Comparison of the level of disturbance in areas subjected to trawling activities with that occurring in temporarily protected areas and its relevance to habitat conservation

Spina M. Florencia [1,2], Lértora H. Pablo[1], Mc Lean B. Gabriela[1] y Godelman Ernesto[1].

[1] **CENTRO DESARROLLO Y PESCA SUSTENTABLE.** Adress: José Rondeau 361. Mar del Plata, Buenos Aires, Argentina. e-mail: info@cedepesca.net
[2] florencia.spina@cedepesca.net

Summary:

The present investigation aims to analyse the impacts of the bottom trawling effects on the benthic ecosystem in a coastal marine zone of the Buenos Aires Province (Argentina). All the sites under study show low diversity levels, which fits in the intermediate disturbance model. We found a moderate disturb degree of the macrobenthic community in areas subjected to trawling activities and in areas temporarily protected from trawling. Furthermore, the specific composition between the trawling areas and the protected ones differs significantly. It's suggested the necessity of preserving the benthic community of the currently protected areas, as macrobenthic species are related to the diet of commercial fish and other vulnerable species. In the bottom trawling areas, the macrobenthic community is dominated by an echinoderm species, which group has been described as predominant in environments subjected to trawling activities. Finally, we suggest the need of checking the control measures in the protected areas reserved for passive fishing arts, to avoid the impact of vessels developing illegal fishing activities according to the current regulations.

Key words: benthos, perturbation, bottom trawling, diversity.

Introduction

The benthos constitutes a source of food for demersal and bottom fish; therefore, its conservation is of critical importance for the preservation of marine ecosystems. If the sea bottom is altered by trawling, the benthic community may also be affected. This might trigger off a series of chain reactions involving the rest of the species and the interactions between the trophic levels in the ecosystem.
Trawling started to be criticized since the perception of damages caused to the environment appeared (Jones, 1992). The impacts of this fishing activity include direct and indirect effects. The direct impacts of trawling over the seabed are produced by the dragging of chains, gates, ropes, dredges, nets or any other chaffing mats or part of the net bag that contact the bottom. The ways the net affects the seabed can be classified in: scraping and ploughing, sediment resuspension and physical destruction, removal, or scattering of non-target benthos. Indirect effects on the seabed include post-fishing mortality of damaged or disturbed organisms, and long-term changes to the benthos community structure (Jones, 1992).

In Argentina, along the coasts of the Buenos Aires Province, there is a bottom trawl fishing fleet. The fishing activities performed by this fleet might involve potential alterations to the benthic community, which could affect commercial species found in this ecosystem as well as those classified as vulnerable or endangered fish species, such as: the narrownose smoothhound (*Mustelus schmitti*), the angel shark (*Squatina spp*), the spiny dogfish (*Squalus acanthias*), the tope shark (*Galeorhinus Galeus*), the spotback skate (*Atlantoraja castelnaui*) and the franciscana dolphin (*Pontoporia blainvillei*).

Pursuant to Resolution No. 18/06 adopted by the Undersecretariat for Fisheries of the Ministry of Agricultural Affairs of Buenos Aires Province, all artisanal vessels using passive fishing gears shall have exclusive access to the first 5 nautical miles of the maritime zone, the use of trawl nets being absolutely banned within the aforementioned area. By way of a supplementary measure, this

resolution suggests the creation of a restricted fishing effort area (ZEC area) of a precautionary nature between 5 and 12 nautical miles. Even though this resolution is currently in force, it is questioned year after year due to the economic interests prevailing in the area; these are related to the trawl fishery for coastal species, which consist of a group of 25 commercial species. Moreover, as a result of the permanent monitoring that the National Research and Development Institute (INIDEP) and the Authority perform if the fishing effort results excessive, the immediate close of the ZEC area may be determined (1). The artisanal fishermen want to reinforce this measure, asking for the protection of this restricted fishing effort area from the trawling impact.
At present, there are no available studies on the impact of the trawl fishery on the benthic ecosystem to support the uninterrupted enforcement of this regulation. Due to the chain reactions that could be originated by the sea floor disturbance and the need of obtaining biological information to support the management measures to preserve the marine ecosystem, we suggest as general objective of this research to analyse the impacts of trawling activities on the ecosystem found in the Partido de la Costa District area in Buenos Aires Province and compare the level of disturbance between areas subjected to bottom trawling and areas where this fishing art is prohibited.

Methodology

a. Study site

The study area belongs to the coastal marine zone included between the localities of La Lucila (36º17´23´´S 56º46´53´´W) and Punta Médanos (36º52´33´´S 56º39´56´´W) (Figure 1). The sites considered as not subjected to bottom trawling are those inside the first 5 nm between La Lucila and Mar de Ajó. The sites located besides the 5 nm. and the Punta Médanos site correspond to bottom trawling areas.
This ecosystem waters, with salinities higher than 27 ups, are dominated by coastal marine fish species. Its icthyofauna is represented by commercial species as the white croacker *Micropogonias furnieri*, the parona leathearjack *Parona signata*, the smoothhound *Mustelus schmitti* and the stripped weakfish *Cynoscion guatucupa* (Lagos, 2001; Lasta y Jaureguizar, 2006). There, also, can be found invertebrates like the shrimps *Pleoticus Muelleri* and *Artemesia longinaris*, which are commercially exploited.

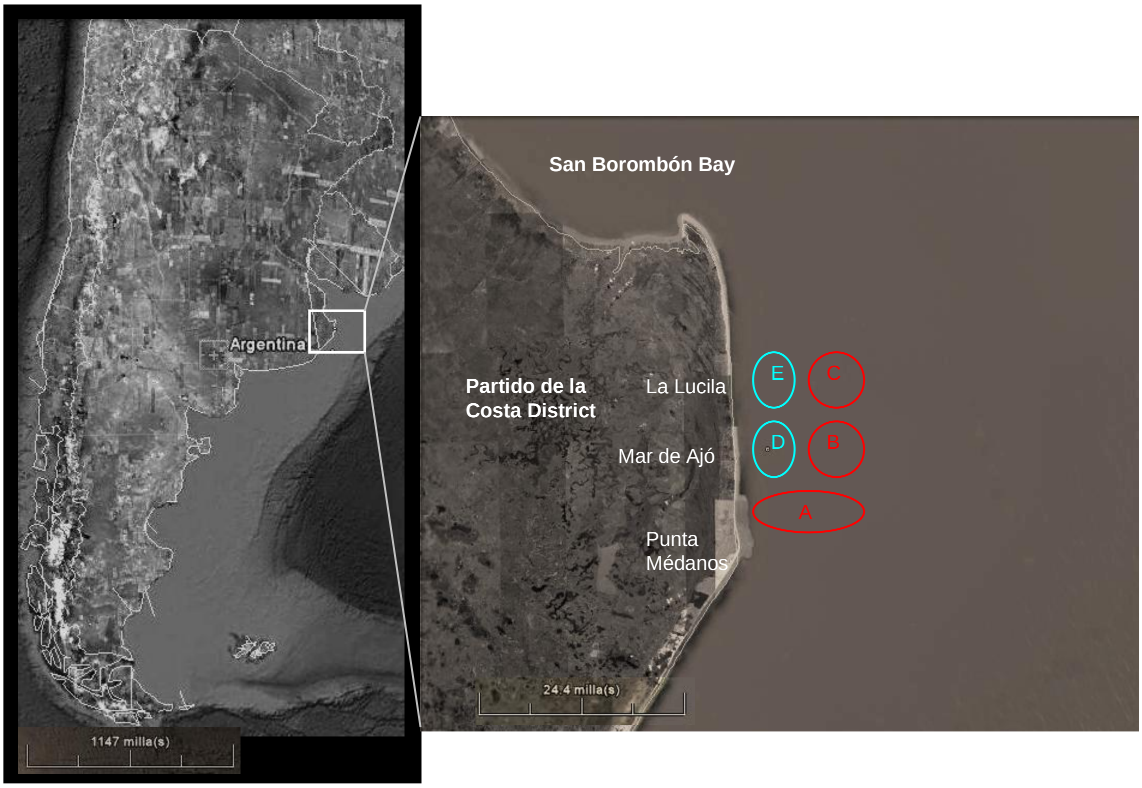

Figure 1. A, B and C are sites subjected to bottom trawling. E and D are sites where bottom trawling is banned according to Resolution 18/06. A) Punta Médanos (PM) B) Mar de Ajó bottom trawling (MA BT) C) La Lucila bottom trawling (LL BT) D) Mar de Ajó protected (MA Prot) E) La Lucila protected (LL Prot).

