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Benthic macroinvertebrate bycatch in the snail *Zidona dufresnei* (Donovan) fishery from the Uruguayan continental shelf

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Abstract. The benthic macroinvertebrate fauna associated with the fishery of "caracol fino" *Zidona dufresnei* (Mollusca, Gastropoda) was analysed during three fishery cruises in the Uruguayan continental shelf. Species composition, richness, diversity and qualitative dominance were estimated from the examination of the bycatch of 172 fishing hauls using a double bottom otter trawl. In the Uruguayan Atlantic waters 55 species of macroinvertebrates were associated with *Z. dufresnei*, being molluscs and crustaceans the dominant taxa in species number and frequency of occurrence. Two gastropods (*Adelomelon beckii* and *Tonna galea*), two decapod crustaceans (*Libinia spinosa* and *Propagurus gaudichaudii*), one asteroid (*Astropecten brasiliensis*), and one Actiniaria ind. were the most representative species in the "caracol fino" bycatch. Further studies considering unexplored bathymetric gradients are strongly recommended, they will help to fill our current gap in the knowledge of the macrobenthic diversity in the Uruguayan continental shelf.

Key words: Benthic macrofauna, fauna associated, diversity, qualitative dominance, Uruguay.

Resumen. Captura incidental de macroinvertebrados bentónicos en la pesquería de caracol fino *Zidona dufresnei* en la plataforma continental uruguaya. La fauna de macroinvertebrados bentónicos asociada a la pesquería de "caracol fino" *Zidona dufresnei* (Mollusca, Gastropoda) en la plataforma continental uruguaya fue estudiada en base a tres cruceros de pesca. Se determinó la composición y riqueza específica, diversidad y dominancia cualitativa mediante el análisis de 172 lances efectuados con red de arrastre de fondo. Se registraron 55 especies de macroinvertebrados asociadas a *Z. dufresnei* en el Atlántico uruguayo, resultando los moluscos y los crustáceos los *taxa* dominantes en número y frecuencia de ocurrencia. Dos gasterópodos (*Adelomelon beckii* y *Tonna galea*), dos crustáceos decápodos (*Libinia spinosa* y *Propagurus gaudichaudii*), un asteroideo (*Astropecten brasiliensis*), y un Actiniaria ind. fueron las especies más representativas en el *bycatch* del "caracol fino". Se recomienda considerar nuevos gradientes batimétricos a los efectos de profundizar en el conocimiento de la diversidad macrobentónica en la plataforma continental uruguaya, en futuros estudios.

Palavras Clave: Macrofauna bentónica, fauna asociada, diversidad, dominancia cualitativa, Uruguay.

Introduction

Bottom trawling and the use of other active fishery techniques disrupt marine bottoms in the same way as logging affects forest ecosystems. Although it is easy to recognize the effects of deforestation on biological diversity and economic sustainability, concern for the loss of marine benthic habitats as a result of fishery is far less common. In fact, it was not until the middle of 1980's that marine biologists started to foresee the potential effects of the generalized disturbance of the sea floor due to the growth in number and capacity of the fleet of bottom trawlers (Watling & Elliot 1998).

Unrestricted fishery has different impacts on marine ecosystems. Fishery has direct effects on target species, reducing populations and stocks, affecting body size composition, and in some cases spawning biomass. Moreover, it has also indirect effects on predator-prey interactions, modifying community structure, even generating temporal alternative states. A genetic selection of certain size classes and reproductive characteristics can also be promoted, reducing or removing local stocks. Two additional indirect perturbations associated with the fishery are the bycatch or mortality of non-target species, and the reduction of habitat complexity, particularly by bottom trawling (Kaiser *et al*. 2001).

Coastal macrobenthic communities are ecologically and economically important. They provide a number of ecological services to mankind, not restricted to their role in the nutrient and organic matter recycling and as supporting biomass for fishes (Caddy 1989).

