	0.08	0.53	0.05	0.07	0.01	0.60	0.10	0.04	0.01	0.00	0.00	3
MEDES	2008	0.05	0.01	0.88	0.08	0.47	0.06	0.06	0.01	0.47	0.06	0.06	0.04	0.01	0.01	3
MEDES	2009	0.11	0.03	0.37	0.03	0.34	0.04	0.07	0.02	0.42	0.04	0.07	0.02	0.00	0.00	3
P.SELVA	2007	0.75	0.11	2.60	0.28	0.33	0.03	0.20	0.03	0.21	0.05	0.07	0.03	0.06	0.01	3
P.SELVA	2008	0.50	0.07	1.57	0.18	0.24	0.04	0.23	0.07	0.17	0.03	0.05	0.02	0.04	0.01	3
P.SELVA	2009	1.12	0.12	1.79	0.22	0.28	0.03	0.31	0.04	0.14	0.04	0.08	0.02	0.04	0.01	3
b)																
YOYs		A. sphynx		P. incognitus		T. tripteronotus		L. trigloides		L. canevae		C. galerita		P. gattorugine		
Zone	Year	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	N
Total	All	0.31	0.27	0.84	0.60	0.28	0.25	0.07	0.05	0.06	0.06	0.03	0.03	0.00	0.00	27
BLANES	All	0.27	0.07	0.34	0.08	0.46	0.36	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	9
MEDES	All	0.06	0.04	0.60	0.20	0.28	0.07	0.06	0.02	0.13	0.04	0.05	0.02	0.00	0.01	9
P.SELVA	All	0.60	0.26	1.59	0.38	0.10	0.02	0.11	0.05	0.06	0.01	0.04	0.02	0.01	0.00	9
All	2007	0.28	0.21	1.04	0.74	0.46	0.36	0.04	0.02	0.06	0.05	0.02	0.02	0.00	0.00	9
All	2008	0.20	0.15	0.76	0.37	0.25	0.13	0.08	0.06	0.05	0.05	0.03	0.03	0.01	0.01	9
All	2009	0.45	0.37	0.73	0.66	0.14	0.06	0.07	0.05	0.08	0.07	0.04	0.03	0.00	0.00	9
BLANES	2007	0.28	0.06	0.40	0.07	0.90	0.11	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	3
BLANES	2008	0.21	0.03	0.35	0.07	0.38	0.08	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	3
BLANES	2009	0.32	0.08	0.27	0.05	0.10	0.02	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	3
MEDES	2007	0.04	0.02	0.72	0.07	0.36	0.04	0.04	0.01	0.12	0.03	0.03	0.01	0.00	0.00	3
MEDES	2008	0.03	0.01	0.74	0.06	0.28	0.02	0.06	0.02	0.12	0.02	0.05	0.03	0.01	0.01	3
MEDES	2009	0.11	0.03	0.34	0.04	0.21	0.04	0.06	0.03	0.16	0.04	0.06	0.02	0.00	0.00	3
P.SELVA	2007	0.52	0.07	2.00	0.17	0.10	0.01	0.06	0.01	0.06	0.01	0.03	0.01	0.00	0.00	3
P.SELVA	2008	0.37	0.05	1.18	0.13	0.10	0.03	0.14	0.05	0.05	0.01	0.02	0.01	0.01	0.00	3
P.SELVA	2009	0.93	0.11	1.60	0.18	0.10	0.04	0.13	0.02	0.06	0.02	0.06	0.02	0.01	0.01	3

Annex 2. Results of the two way analyses ANOSIM (a) and SIMPER (b) showing the contribution of species to dissimilarities among different zones and years.

a)

ANOSIM Pairwise Tests

Zones	**R Statistic**	**Sig. Level %**	**Possible perm.**	**Actual perm.**	**Num ≥ obs.**
BLANES, MEDES	1	0,1	1000	999	0
BLANES, P.SELVA	1	0,2	1000	999	1
MEDES, P.SELVA	1	0,2	1000	999	1

ANOSIM Pairwise Tests

Years	**R Statistic**	**Sig. Level %**	**Possible perm.**	**Actual perm.**	**Num ≥ obs.**
2007, 2008	0,531	2,2	1000	999	21
2007, 2009	1	0,1	1000	999	0
2008, 2009	0,914	0,1	1000	999	0

b)