b. Field Work and Data Analysis

Samples were taken in 318 points using a dredge and a total of 11.020 individuals were collected (Figure 2). We identified 46 species included in 29 families (Table 1). The sampling stations were replicated and located in sites where trawling is banned and in sites subjected to bottom trawling. We registered the geographic position, the type of sediments and the length of the dredged area. Based on the length of the dredged area and the width of the dredge, we established the corresponding surface, and the abundance (number of individuals of each species/m^2) and biomass (grams/m^2) of the populations were estimated for each surveyed area.
Samples collected, fixed and kept in labelled bottles were analysed in the laboratory, determining the individuals to the lowest possible level, including its weight and length.

Diversity (Shannon Wiener), richness (Chao 2) and evenness (Pielou) indixes of the macrobenthic community were estimated for each sample station.
The Shannon Wiener index (H') considers the number of species present in the area (richness) and, also, the relative abundance of each species (Krebs, 1989). The Shannon Wiener index formula used in this research was: $H' = - \sum_{i=1}^{S} pi * \log_2 pi$
Where:

S: the number of species
pi: the proportion of individuals of the species i regarding the total number of individuals (relative abundance of species i)

The Shannon Wiener index values range from 1 to 5 in most natural ecosystems. Values close to 1 indicate low diversity. Instead, values close to 5 indicate high diversity areas (Krebs, 1989).

The Pielou index determines how evenly are the proportions of the different taxa in a sample (Krebs, 1989). This index was calculated as: $J' = H' / H'_{max}$

Where:

H': the Shannon Wiener index

$H'_{max} = \ln S$

S: the number of species observed

In this case, the values range from zero to one, resulting close to one when the species are equally abundant (Krebs, 1989).

We used the Chao 2 index as a richness estimator (Chao, 1984), it's based on the rare species and was calculated as: $S = D + Q_1/2Q_2$

Where D is the number of species registered, Q_1 is the number of species present in only one sample and Q_2 is the number of species present in two samples.

On the other hand, **ABC curves** (Warwick, 1986) were calculated for each site to assess the fishing effects over the community dominance patterns and the degree of disturbance. This methodology is based on the K and R strategies theory, assuming that in not perturbed areas macrobenthic communities would be dominated by K strategist species (big size, slow growth, late maturity), which are not usually numerically dominant, but dominate the biomass. Instead, in areas under more disturbance levels, the low growth species are no longer dominant and become more important the R strategists or opportunistic species characterized by its small size, fast growth and high abundance (Warwick, 2008; McManus y Pauly, 1990; Yemane *et.al*., 2005).

Species are ranked in order of importance, according to their biomass or abundance, on the x-axis logarithmic scale (Warwick, 2008). The logarithmic transformation of the data allows a better visual discrimination between the abundance (A) and biomass (B) curves (Clarke 1990). In the y axis, there are the percentages of cumulative dominance (Warwick, 2008).

In areas with moderate perturbation, the dominant big size species are eliminated, but there is no explosion of small opportunistic species. So the difference of sizes between numerically dominant species and species that dominate the biomass is reduced. For this reason, the biomass and abundance curves intersect one or more times (Warwick, 2008).

This technique doesn't need of control samples in space or time, because both curves act as an internal control one of the other. However, the confirmatory comparisons with reference zones in time or space are desirable (Warwick, 2008). The difference between both curves (B and A) represents the W statistic, which presents a negative sign when the biomass curve is under the abundance curve suggesting that the community is disturbed. If both curves are superimposed, this method indicates that the community is moderately perturbed with a W statistic close to zero. Finally, if the biomass curve is over the abundance curve ($W>0$), this technique would indicate an undisturbed community (Warwick, 2008; Yemane *et.al.,* 2005).

One of the problems of the ABC curves is that the cumulative curves become dependent of the few most dominant species. The unexpected presence of a large number of small biomass species or the presence of juveniles from one species could give a false disturbance impression (Warwick, 2008). In case of a genuine perturbation, it is expected that the ABC curves pattern is not affected by the removal of the first or second more dominant species in terms of biomass or abundance. From this suggestion, the **partial dominance curves** arise, which calculate the dominance of the second species over the others (without considering the most dominant species) and so on. The partial dominance curves from a site without disturbance must show the biomass curve above the abundance curve throughout the extension. In the case of undisturbed sites, the abundance curve results less variable than the biomass curve. Instead, in disturbed sites there is a change in the curves positions being the abundance curve above the biomass curve and resulting in the abundance curve more variable than the biomass one. In moderately perturbed sites, the biomass and abundance curves intersect (Warwick, 2008).

The partial dominance curves aren't even, which makes them not visually appealing. But, they result in a useful alternative, more robust against the fluctuations in the abundance of small size species numerically dominant than the ABC curves (Warwick, 2008). That's the reason why we also estimated the partial dominance curve in each study site.

Also, to compare the stress levels of the five sites under study, we calculated the K – dominance curves. These curves present the accumulated abundance of the species ranked in terms of abundance (Lambshead *et. al*, 1983). This method assumes that the environmental stress causes a group of species that tolerates the perturbations to succeed, whereas another group of intolerant species becomes rare. These changes in specific composition of the disturbed areas would cause K – dominance curves higher on the right side than the curves from undisturbed areas (Rice, 2000).

Finally, through a one way **Analysis of Similarities (ANOSIM)** we assessed the existence of differences in the species composition between the five study sites. ANOSIM is a non parametric similarity analysis between the sampling stations, where R statistics ranges from -1 to 1 and allows comparing pairs of sites under study (Clarke, 1993). If R trends to one, the composition of species between both sites is very different. Instead, when R is towards zero, there exist small differences in the species composition between the compared sites (Clarke, 1993). Then, due to the differences observed in the composition of species between the five sites, we carried out a **Similarity Percentage Analysis (SIMPER)** (Clarke, 1993) to determine which species contributed to the 90% of dissimilarity (discriminant species) between the compared sites. The SIMPER analysis determines the contribution of each species to the average similarity / dissimilarity. Those species that contribute to the 90% of similarity between sites are considered as common or typical, whereas the discriminant species contribute to the 90% of dissimilarity.