Given their relevance, identification of priority areas for marine conservation is critical, and in order to do so, basic knowledge on macrobenthic diversity is essential (Costello 1998). Exploratory studies on macrobenthic spatial patterns will contribute to a more responsible use of the marine environment (Van Hoey *et al*. 2004). Unfortunately, large portions of the coastal sea-bed, particularly in the Southern Hemisphere, remain poorly described, even in aspects as basic as species composition and habitat associations. The knowledge on faunal composition at the continental shelf will facilitate the prediction of potential impacts resulting from the development and growth of demersal fisheries, and will help to identify species potentially important from a socio-economic point of view.

Although several studies have described benthic communities in the South Atlantic region (Buckup & Thomé 1962, Olivier *et al*. 1968, Escofet *et al*. 1978, Roux *et al*. 1993, Capitoli 1996, Klein *et al*. 2001, Giberto *et al*. 2004), studies focusing on the benthic associations in the Uruguayan shelf are rather scarce (Juanicó & Rodríguez-Moyano 1975, Milstein *et al*. 1976, Riestra 2000). Most of these previous studies focused on specific groups such as molluscs (Olivier & Scarabino 1972, Scarabino 1973, Layerle & Scarabino 1984), decapod crustaceans (Itusarry 1984), echinoderms (Barattini 1938, Bernasconi 1966, Lucchi 1985) and polychaetan annelids (Faget 1983). The focus of this study encompasses an array of these invertebrates, analyzing the benthic macroinvertebrates associated with the marine gastropod *Zidona dufresnei* (Donovan, 1823), a volutid snail locally known as "caracol fino", an important fishery resource in the Uruguayan continental shelf.

Materials and Methods

Study Area

The study was carried out in the north-eastern zone of the Uruguayan continental shelf, between 34º20' - 35º22' Lat S and 52º47' - 54º53' Long W, which represents the most important fishing grounds for *Zidona dufresnei* in Uruguay (DINARA 1997). The snail's fishing area is 30 to 70 m deep (Fig. 1), with sandy, muddy, and occasionally rocky bottoms. This zone is influenced by the Malvinas and Brazil currents, plus a significant flow of fresh water from the Río de la Plata, which results in a peculiar hydrographical system (Guerrero & Piola 1997, Ortega & Martínez 'in press').

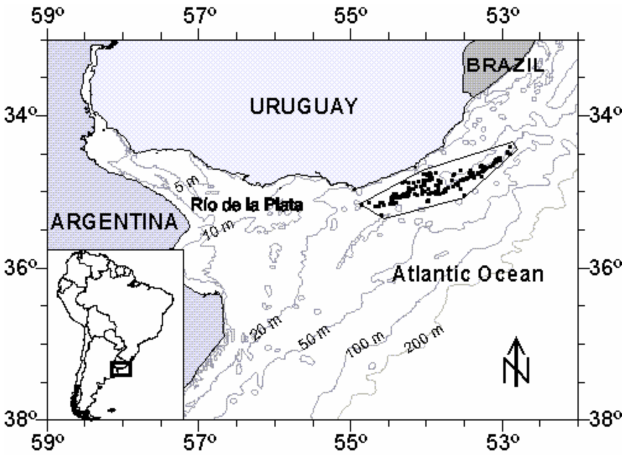

Figure 1. Portion of the Uruguayan continental shelf where fishing operations were carried out.

Sampling and laboratory methods

A total of 172 fishing hauls were undertaken during three commercial fishing trips (September and November 2000, and May 2001), with scientific observers from the National Direction of Aquatic Resources (DINARA) on board (Fig. 1). Commercial outrigger trawlers, rigged to tow one bottom otter trawl on each outrigger, were used in the three fishing trips where benthic macroinvertebrate samples were taken (FAO 2005). The trawls employed in the *Z. dufresnei* fishery had a 100 mm mesh size between opposed knots, a mouth framed by a headline with floats providing a maximum vertical opening of 1.5 m and a ground gear with chains, designed according to the bottom condition to maximize the catches and protect the gear from damage.