SIMPER BLANES *vs* MEDES

Average dissimilarity = 42,84

	BLANES	**MEDES**				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
L. canevae	0,01	0,5	14,72	6,24	34,36	34,36
T. tripteronotus	0,69	0,45	9,1	1,97	21,25	55,61
A. sphynx	0,35	0,07	8,75	2,26	20,42	76,03
P. incognitus	0,46	0,73	7,47	1,71	17,44	93,47

SIMPER BLANES *vs* P.SELVA

Average dissimilarity = 55,79

	BLANES	**P.SELVA**				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
P. incognitus	0,46	1,99	29,16	6,59	52,27	52,27
T. tripteronotus	0,69	0,28	8,67	1,64	15,55	67,82
A. sphynx	0,35	0,79	8,64	1,87	15,48	83,3
L. trigloides	0,05	0,25	3,93	2,39	7,04	90,35

SIMPER MEDES *vs* P.SELVA

Average dissimilarity = 49,50

	MEDES	**P.SELVA**				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
P. incognitus	0,73	1,99	22,47	3,55	45,39	45,39
A. sphynx	0,07	0,79	13,2	2,78	26,66	72,05
L. canevae	0,5	0,17	5,98	4,33	12,09	84,14
L. trigloides	0,07	0,25	3,36	2,48	6,79	90,92

SIMPER 2007 *vs* 2008

Average dissimilarity = 16,73

	2007	**2008**				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
P. incognitus	1,36	0,98	6,57	1,04	39,25	39,25
T. tripteronotus	0,68	0,47	5,25	0,89	31,36	70,61
A. sphynx	0,39	0,27	2,35	1,3	14,02	84,63
L. canevae	0,27	0,21	1,36	0,81	8,15	92,78

SIMPER 2007 *vs* 2009
Average dissimilarity = 29,65

	2007	**2009**				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
T. tripteronotus	0,68	0,27	12,35	0,89	41,66	41,66
P. incognitus	1,36	0,83	10,86	2,3	36,61	78,27
A. sphynx	0,39	0,55	3,14	1,44	10,59	88,86
L. canevae	0,27	0,19	1,95	0,8	6,58	95,43

SIMPER 2008 *vs* 2009
Average dissimilarity = 25,38

	2008	**2009**				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
P. incognitus	0,98	0,83	8,54	1,6	33,66	33,66
T. tripteronotus	0,47	0,27	8,34	0,93	32,84	66,5
A. sphynx	0,27	0,55	5,99	1,49	23,61	90,12

CHAPTER 17

Littoral Fisheries Resources

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Abstract

We analysed the potential impact of the Sant Esteve storm on coastal fish populations by studying the artisanal daily catch statistics, from January 2008 to October 2009, of the fleet of Palamós, Costa Brava. Results showed that the abundance of most of the species accessible to artisanal nets and bottom long-lines was not altered by the storm. However, the catch rate patterns of a significant number of species (up to 18) changed substantially. Most species showed an increase in catch rates. This phenomenon might be due to an increase in the spatial aggregation of the species, which increased their fishing availability. If this proved true, the observed changes would be suggestive of an increase in species vulnerability and, therefore of a negative effect on the populations in the medium term. These results cannot be considered completely reliable because only a short time period could be analysed, and thus extrapolations from this report should be made with caution.

Image: *Palinurus elephas*, Columbretes, Spanish Western Mediterranean, by D. Díaz

Gordoa, A. & Dimitriadis, C. (2012) Impact of the Sant Esteve's extreme storm (2008) on littoral fisheries resources. In: Mateo, M.A. and Garcia-Rubies, T. (Eds.), Assessment of the ecological impact of the extreme storm of Sant Esteve's Day (26 December 2008) on the littoral ecosystems of the north Mediterranean Spanish coasts. Final Report (PIEC 200430E599). Centro de Estudios Avanzados de Blanes, Consejo Superior de Investigaciones Científicas, Blanes, pp. 249 – 264.