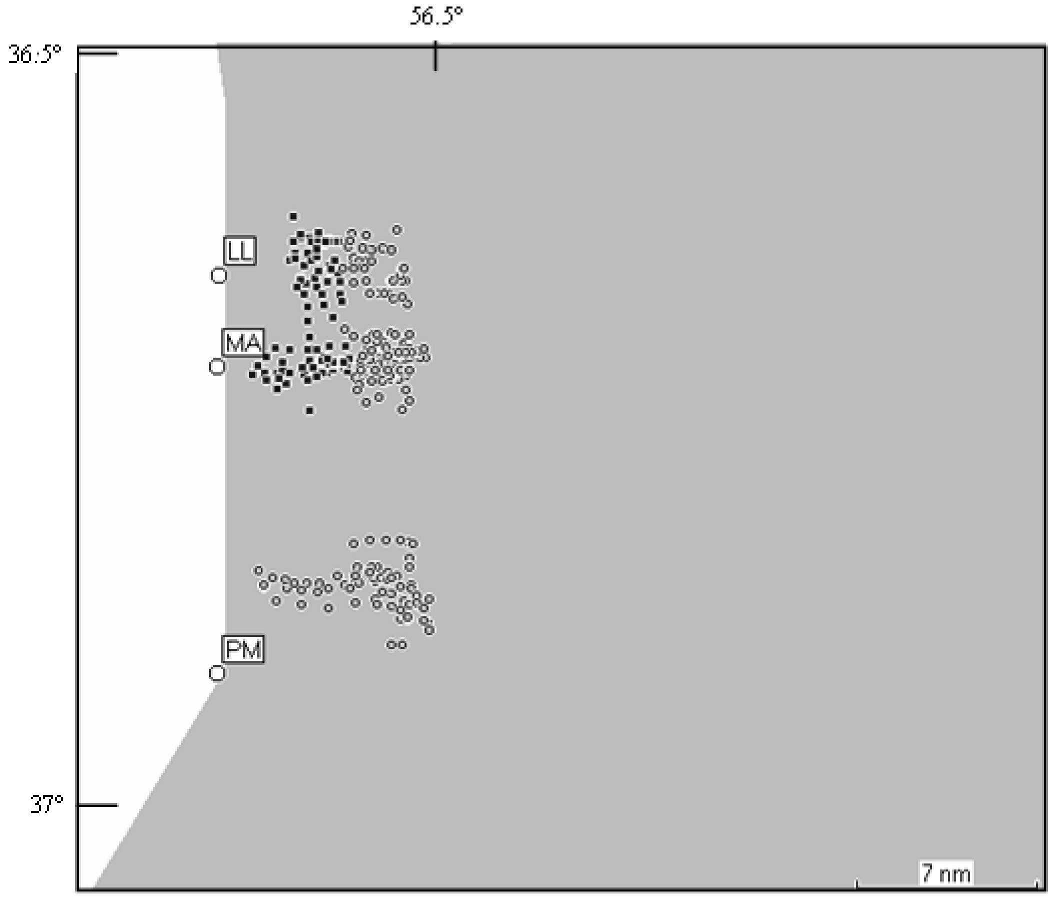

Figure 2. Location of the sample points in the study area in front of the 3 localities (La Lucila (LL), Mar de Ajó (MA) and Punta Médanos (PM)). The black dots represent samples taken inside the protected sites where bottom trawling is banned. White dots represent samples taken in bottom trawling sites.

Table 1. Classification of the sampled identified species. Bibliographic sources used for species determinations: Otero (1992) and Boschi and Cousseau (2004).

Phylum	Class	Order	Family	Species
Cnidaria	Hexacorallia	Anthozoa	Actinostolidae	*Antholoba achates*
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra viridis*
Arthropoda	Cirripedia	Pedunculata	Balanidae	*Sin identificar*
	Malacostraca	Isopoda	Cirolanidae	*Exirolana braziliensis*
			Idoteidae	*Macrochiridothea giambiagiae*
			Serolidae	*Serolis bonaerensis*
			Sphaeromatidae	*Sphaeroma serratum*
		Cumacea	Bodotriidae	*Cyclaspis micans*
			Diastylidae	*Macrokylindrus bacescui*
		Decapoda	Belliidae	*Corystoides chilensis*
			Diogenidae	*Loxopagurus loxochelis*
			Grapsidae	*Cyrtograpsus altimanus*
				Cyrtograpsus angulatus
			Majidae	*Libinia spinosa*
				Leucipa pentagona
				Pelia rotunda
			Paguridae	*Pagurus exilis*
				Pagurus criniticornis
			Penaeidae	*Artemesia longinaris*
			Pinnotheridae	*Pinnixa brevipollex*
				Pinnixa patagoniensis
				Dissodactylus crinitichelis
Molusca	Gastrópoda	Archaeogastropoda	Nassariidae	*Buccinanops lamarckii*
				Buccinanops globolosum
				Buccinanops monilifer
				Buccinanops uruguayensis
			Olividae	*Olivancillaria auricularia*
				Olivancillaria carcellesi
				Olivancillaria deshayesiana
				Olivancillaria urceus
				Olivella puelcha
				Olivella tehuelcha
			Volutidae	*Adelomelon brasiliana*
				Zidona dufresnei
			Epitoniidae	*Epitonium georgetina*
		Caenogastropoda	Naticidae	*Natica isabelleana*
		Hypsogastropoda	Terebridae	*Terebra gemulata*
	Bivalvia	Arcoida	Nuculanidae	*Adrana electa*
		Myoida	Corbulidae	*Corbula patagonica*
		Veneroida	Mactriidae	*Mactra isabelleana*
			Veneridae	*Pitar rostrata*
				Amiantis purpurata
				Tivela isabelleana
			Tellinidae	*Tellina petitiana*
				Macoma uruguayensis
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	*Ophioplocus januarii*
	Echinoidea	Clypeasteroida	Scutellidae	*Encope emarginata*

RESULTS

DIVERSITY, RICHNESS AND EVENNESS INDEXES

The higher diversity values were observed in PM, which is probably related to its higher richness and evenness values. The diversity levels result close to 1 in the five study sites, so all of them are low diversity areas. The lowest evenness site is LL PROT and the lowest richness values are observed in LL BT (Figure 3).

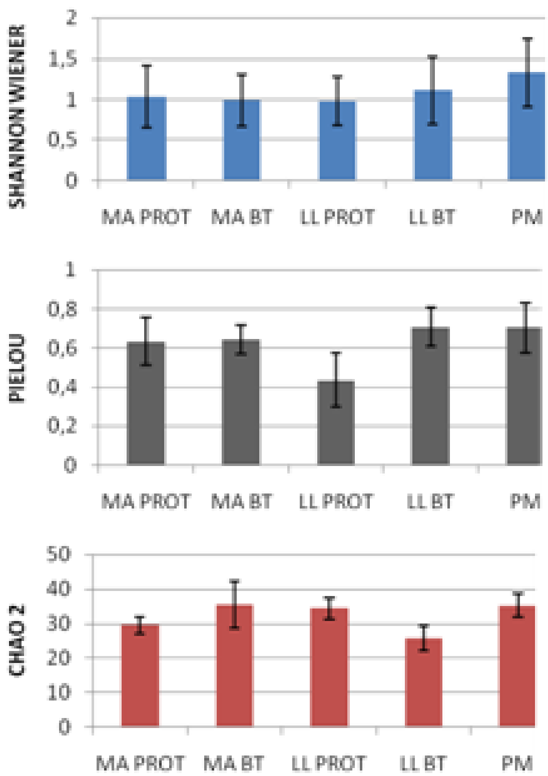

Figure 3. Diversity, evenness and richness indexes obtained for the five sampling sites.