Samples of the benthic macroinvertebrate bycatch were taken along each one of the three campaigns and from each fishing haul, labelled and fixed in 10% formaldehyde. Afterwards, in the laboratory, the organisms collected were identified to the lowest possible taxonomic level, in most of the cases to species level. Sampling location (GPS), depth, speed and tow's duration were also registered for each fishing haul. The total swept area (square nautical miles: nm^2) in each campaign was calculated using the vessel speed, the maximum horizontal gear opening and the duration of each trawl.

Data analyses

Mean species richness (Sm) for each trip was obtained from the species richness of each haul, based on the number of benthic macroinvertebrate species obtained. Mean diversity (Shannon-Weaver 1979: H'm) for each campaign was also calculated, using the diversity of each haul. A Chi-square test (χ^2) was performed to test for differences in Sm and H'm between fishing trips (Zar 1999).

The relative importance of the different species in the three trips combined was assessed using Qualitative dominance (Bouderesque 1971) according to the frequency of occurrence (%). Five categories were defined by this author: occasional (0-20%), scarce (21-40%), common (41-60%), abundant (61-80%) and very abundant (81-100%).

Based on the presence-absence species matrix, and employing a Similarity Coefficient (Q-mode), the similarity between species was calculated for each trip. An Unweighted Pair Group Method for Arithmetic averages (UPGMA) (Legendre & Legendre 1979) was applied as a technique of average linking.

Results

The mean duration of campaigns was 13 days, with a maximum number of fishing hauls in September and May (59 hauls) and a minimum in November (54 hauls). Mean haul duration (± SE) was shorter in May (3.14 ± 0.12 hours) than in November (3.38 ± 0.49 hours) and September (3.45 ± 0.46 hours). The shortest (1.00 hour) and the longest (4.35 hours) hauls occurred in May. However, mean haul speed (± SE) was faster in November (3.1 ± 0.13 knots) than in May (2.8 ± 0.08 knots) and September (2.8 ± 0.15 knots). The bottom swept area was larger in November (6.9 nm^2) than in May (5.9 nm^2) and September (5.8 nm^2).

Bycatch

The macroinvertebrate bycatch associated with the snail *Zidona dufresnei* fishery in the Uruguayan continental shelf included 55 species (data of all trips combined). These species belong to 5 phyla (Table I and II): mollusks (45%) and arthropods (36%) were the most represented, followed by echinoderms (7%), cnidarians (7%) and annelids (6%).

Species richness and diversity

The total number of species (S) identified in September 2000 (S = 33 species) was larger than in November 2000 (S = 31 species) and May 2001 (S = 25 species). However, the total number of species, the mean species richness and the mean diversity did not differ significantly among campaigns (Table II).

Qualitative dominance

Based on data of the three campaigns combined, the very abundant category was composed of the exploited target species *Z. dufresnei* (98%), *Libinia spinosa* Milne-Edwards, 1834 (89%) and *Adelomelon beckii* (Broderip, 1836) (87%). *Tonna galea* (Linnaeus, 1758), *Propagurus gaudichaudii* Milne-Edwards, 1836, Actiniaria ind. and *Astropecten brasiliensis* Müller & Troschel, 1842, were abundant, 4 species were common, 7 were scarce and 37 were occasional (Table III). Other species with very low occurrence (scarcely present in one haul), were not considered for this analysis: *Astrangia rathbuni* Vaughan, 1906, *Aequipecten tehuelchus* d'Orbigny, 1842, *Lithophaga patagonica* (d'Orbigny, 1842), *Pododesmus rudis* (Broderip, 1834), *Pteria hirundo* (Linnaeus, 1758), *Transenpitar americana* (Doello-Jurado, 1951), *Bostrycapulus aculeatus* (Gmelin, 1791), *Crepidula* sp., *Polystira formosissima* (E. A. Smith, 1915), Balanidae ind., *Heterosquilla platensis* (Berg, 1900), *Corystoides chilensis* Lucas, 1844, *Leucippa pentagona* Milne-Edwards, 1833, *Ovalipes trimaculatus* (De Haan, 1933), *Pinnotheres* sp. and *Portunus spinicarpus* (Stimpson, 1871).