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Impacts of 26th December 2008 storm on littoral fisheries resources

By

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Resumen

El impacto potencial de la tormenta de Sant Esteve sobre las poblaciones de peces litorales fue analizada mediante el estudio de las estadísticas diarias de capturas de la flota artesanal de Palamós, Costa Brava. El estudio se realizó con resolución mensual con datos entre Enero de 2008 y Octubre de 2009. Los resultados mostraron que la mayoría de especies accesibles a redes artesanales y palangres no fueron alteradas por la tormenta. No obstante, un número significativo de especies (hasta 18), sufrieron cambios sustanciales. La mayoría de especies experimentaron un aumento en las tasas de captura. Creemos que puede ser debido a un aumento en su accesibilidad debido a un aumento en la agregación espacial. De ser cierto, los cambios observados sugerirían un incremento en la vulnerabilidad de las especies con efectos negativos. Los resultados presentados en este estudio se deben considerar con prudencia ya que el periodo de estudio analizado es corto para aplicar ningún tipo de proyección.

Abstract

We analysed the potential impact of the Sant Esteve storm on coastal fish populations by studying the artisanal daily catch statistics, from January 2008 to October 2009, of the fleet of Palamós, Costa Brava. The temporal analysis was performed on a monthly basis. Results showed that the abundance of most of the species accessible to artisanal nets and bottom long-lines was not altered by the storm. However, the catch rate patterns of a significant number of species (up to 18) changed substantially. Most species showed an increase in catch rates. This phenomenon might be due to an increase in the spatial aggregation of the species, which increased their fishing availability. If this proved true, the observed changes would be suggestive of an increase in species vulnerability and, therefore of a negative effect on the populations. The results presented here should be taken with caution because the analysed period is short and they should not be used for any further projection.

Introduction

Although artisanal fisheries still represent a strong socio-cultural sector along the Mediterranean shoreline, there has been little research into their activity. The fleets are generally composed of a large number of boats, mostly of low tonnage, based in many different ports (Colloca et al., 2004). Although the size of the artisanal fleet has decreased by around 30% in Catalonia since 2006, this fleet is still

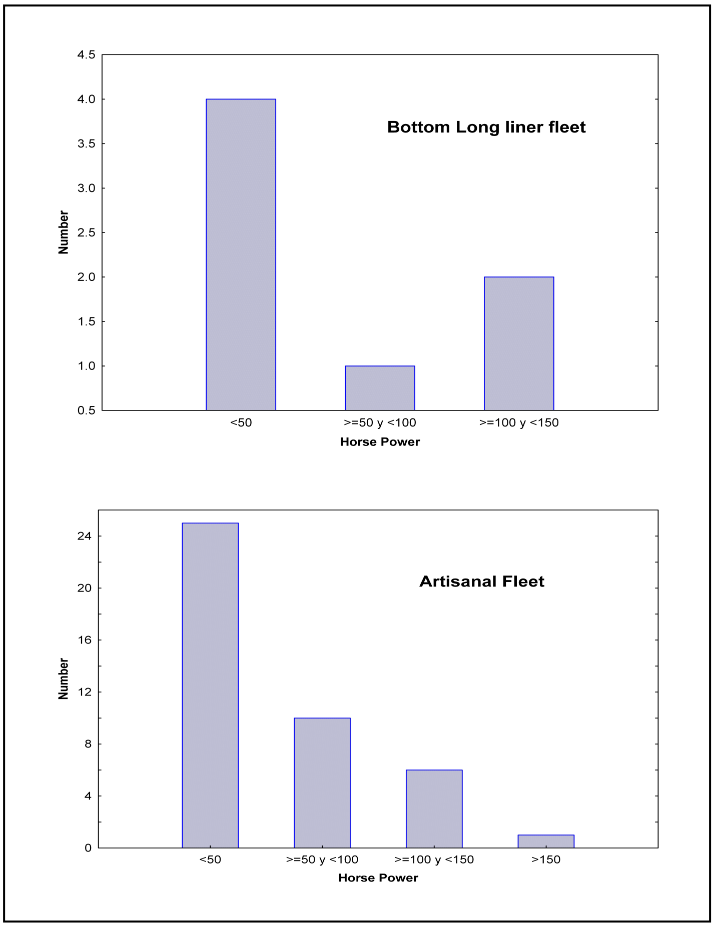

Figure 1. Characterization of the power of the artisanal fishery fleet of the port of Palamós.

significantly large and has around 550 vessels. Artisanal fishing is often associated with the notion of "coastal fishing" and consequently the catch is influenced by changes or disruptions in coastal fish populations. Based on this, we analysed the potential impact of the Sant Esteve storm on coastal fish populations by studying the artisanal daily catch statistics of the fleet moored in Palamós fishing port, a major fishing port on the Costa Brava.