HABITAT PERTUBATION INDICATORS: ABC CURVES, PARTIAL DOMINANCE CURVES AND K – DOMINANCE CURVES

Through the data analysis in each study site with the ABC curves method, there exist two sites moderately disturbed: MA and LL protected (first 5 nm.). In those cases, the abundance and the biomass curves intersect (Figure 4) and the W statistic is negative and close to zero (Table 2). The other three study sites subjected to trawling present curve patterns that indicate the absence of perturbation (Figure 5) and show positive W values close to zero (Table 2).
The partial dominance curves method indicates that all sites are moderately disturbed, which is deducted from the curves intersection and the observed variability in the abundance curve (Figure 6 and Table 2).
The K – dominance curves indicate that the higher stress site is LL PROT, because it presents a higher curve on the right side of the graphic than the other sites. The PM, MA BT and MA PROT sites present similar stress levels (Figure 7).

Table 2. W statistic values and perturbation degree determined from the ABC and partial dominance curves methods in the five study sites.

Areas	ABC curves		Partial Dominance Curves
	W	Disturbance degree	
Mar de Ajó Norte protected	-0,044	Moderately perturbed	Moderately perturbed
Mar de Ajo Norte bottom trawling	0,105	No perturbation	Moderately perturbed
La Lucila protected	-0,018	Moderately perturbed	Moderately perturbed
La Lucila bottom trawling	0,19	No perturbation	Moderately perturbed
Punta Médanos	0,072	No perturbation	Moderately perturbed

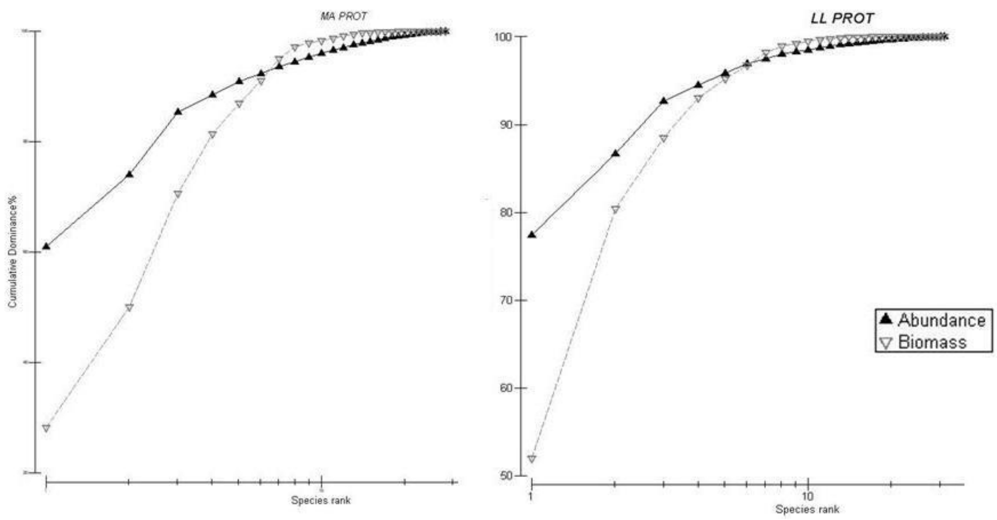

Figure 4. ABC curves from sites where trawling is banned by resolution 18/06.

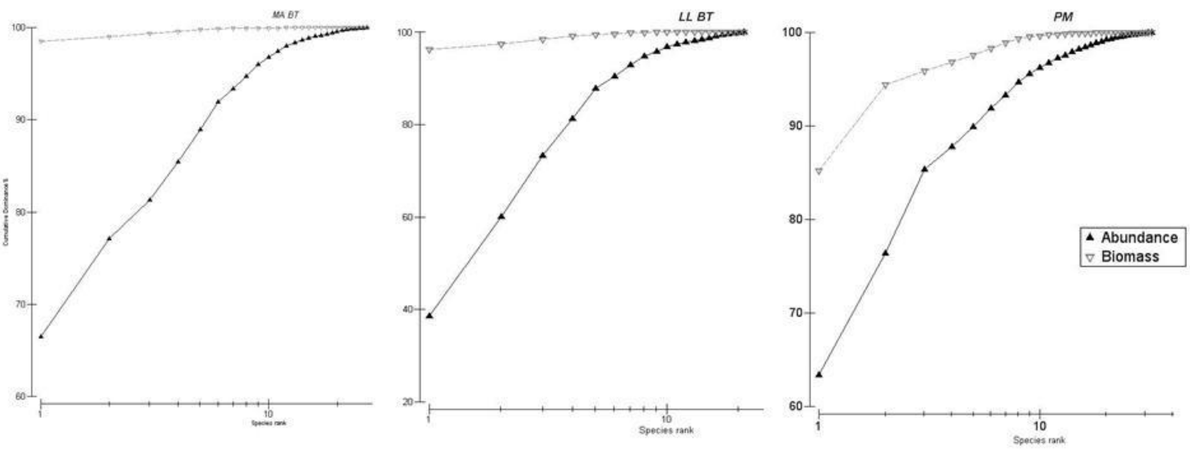

Figure 5. ABC curves of the bottom trawling sites.