Similarity

Based on the cluster analysis, the highest similarity (> 93%) was found between *Z. dufresnei*, *L. spinosa* and *A. beckii* for both September (Fig. 2a) and November (Fig. 2b) campaigns. However, in May 2001, the highest similarity (90%) was found between the fishing target species and *T. galea* (Fig. 2c). Considering a level of similarity

Table I - Species composing of the benthic macroinvertebrate bycatch of the snail *Zidona dufresnei* fishery in the Uruguayan continental shelf.

Phylum Cnidaria
- Class Anthozoa
  - Alcyonaria ind.
  - *Antholoba achates* (Drayton, 1846)
  - *Astrangia rathbuni* Vaughan, 1906
  - *Phlyctenanthus australis* Carlgren, 1950

Phylum Annelida
- Class Polychaeta
  - *Aphrodita longicornis* Kingberg, 1855
  - *Phyllochaetopterus socialis* Claparède, 1870
  - Polychaeta ind.

Phylum Mollusca
- Class Polyplacophora
  - *Chaetopleura angulata* (Spengeler, 1797)
- Class Bivalvia
  - *Aequipecten tehuelchus* d'Orbigny, 1842
  - *Corbula patagonica* d'Orbigny, 1846
  - *Ennucula uruguayensis* (E.A. Smith, 1885)
  - *Lithophaga patagonica* (d' Orbigny, 1842)
  - *Mytilus edulis* Linnaeus, 1758
  - *Ostrea puelchana* d' Orbigny, 1842
  - *Panopea abbreviata* Valenciennes, 1839
  - *Pitar rostratus* (Koch, 1844)
  - *Pododesmus rudis* (Broderip, 1834)
  - *Pteria hirundo* (Linnaeus, 1758)
  - *Trachycardium muricatum* (Linnaeus, 1758)
  - *Transenpitar americana* (Doello-Jurado, 1951)
- Class Gastropoda
  - *Adelomelon beckii* (Broderip, 1836)
  - *Adelomelon brasiliana* (Lamarck, 1811)
  - *Buccinanops cochlidium* (Dillwyn, 1817)
  - *Bostrycapulus aculeatus* (Gmelin, 1791)
  - *Crepidula* sp.
  - *Cymatium parthenopeum* (von Salis, 1793)
  - *Polystira formosissima* (E.A. Smith, 1915)
  - *Prunum martini* (Petit, 1853)
  - *Tonna galea* (Linnaeus, 1758)
  - *Zidona dufresnei* (Donovan, 1823)
- Class Cephalopoda
  - *Loligo sanpaulensis* Brakoniecki, 1984
  - *Octopus tehuelchus* d' Orbigny, 1834

Phylum Echinodermata
- Class Asteroidea
  - *Asterina stelliffer* (Möbius, 1859)
  - *Astropecten brasiliensis* Müller & Troschel, 1842
  - *Luidia* sp.
- Class Ophiuroidea
  - Ophiuroidea ind.

Phylum Arthropoda
- Class Crustacea
  - Balanidae ind.
  - *Callinectes sapidus* Rathbun, 1896
  - *Corystoides chilensis* Lucas, 1844
  - *Farfantepenaeus paulensis* (Pérez-Farfante, 1967)
  - *Hepatus pudibundus* (Herbst, 1785)
  - *Heterosquilla platensis* (Berg, 1900)
  - *Leucippa pentagona* Milne-Edwards, 1833
  - *Leurocyclus tuberculosus* Milne-Edwards & Lucas, 1842
  - *Libinia spinosa* Milne-Edwards, 1834
  - *Metanephrops rubellus* (Moreira, 1905)
  - *Ovalipes trimaculatus* (De Haan, 1933)
  - *Propagurus gaudichaudii* Milne-Edwards, 1836
  - *Peltarion spinosulum* (White, 1843)
  - *Persephona mediterranea* (Herbst, 1794)
  - *Pinnotheres* sp.
  - *Platyxanthus crenulatus* Milne-Edwards, 1879
  - *Platyxanthus patagonicus* Milne-Edwards, 1879
  - *Pleoticus muelleri* (Bate, 1888)
  - *Portunus spinicarpus* (Stimpson, 1871)
  - *Scyllarides deceptor* Holthuis, 1963