The potential economic impact of the storm on the fishing fleet and the impact on the fishery resources were evaluated from the daily catch per boat reported in the port of Palamós.

The analysis focused on assessing the possible effects of the storm on coastal fishery resources by analysing fluctuations in the catch rate from January 2008 to October 2009. The aim of the study was to observe if there were any abnormal temporal patterns that could be related to the impact of the storm. In this study we analysed the total catch of 49 vessels (42 operating mainly with nets and 7 with bottom long-lines). A total of 5681 daily catch reports were analysed.

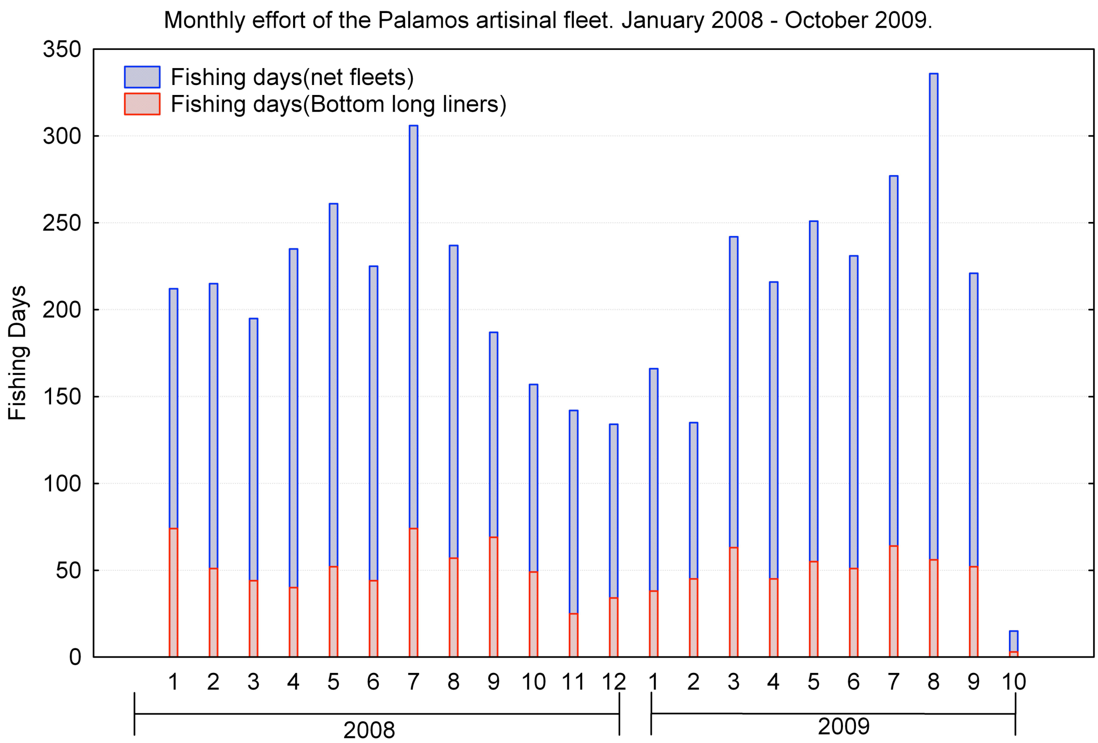

Figure 2. Monthly fishing days of the artisanal fleet of Palamós during the period studied.

Materials and Methods

Characterization of the fishing fleet and activity

The artisanal fleet is characterised by low power vessels, from a minimum of 8 horse power (HP) to a maximum of 204 HP (Figure 1); 50% of the boats do not exceed 50 HP. In 2008 the artisanal fishery caught up to 135 t with sales to a value of 936 086 €, while the bottom long-line catch was around 39 t and made 266 966€. Although fishing is carried out continuously throughout the year (Figure 2) there is some seasonal variability, in particular there is a decrease in activity from October to February.

The temporal analysis was performed on a monthly basis. The catch rate at species level was analysed for the whole fleet. It is accepted that the catch rate or catch per unit effort (CPUE) is proportional to resource abundance (fishing mortality induced by each unit of fishing effort) (e.g. Hilborn and Walters 1992). Catch rate patterns in monthly units are not related to changes in abundance but may be indicative of changes in the local density or spatial distribution of the resources. Thus, monthly catch rate patterns are indicative of monthly patterns in catchability and the fishing mortality induced by the fleet.