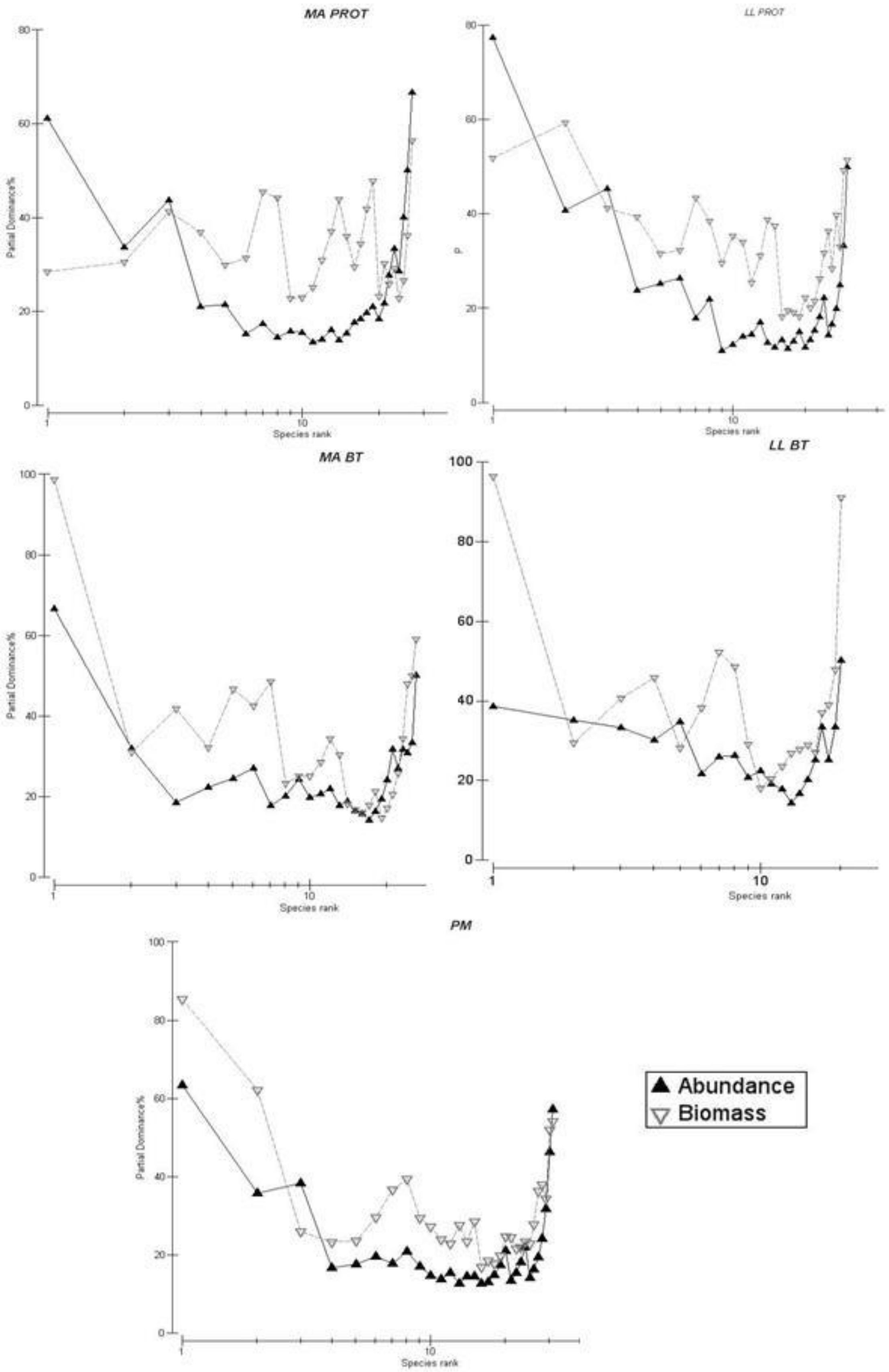

Figure 6. Partial dominance curves from the five study sites.

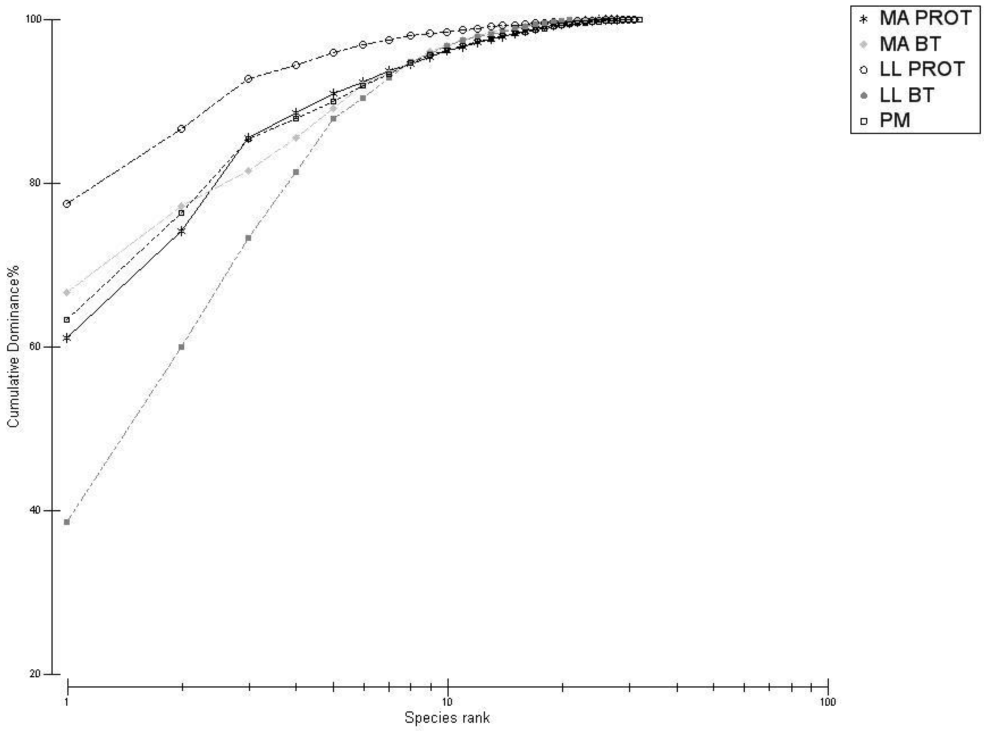

Figure 7. K – Dominance curves obtained in the five study site.

SPECIFIC COMPOSITION OF THE MACROBENTHIC COMUNITY

The one way Analysis of Similarities (ANOSIM) indicates significant differences between most of the sites except between LLBT and MA BT and LLBT and PM (Table 3). The greater differences in specific composition are observed between the trawling sites and the protected ones. The SIMPER analysis indicates that the species that contribute to the major differences are: *Encope emarginata*, *Corbula patagónica* and *Diopatra viridis*. The bivalve species *C. patagonica* as the polychaete *D. viridis* show an important abundance in areas not subjected to bottom trawling (MA PROT and LL PROT). On the other side, the echinoderm *E. emarginata* presents high abundance levels in the bottom trawling sites particularly in MA BT and LL BT (Tables 4 – 14)

Table 3. R statistic values and significance levels obtained in one way ANOSIM analysis. Significance level: 0,1 %.

Sites	R statistic	Significance level (%)
MA PROT , MA BT	0,57	0,1
MA PROT, LL PROT	0,129	0,1
MA PROT, LL BT	0,409	0,1
MA PROT, PM	0,162	0,1
MA BT, LL PROT	0,808	0,1
MA BT, LL BT	0,065	2,8
MA BT, PM	0,178	0,1
LL PROT, LL BT	0,804	0,1
LL PROT, PM	0,39	0,1
LL BT,PM	0,014	24,6

Table 4. Average abundance values per site and percentage of dissimilarity between MA PROT and MA BT generated by the discriminant species.

Species	MA PROT	MA BT	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Encope emarginata	5,69	45,18	24,48	24,48
Diopatra viridis	31,2	10,63	18,55	43,03
Corbula patagonica	18,91	4,74	11,83	54,86
Artemesia longinaris	5,96	6,68	5,89	60,75
Dissodactylus crinitichelis	1,34	8,09	5,12	65,87
Loxopagurus loxochelis	2,41	5,54	4,1	69,98
Pitar rostrata	6,84	0	4,06	74,03
Buccinanops lamarckii	5,63	0,82	3,61	77,64
Olivella tehuelcha	3,32	3,36	3,33	80,97
Pagurus exilis	3,31	3,15	3,28	84,25
Olivancillaria carcellesi	0,91	3,5	2,45	86,7
Antholoba achates	3,21	0	1,91	88,6
Cyrtograpsus altimanus	0,9	2,36	1,84	90,45

Table 5. Average abundance values per site and percentage of dissimilarity between MA PROT and LL PROT generated by the discriminant species.

Species	MA PROT	LL PROT	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Diopatra viridis	31,2	12,46	20,71	20,71
Corbula patagonica	18,91	34,09	17,15	37,86
Pitar rostrata	6,84	5,82	6,87	44,73
Buccinanops lamarckii	5,63	8,1	6,65	51,37
Artemesia longinaris	5,96	5,95	6,57	57,94
Antholoba achates	3,21	4,55	4,49	62,43
Encope emarginata	5,69	0,6	4,27	66,69
Olivella tehuelcha	3,32	3,17	3,93	70,63
Adelomelon brasiliana	2,33	3,24	3,41	74,04
Pagurus exilis	3,31	1,18	2,84	76,88
Olivancillaria carcellesi	0,91	3,36	2,8	79,68
Buccinanops monilifer	1,06	2,67	2,38	82,05
Loxopagurus loxochelis	2,41	1,08	2,25	84,31
Macrochiridothea giambiagiae	0	2,96	2,08	86,38
Libinia spinosa	0,61	1,74	1,54	87,92
Dissodactylus crinitichelis	1,34	0,6	1,32	89,24
Serolis bonaerensis	0,55	1,24	1,2	90,43

Table 6. Average abundance values per site and percentage of dissimilarity between MA BT and LL PROT generated by the discriminant species.