of 80%, the Actiniaria ind. and *Buccinanops cochlidium* were added to the original group, and an association between *Octopus tehuelchus* and *A. brasiliensis* appeared in September 2000 (Fig. 2a). *Propagurus gaudichaudii*, *Pitar rostratus*, *T. galea*, *Ostrea puelchana* and *A. brasliensis* were included in the initial similarity group in November 2000 (Fig. 2b), and *P. gaudichaudii* and *L. spinosa* were incorporated to the initial group in May 2001 (Fig. 2c). Considering a 60% similarity level, the same seven species were associated in the three campaigns: *Z. dufresnei*, *A. beckii*, *T. galea*, *L. spinosa*, *P. gaudichaudii*, *A. brasiliensis* and Actiniaria ind. (Figs. 2 a, b and c).

Discussion

Some methodological constraints must be considered before the discussion of the results. The objective of the fishing campaigns and mainly the sampling procedure employed, which only caught large macroepifauna (> 50 mm), not allow a comparison with previous studies in the region.

The 55 species of benthic macro-invertebrates that form the bycatch of the snail *Z. dufresnei*'s fishery on the Uruguayan continental shelf represent a lower species richness than for other areas of the Southeastern Atlantic region already described, such as the southern Brazilian Atlantic littoral (Klein *et al.* 2001), the Rio de la Plata estuary and adjacent shelf

Table II - Mean species richness (Sm ± SE), mean diversity (H'm ± SE), associated χ^2 test statistics, and phyla composition (%) of the bycatch of the three fishing campaigns.

		Sep 2000	Nov 2000	May 2001
Mean species richness		12 ± 3.6	11 ± 2.5	9 ± 2.9
		χ^2 = 1.17; *P* = 0.56		
Mean diversity		2.5 ± 0.3	2.3 ± 0.3	2.2 ± 0.3
		χ^2 = 0.02; *P* = 0.99		
Phyla composition	Mollusca	43	46	52
	Arthropoda	33	32	28
	Echinodermata	9	13	8
	Annelida	9	6	8
	Cnidaria	6	3	4

waters (Giberto *et al*. 2004), and the Mar del Plata (Argentina) region (Roux *et al*. 1993). It must be taken into account that the lack of previous studies in the region, regarding the macrobenthic bycatch in the *Z. dufresnei*'s fishery, does not allow an adequate comparison. Nevertheless, the Shannon-Weaver diversity index obtained for the Uruguayan continental shelf was in agreement with those documented for the Argentinean zone (Roux *et al*. 1993, Roux & Bremec 1996).

The macroinvertebrate community defined as the bycatch of the *Z. dufresnei*'s fishery showed faunal components of warm-temperate (e.g., *H. platensis*, *L. pentagona* and *P. muelleri*) and cold-temperate regions (e.g., *P. gaudichaudii* and *P. spinosulum*) (Boschi *et al*. 1992). This could be explained by the convergence of different water masses with contrasting thermohaline that characterize the Uruguayan continental shelf (Ortega & Martínez 'in press'). Tropical Water carried southward by the Brazil Current (Sverdrup *et al*. 1942), Subantarctic Water advected northwards by the Malvinas Current (Bianchi *et al*. 1993) and Coastal Waters mainly from the Rio de la Plata estuary, result in this peculiar hydrographical system (Guerrero & Piola 1997, Ortega & Martínez 'in press').

The highest qualitative dominance values corresponding to molluscs and crustaceans are in agreement with those found for the Argentinean and Brazilian continental shelves (Bastida *et al*. 1992, Roux *et al*. 1993, Roux & Bremec 1996, Bremec & Roux 1997, Klein *et al*. 2001), although those authors used different sampling methods.