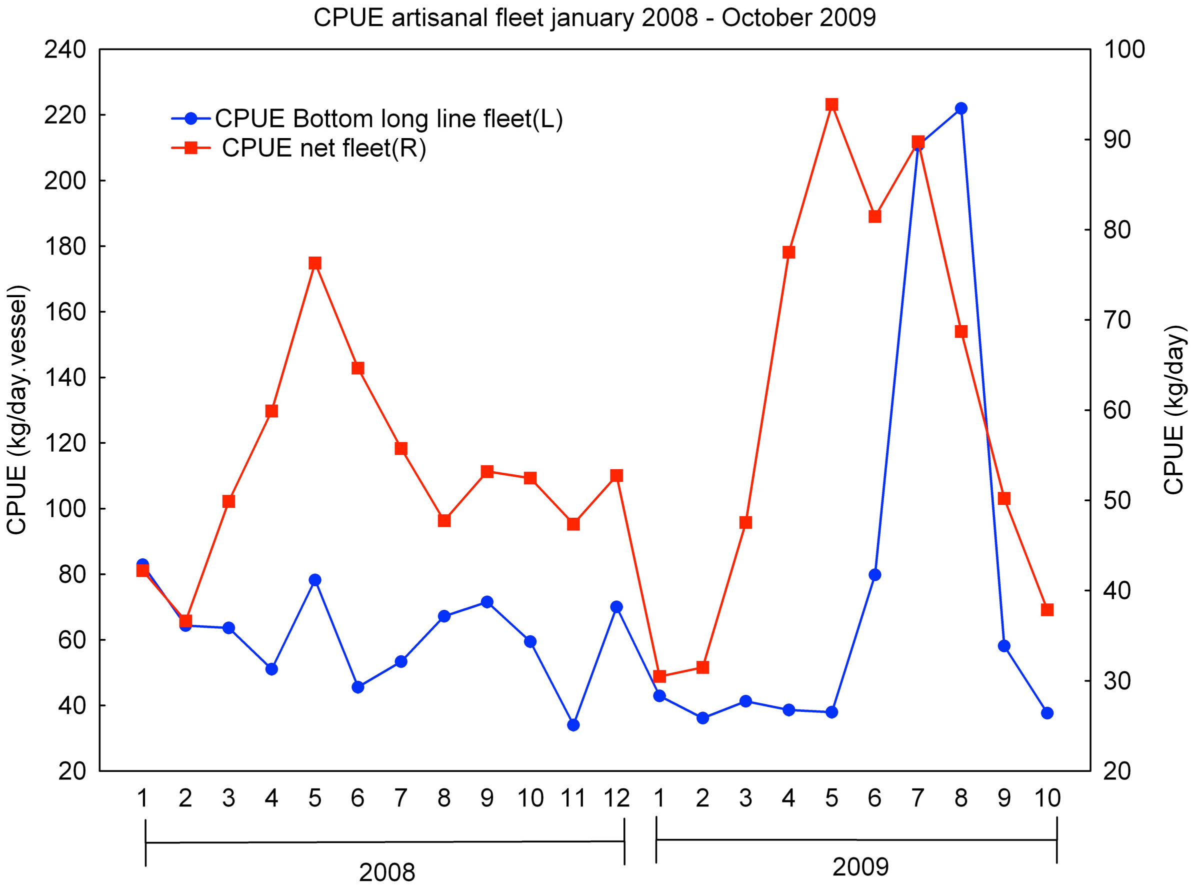

Figure 3. Evolution of catch per unit effort of the artisanal fleet of Palamós during the period studied in this work. The interpretation of total yield is complex and requires a detailed analysis of the temporal evolution of each specific catches.

At species level the monthly catch rate (∑kg/∑fishing days) was analysed jointly with the catch frequency analyses (number of days caught/number of fishing days). The two variables can provide complementary information on changes in the spatial distribution of fish resources. Frequency fluctuations are usually proportional to fluctuations in the local abundance, estimated according to daily catch rates. Therefore, an increase in CPUE normally implies an increase in the catch frequency. However, this pattern can be altered by changes in the spatial aggregation or dispersion of a species. Thus, if one species aggregates, the frequency of occurrence will diminish even though catch rates can be enhanced due to an increase in local density. As a consequence, the vulnerability of the species increases. If spatial dispersion occurs, the CPUE can decrease though the frequency may increase.