Species	MA BT	LL PROT	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Encope emarginata	45,18	0,6	25,27	25,27
Corbula patagonica	4,74	34,09	18,27	43,54
Diopatra viridis	10,63	12,46	8,61	52,15
Artemesia longinaris	6,68	5,95	5,03	57,18
Dissodactylus crinitichelis	8,09	0,6	4,73	61,91
Buccinanops lamarckii	0,82	8,1	4,72	66,63
Loxopagurus loxochelis	5,54	1,08	3,46	70,09
Olivancillaria carcellesi	3,5	3,36	3,42	73,51
Pitar rostrata	0	5,82	3,29	76,8
Olivella tehuelcha	3,36	3,17	3,19	79,98
Antholoba achates	0	4,55	2,57	82,56
Pagurus exilis	3,15	1,18	2,23	84,79
Macrochiridothea giambiagiae	0,47	2,96	1,86	86,65
Adelomelon brasiliana	0	3,24	1,83	88,48
Buccinanops monilifer	0,3	2,67	1,64	90,12

Table 7. Average abundance values per site and percentage of dissimilarity between MA PROT and LL BT generated by the discriminant species.

Species	MA PROT	LL BT	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Encope emarginata	5,69	47,2	26,12	26,12
Diopatra viridis	31,2	12,42	18,23	44,35
Corbula patagonica	18,91	1,66	11,26	55,61
Artemesia longinaris	5,96	9,35	7,04	62,65
Loxopagurus loxochelis	2,41	6,76	4,81	67,46
Dissodactylus crinitichelis	1,34	6,9	4,55	72,01
Buccinanops lamarckii	5,63	2,87	4,18	76,19
Pitar rostrata	6,84	0,22	4,15	80,34
Olivella tehuelcha	3,32	3,31	3,32	83,66
Antholoba achates	3,21	1,05	2,41	86,07
Pagurus exilis	3,31	0,52	2,2	88,27
Olivancillaria carcellesi	0,91	2,94	2,15	90,42

Table 8. Average abundance values per site and percentage of dissimilarity between MA BT and LL BT generated by the discriminant species.

Species	MA BT	LL BT	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Encope emarginata	45,18	47,2	27,12	27,12
Diopatra viridis	10,63	12,42	13,41	40,53
Dissodactylus crinitichelis	8,09	6,9	9,61	50,14
Artemesia longinaris	6,68	9,35	9,2	59,33
Loxopagurus loxochelis	5,54	6,76	8,34	67,67
Corbula patagonica	4,74	1,66	5,02	72,69
Olivancillaria carcellesi	3,5	2,94	4,79	77,48
Olivella tehuelcha	3,36	3,31	4,73	82,22
Pagurus exilis	3,15	0,52	2,96	85,18
Buccinanops lamarckii	0,82	2,87	2,93	88,11
Cyrtograpsus altimanus	2,36	0	1,98	90,09

Table 9. Average abundance values per site and percentage of dissimilarity between LL PROT and LL BT generated by the discriminant species.

Species	LL PROT	LL BT	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Encope emarginata	0,6	47,2	26,7	26,7
Corbula patagonica	34,09	1,66	18,65	45,35
Diopatra viridis	12,46	12,42	8,36	53,71
Artemesia longinaris	5,95	9,35	6,02	59,73
Buccinanops lamarckii	8,1	2,87	4,85	64,58
Loxopagurus loxochelis	1,08	6,76	4,16	68,74
Dissodactylus crinitichelis	0,6	6,9	4,13	72,87
Pitar rostrata	5,82	0,22	3,38	76,26
Olivella tehuelcha	3,17	3,31	3,21	79,47
Olivancillaria carcellesi	3,36	2,94	3,19	82,66
Antholoba achates	4,55	1,05	2,95	85,61
Adelomelon brasiliana	3,24	0	1,85	87,46
Macrochiridothea giambiagiae	2,96	0	1,69	89,15
Buccinanops monilifer	2,67	0	1,53	90,67

Table 10. Average abundance values per site and percentage of dissimilarity between MA PROT and PM generated by the discriminant species.

Species	MA PROT	PM	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Diopatra viridis	31,2	16,06	18,49	18,49
Encope emarginata	5,69	22,86	14,35	32,84
Corbula patagonica	18,91	7,8	12,91	45,75
Artemesia longinaris	5,96	8,49	7	52,75
Olivella tehuelcha	3,32	6	4,62	57,37
Dissodactylus crinitichelis	1,34	6,67	4,51	61,88
Buccinanops lamarckii	5,63	2,84	4,39	66,28
Pitar rostrata	6,84	0	4,26	70,54
Pagurus exilis	3,31	4,15	3,81	74,35
Loxopagurus loxochelis	2,41	3,57	3,3	77,66
Antholoba achates	3,21	1,5	2,76	80,41
Olivancillaria carcellesi	0,91	3,54	2,55	82,97
Serolis bonaerensis	0,55	2,81	2,03	85
Adelomelon brasiliana	2,33	0,31	1,61	86,61
Ofiuro	0,16	1,81	1,21	87,82
Macrokylindrus bacescui	0,8	1,11	1,15	88,98
Corystoides chilensis	0	1,75	1,09	90,07

Table 11. Average abundance values per site and percentage of dissimilarity between MA BT and PM generated by the discriminant species.

Species	MA BT	PM	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Encope emarginata	45,18	22,86	24,88	24,88
Diopatra viridis	10,63	16,06	12,07	36,94
Corbula patagonica	4,74	7,8	7,88	44,82
Dissodactylus crinitichelis	8,09	6,67	7,64	52,46
Artemesia longinaris	6,68	8,49	7,5	59,96
Loxopagurus loxochelis	5,54	3,57	5,48	65,44
Olivella tehuelcha	3,36	6	5,31	70,74
Pagurus exilis	3,15	4,15	4,31	75,05
Olivancillaria carcellesi	3,5	3,54	4,29	79,35
Buccinanops lamarckii	0,82	2,84	2,44	81,79
Serolis bonaerensis	0,42	2,81	2,23	84,02
Cyrtograpsus altimanus	2,36	0,58	2,02	86,04
Leucipa pentagona	1,18	1,61	1,84	87,88
Corystoides chilensis	0,3	1,75	1,44	89,32
Ofiuro	0	1,81	1,28	90,6

Table 12. Average abundance values per site and percentage of dissimilarity between LL PROT and PM generated by the discriminant species.

Species	LL PROT	PM	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Corbula patagonica	34,09	7,8	19,08	19,08
Encope emarginata	0,6	22,86	13,98	33,06
Diopatra viridis	12,46	16,06	8,94	42
Artemesia longinaris	5,95	8,49	6,21	48,2
Buccinanops lamarckii	8,1	2,84	5,33	53,53
Olivella tehuelcha	3,17	6	4,68	58,21
Dissodactylus crinitichelis	0,6	6,67	4,27	62,48
Olivancillaria carcellesi	3,36	3,54	3,65	66,13
Pitar rostrata	5,82	0	3,57	69,69
Antholoba achates	4,55	1,5	3,42	73,11
Pagurus exilis	1,18	4,15	2,92	76,03
Loxopagurus loxochelis	1,08	3,57	2,63	78,66
Serolis bonaerensis	1,24	2,81	2,37	81,03
Adelomelon brasiliana	3,24	0,31	2,11	83,14
Macrochiridothea giambiagiae	2,96	0,15	1,88	85,01
Buccinanops monilifer	2,67	0	1,64	86,65
Leucipa pentagona	0,8	1,61	1,39	88,04
Corystoides chilensis	0,32	1,75	1,26	89,3
Libinia spinosa	1,74	0,29	1,21	90,51

Table 13. Average abundance values per site and percentage of dissimilarity between LL BT and PM generated by the discriminant species.