Results and discussion

Fishing activity is continuous all year round (Figure 2), although it shows some seasonality and is at its lowest between October and February.

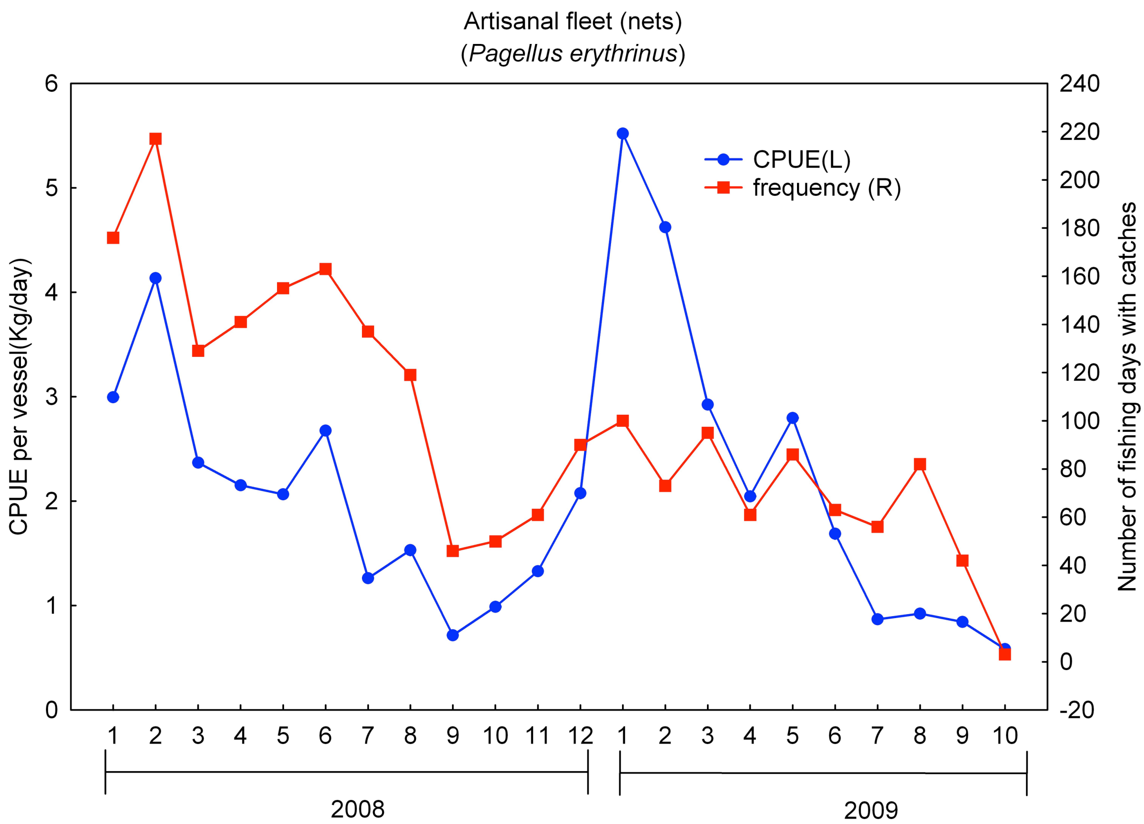

Figure 4. Monthly CPUE and frequency for *Pagellus erythrinus* catch of Palamós artisanal fleet.

The analysis of individual vessel activity demonstrated high variability in the reported fishing days per year. Annual fishing days per vessel varies from a minimum of just 1 fishing day per year to a maximum of 175 days. It is worth highlighting the large variability in the fishing days and the low activity recorded for most of the fleet. In fact, 17 boats reported less than 30 fishing days per year. The average number of officially declared fishing days was around 60 days per year for the boats operating with nets, and 87 days for those working with bottom long-lines. In addition, annual sales did not exceed €10 000 per boat and year in 26 out of the total 47 boats registered at the port. The low activity, together with the small profits, could mean that fishing only represents a small fraction of the professional activity of the fishermen or that the catches were not sold in an official way, reaching the final consumer through uncontrolled channels.