Species	LL BT	PM	Percentage of dissimilarity	Percentage of dissimilarity accumulated
	Average abundance	Average abundance		
Encope emarginata	47,2	22,86	27,05	27,05
Diopatra viridis	12,42	16,06	11,41	38,46
Artemesia longinaris	9,35	8,49	8,52	46,98
Dissodactylus crinitichelis	6,9	6,67	7,42	54,4
Corbula patagonica	1,66	7,8	6,32	60,72
Loxopagurus loxochelis	6,76	3,57	6,31	67,03
Olivella tehuelcha	3,31	6	5,33	72,36
Olivancillaria carcellesi	2,94	3,54	4,02	76,38
Buccinanops lamarckii	2,87	2,84	3,51	79,89
Pagurus exilis	0,52	4,15	3,19	83,08
Serolis bonaerensis	0,28	2,81	2,17	85,25
Leucipa pentagona	1,16	1,61	1,84	87,09
Antholoba achates	1,05	1,5	1,76	88,85
Ofiuro	0	1,81	1,29	90,14

Tabla 14. Percentages of average dissimilarity between the five study sites.

	MA PROT	MA BT	LL PROT	LL BT	PM
MA PROT	-	-	-	-	-
MA BT	84,31	-	-	-	-
LL PROT	71,21	88,41	-	-	-
LL BT	83,42	59,49	87,53	-	-
PM	80,33	70,86	81,57	69,92	-

DISCUSION

Researches carried out in areas of soft seabeds indicate that those can be affected by trawling, due to the sediments resuspention generated by the turbulence produced by the gates during the dredging contributing to raise the fish captures (Main y Sangster, 1979; Main y Sangster, 1981 in Jones (1992)). In our study area, soft types of seabeds of mud or sand have been observed, finding muddy beds on some of the sample sites. The disturbance of these seabeds includes the sediments resuspension. Some investigations indicate that the trawling of chains and bags of nets cause such impacts that the trawling areas can´t recover from the effects of sediments redeposition during 6 months (Jones, 1992). Furthermore, there are researches that indicate higher natural mortality rates and indirect mortality rates caused by fishing in scallop seabeds under trawling activities than in those not subjected to this kind of fishing (Jones, 1992).

The ABC curves used in this research were proposed as environmental disturbance indicators in macrobenthic marine assemblages that constitute the main purpose in the marine environment monitoring programs (Warwick, 2008). That's the reason why we estimated the curves correspondent to the five study sites, whose results indicate that the disturbance degree observed in the areas not subjected to bottom trawling is moderate. A possible explanation for this observation could be that before the establishment of resolution 18/06 the frequency of vessels bottom trawling near the coast was high and, considering this is a relatively recent regulation, these areas haven't reached an adequate recovery. Besides, during the year it is possible to observe different vessels that are not controlled by satellite positioning systems, get into the protected areas to perform trawling activities. These illegal activities can also explain why the areas not subjected to bottom trawling still show a moderate perturbation degree.

In the case of the bottom trawled areas, the ABC curves indicate that these sites were undisturbed. However, when applying the partial dominance curves method to analyse the environmental perturbation, these show that both protected areas and the three areas subjected to trawling activities are moderately disturbed. Considering the observed dominance of small biomass species (belonging to the polychates and bivalves groups) in areas protected from trawling activities and the dominance of the echinoderm *E. emarginata*, species of higher biomass, in areas under bottom trawling, we consider that the partial dominance curves results are more robust. From this interpretation, we could suggest that our results indicate that all the sites under study are moderately disturbed.

Most of the studies suggest that the ABC curves respond to anthropogenic perturbations, but are not affected by long term environmental stress because the organisms can adapt to such conditions (Warwick, 2008). However, there are difficulties to attribute the observed changes in the benthos to the effects of trawling due to the existence of environmental variability (Jones, 1992). In the case of our research, we assumed that the environmental perturbations observed were caused by bottom trawling activities, but we recognized that in our study area environmental fluctuations exist and could generate disturbances in coastal areas like ours. Taking into account this observation, we complemented the analysis done with the ABC and partial dominance curves with the estimation of diversity, richness and evenness indexes together with the species composition analysis of the five sites.

Generally, the response of benthic communities to trawling matches with the intermediate disturbance general model, in which a raise in the number of small and fast growth species and a reduction of diversity and evenness can be observed (de Vooys y van de Meer, 1998; Hall, 1999). The use of mobile fishing arts breaks and exposes macrobenthic individuals reducing the structural diversity of the impacted area. These disturbances alter the diversity patterns affecting the species composition, the spatial structure and the biogeochemical cycles (Wattling y Norse, 1998). Our research shows low diversity levels in all study sites and the lower species richness in a bottom trawled area. Moreover, it must be considered that the protected areas present a specific composition significantly different from those of areas subjected to bottom trawling.

In regard to the species composition, our data analysis in trawled areas agree with other researches which indicate that benthic communities subjected to trawling activities show a trend towards echinoderm and other depredatory / scavengers groups dominance (Kaiser y Spencer, 1996; Lindeboom y de Groot, 1998; Hill *et al*., 1999; Bradshaw *et al*., 2002; Guijarro-García *et al*., 2006). In this case, the sites under bottom trawling pressure are dominated by the echinoderm *E. emarginata*, species that represents the major percentages of dissimilarity between trawling areas and protected ones.

The impacts of fishing over benthic communities must be considered as part of any research with ecosystem approach, because benthic invertebrates constitute one of the most important sources of food for many commercially exploited fish species. Moreover, these invertebrates provide a cover and have a significant role in sustaining ecosystem processes such as the nutrient cycles. In this investigation, we observed that benthic species that result more abundant in protected areas are those found in the stomach contents of the commercial fish species from the area. Between the species eaten by commercial species like the smooth hound *Mustelus schimitii* and the White croaker *Mycopogonias furnieri* we found species representatives of the polychaetes group (Cousseau y Perrota, 2000; Giberto *et al*., 2007; Giberto *et. al*., 2008; Lértora *et al*., 2009), which result significantly more abundant in the areas not subjected to bottom trawling. In the case of *M. furnieri,* some bivalves and gastropod species are important prey items as well (Cousseau y Perrota, 2000; Giberto *et al.,* 2007; Giberto *et. al*., 2008; Lértora, *et. al*., 2009), and these are also more abundant in the protected areas.

As was stated earlier, the bottom trawled areas showed as principal species the echinoderm *E. emarginata*, that represents the major percentages of dissimilarity between both types of areas and doesn't represent a prey item found in the fish species of this area. In the areas subjected to bottom trawling, we also found the presence of the crab *Dissodactylus crinitichelis*, the hermit crab *Loxopagurus loxochelis* and the shrimp *Artemesia longinaris* all of them collected in stomach contents of smooth hounds in the study area (Lértora *et al*., 2009).

Our results indicate that the five study sites have a moderate disturbance degree. Moreover, we point out the necessity of preserving the benthic community from the currently protected areas, whose macrobenthic species are related to the diets of commercial fish and other vulnerable species. By doing this, a series of chain reactions involving the rest of the species and the interactions between the trophic levels in the ecosystem might be avoided. The areas currently subjected to trawling have also showed a species composition composed of some species that result important in the interactions between the benthos and other species from the ecosystem. For this reason, the benthos preservation in the five sites would be relevant to preserve these ecosystem interactions.

We consider this research to be a first approach to the topic, it will be necessary to continue gathering information about the benthic community along the time to establish future comparisons and analyze possible ecosystem disturbances. The indicators of habitat perturbation found in this study constitute a first evidence in support of efforts to continue preserving the area not subjected to bottom trawling and start working for the preservation of the areas currently subjected to trawling activities. It's important to suggest the need of reinforcing the control measures in the protected areas reserved for passive fishing arts, in order to avoid the impact of vessels incurring on illegal fishing activities according to the current regulations (Provincial Law 11.477 and decree 3237/95 and the Resolution No. 18/06 from the Subsecretary of Fishing Activities of the Buenos Aires Province).

In coastal areas where information is not available, precautionary management measures should be implemented, such as creating refuges free of active fishing arts like bottom trawling in order to protect the biological diversity and the environment where commercial fish feed (Watling y Norse, 1998). Meanwhile, monitoring should be improved to increase the predictive capabilities (Auster y Laugton, 1999). We consider that other data may be obtained to deepen this research, for example: data related to the spatial scale of the fishing activities which would allow to analyze the fishing effort gradient and its effects on the ecosystem, damage data caused by an specific type of net and data about the role of benthos over the fish population dynamic in the area (Auster y Laugton, 1999). Furthermore, there are different ways to study the fishing disturbance history through the analysis of data from species that can register physical damages produced by fishing activities. In the case of some species which individuals survive to the trawling, there can be observed marks like those done on the mollusk's valves (Kaiser, 1998). This kind of information could be important to reach an optimum management of this ecosystem based on scientific researches.

ACKNOWLEDGMENTS: We are grateful for the cooperation of PhD. Ricardo Bastida in regard to macrobenthic species determination and his suggestions for the development of this research, also for the assistance of the artisanal fishermen during the sampling days, the cooperation of PhD. Wilmer Carbajal in regard to data analysis and the financial support of Rufford Small Grants Foundation.

The Rufford Small Grants Foundation
www.ruffordsmallgrants.org

REFERENCES

Auster P. J. and R. Langton. 1999. The effects of fishing on fish habitat. American Fisheries Society Symposium.

Boschi E. and Cousseau M. B. 2004. La vida entre mareas: vegetales y animales de las costas de Mar del Plata, Argentina. Instituto Nacional de Investigación y Desarrollo Pesquero. Secretaría de Agricultura, Ganadería, Pesca y Alimentos. Mar del Plata (Argentina).

Bradshaw C, L. O. Veale and A. R. Brand. 2002. The role of scallop-dredge disturbance in long-term changes in Irish Sea benthic communities: a re-analysis of an historical dataset. J Sea Res (47): 161-184.

Chao A. 1984. Nonparametric estimation of the number of classes in a population. Scandinavian Journal of Statistics, Vol. 11: 265 - 270.

Clarke K. R. 1990. Comparisons of dominance curves. I. Exp. Mar. Biol. Ecol., Vol. 138: 143-157.

Clarke K. R. 1993. Non-parametric multivariate analyses of changes in community structure.

Australian Journal of Ecology, Vol. 18: 117–143.

Cousseau M.B. and R.G. Perrota (eds). 2000. Peces marinos de Argentina: biología, distribución, pesca. Instituto Nacional de Investigación y Desarrollo Pesquero, Mar del Plata (Argentina). 2daed. 167 pp.

Cousseau M.B., D.E. Figueroa, J.M. Díaz de Astarloa, E. Mabragaña and L.O. Lucifora. 2007. Rayas, chuchos y otros batoideos del Atlántico Sudoccidental (34º - 55º S). Mar del Plata (Argentina). 104 pp.

Craeymeersch J. A. 1991. Applicability of the abundance / biomass comparison method to detect pollution effects on intertidal macrobenthic communities. Hydrobiol. Bull. Vol. 24: 133 – 140.

de Vooys CGN and van der Meer J. 1998. Changes between 1931 and 1990 in the by-catches of 27 animal species from the southern North Sea. J Sea Res 39: 291-298.

Giberto D. and Bremec C. 2003. Benthic diversity of the Rio de La Plata estuary and adjacent marine waters. PNUD Project/Gef RLA/99/G31.

Giberto D. A., Bremec C., Acha M. and Mianzan H. 2007. Feeding of the whitemouth croaker Micropogonias furnieri (Scianidae; pisces) in the estuary of the Rio de La Plata and adjacent uruguayan coastal waters.

Giberto D. A., Bremec C. and Acha M. 2008. Dieta de seis species de Scianidae en el Rio de La Plata y zona costera adyacente entre el 2001 y 2005. Informe Técnico Nº 6 (INDIEP).

Guijarro García E, A. R. Stéfan and E. Hranfnkell. 2006. Effects of scallop dredging on macrobenthic communities in west Iceland. ICES J Mar Sci (63): 434-443.

Hall SJ. 1999. The effects of fishing on marine ecosystems and communities. Blackwell Science, Oxford.

Hill A. S., L. O. Veale, D. Pennington, S. G. Whyte, A. R. Brand and R. G. Hartnoll. 1999. Changes in Irish Sea Benthos: Possible Effects of 40 years of Dredging. Est Coastal and Shelf Science (48): 739-750.

Jones J. B. 1992. Environmental impact of trawling on the seabed: a review. New Zealand Journal of Marine and Freshwater Research, Vol. 26: 59 - 67.

Kaiser M. J. 1998. Significance of Bottom-Fishing Disturbance. Conservation Biology, Vol. 12: 1230–1235.

Kaiser M. J., B. E. Spencer. 1996. Behavioural responses of scavengers to beam trawl disturbance. En: Greenstreet SPR, ML Tasker (eds) Aquatic predators and their prey, Liverpool University Press, Liverpool, pp 169- 218.

Krebs, C. J. 1989. Ecologycal methodology. Harpercollins Publishers Inc. NY.

Lambshead, P.J.D, H.M. Platt and K.M.Shaw. 1983. The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. Journal of Natural History, Vol. 17: 859-874.

Lértora H. P., Spina M. F., Godelman E. and Fernández M. S. 2009. Rol de la saraca Brevoortia aurea en el ecosistema costero del Partido de La costa, Provincia de Buenos Aires (Argentina). Jornadas Nacionales de Ciencias del Mar (Bahía Blanca, Argentina).

Lindeboom H. J. and S. J. Groot (1998). The Effects of Different Types of Fisheries on the North Sea and Irish Sea Benthic Ecosystems. Niozrapport 1998-1, RIVO-DLO Report C003/98.

McManus J. W. and Pauly D. 1990. Measuring ecological stress: variations on a theme by R. M. Warwick. Marine Biology, Vol. 106: 305 – 308.

Otero H. (ed). 1992. Frente Marítimo. Volumen 10.. Comisión Técnica Mixta del Frente Marítimo.

Rice, J. C. 2000. Evaluating fishery impacts using metrics of community structure. Journal of Marine Science, Vol. 57: 682–688.

Watling L. and Elliott A.N. 1998. Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. Conservation Biology, Vol. 12: 1180 – 1197.

Warwick R. M. 1986. A new method for detecting pollution effects on marine macrobenthic communities. Mar. Biol., Vol. 92: 557 – 562.

Warwick R. M. 2008. Abundance Biomass Comparison Method. In: Jørgensen, S E (ed). Encyclopedia of Ecology. Elsevier, Oxford: 11–15.

Yemane, D., Field, J. G., and Leslie, R. W. 2005. Exploring the effects of fishing on fish assemblages using Abundance Biomass Comparison (ABC) curves. ICES Journal of Marine Science, Vol. 62: 374 - 379.

Links:

(1) Dirección Provincial de Pesca (DDP): http://www.maa.gba.gov.ar/pesca/