Temporal evolution of fishery resources

The monthly CPUE pattern of the artisanal fishery showed clear seasonality (Figure 3), with a peak around May and a minimum from January to February. Inter-annual differences were observed in: a) a larger period of maximum yield; b) the highest yield obtained in 2009; and c) the minimum values were observed at

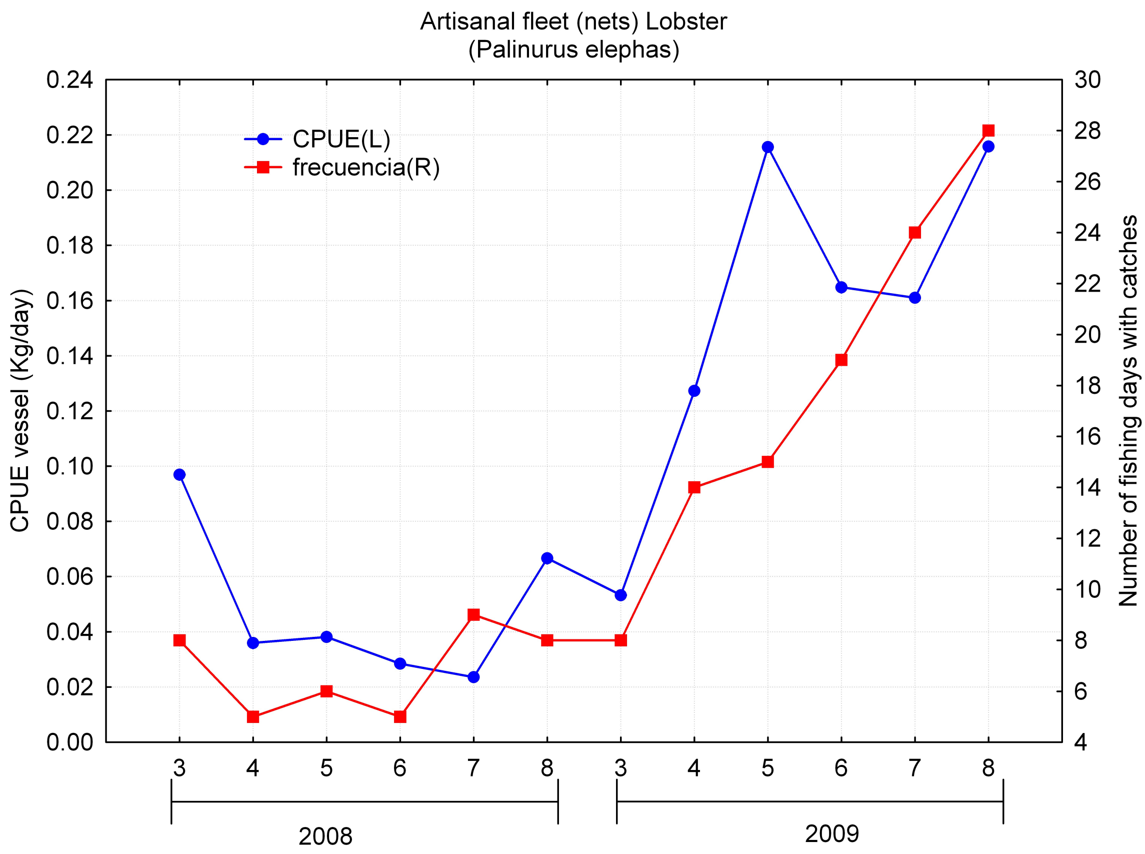

Figure 5. Monthly evolution of the CPUE and frequency of spiny lobster, *Palinurus elephas,* in the catch of the artisanal fleet of Palamós.

the beginning of 2009 (January and February).

The bottom long-line fishery showed a quite different pattern during 2008 (before the storm) without marked seasonality, although the maximum yield during the summer of 2009 might indicate otherwise. The low yields during the first five months of 2009 should also be highlighted (Figure 3).

Annex 1 contains the 53 species caught by artisanal nets according to the sales data of 2008 for the port of Palamós. The 27 species caught by bottom long-lines are shown in Annex 2. The species which were not present at least in 25 days per year were excluded from the two tables (Tables 1 and 2). Catches of hake were segmented into three size classes in increasing order, according to the different value of small, medium and big hakes. It seems that some species are hardly accessible by the reported gear, such as the swordfish, which is the third most abundant species among the bottom long-line catches. These inconsistencies in the data can be attributed to the high fishing versatility of a single boat, which can use different gears in spite of being classed in one single category.

Monthly catch rates and species frequency showed possible storm-related alterations in 18 of the species studied. These changes differed in sign