To characterize the macrobenthic invertebrates associated with the snail *Z. dufresnei* in the Uruguayan continental shelf, six species with a coefficient of similarity higher than 60% were chosen: two gastropod molluscs (*A. beckii* and *T. galea*), two decapod crustaceans (*L. spinosa* and *P. gaudichaudii*), one asteroid echinoderm (*A. brasiliensis*) and one Actiniaria ind. These results agree partially with those of Buckup & Thomé (1962), who considered *Z. dufresnei*, *L. spinosa* and *Adelomelon brasiliana* as very frequent species in the Rio Grande do Sul continental shelf (Brazil) between 20 and 50 m deep. In the present study, *A. brasiliana* did not follow that association, being classified as an occasional species.

Despite *L. spinosa* and the hermit crab *Dardanus arrosor insignis* were documented as very frequent species for that zone by Itusarry (1984), only the first one was founded in our study. The unexpected absence of this hermit crab could be partially ascribed to a potential error in the identification of the hermit crabs. In the other hand, the frequent occurrence of A. brasiliensis is in agreement with the results of Juanicó & Rodríguez-Moyano (1975) for the south-eastern zone of La Paloma (Rocha, Uruguay), where it was the second faunal component, only preceded by *Mytilus edulis*, between 35 and 50 m deep. This asteroid was also very well represented in the *Euvola ziczac* shell banks at the Brazilian south coast (20 to 50 m depth) (Klein *et al*. 2001). The very low frequency obtained for *Mytilus platensis*, *Lithophaga patagonica*, *Bostrycapulus aculeatus*, and *Chaetopleura isabellei* could be explained by the fact that these species are highly associated with hard bottoms (Roux *et al*. 1993), where the Uruguayan *Z. dufresnei* fishery does not operates.

A biological association between the snail *B. cochlidium* and the actinian *Phlyctenanthus australis*, described by Pastorino (1993) for Patagonian coastal waters (Argentina), was also observed in our study. Other associations that were

Table III - Qualitative Dominance (%) (Bouderesque, 1971) of each species and their corresponding phylum: (A) Arthropoda, (An) Annelida, (C) Cnidaria, (E) Echinodermata, (M) Mollusca.

Category	Species	Phylum	Qualitative dominance (%)
Very Abundant	*Zidona dufresnei*	M	98.3
	Libinia spinosa	A	89.2
	Adelomelon beckii	M	86.6
Abundant	*Tonna galea*	M	74.7
	Propagurus gaudichaudii	A	74.0
	Actiniaria ind.	C	71.0
	Astropecten brasiliensis	E	68.1
Common	*Buccinanops cochlidium*	M	56.3
	Aphrodita longicornis	An	55.4
	Platyxanthus crenulatus	A	48.8
	Octopus tehuelchus	M	43.1
Scarce	*Pitar rostratus*	M	39.4
	Asterina stellifer	E	35.8
	Platyxanthus patagonicus	A	33.5
	Phyllochaetopterus socialis	An	33.1
	Leurocyclus tuberculosus	A	31.5
	Ostrea puelchana	M	24.6
	Farfantepenaus paulensis	A	23.1
Occasional	*Loligo sanpaulensis*	M	17.2
	Cymatium parthenopeum	M	13.6
	Metanephrops rubellus	A	11.6
	Mytilus edulis	M	10.0
	Peltariom spinosulum	A	9.6
	Chaetopleura angulata	M	8.9
	Luidia sp.	E	6.2
	Adelomelon brasiliana	M	5.5
	Panopea abbreviata	M	4.9
	Trachicardium muricatum	M	4.0
	Ophiuroidea *ind.*	E	3.1
	Persephona mediterranea	A	2.4
	Ennucula uruguayensis	M	1.7
	Ovalipes trimaculatus	A	1.7
	Pleoticus muelleri	A	1.7
	Polychaeta ind.	An	1.2
	Alcyonaria ind.	C	1.1
	Astrangia rathbuni	C	0.6
	Aequipecten tehuelchus	M	0.6
	Balanidae ind.	C	0.6
	Bostrycapulus aculeatus	M	0.6
	Callinectes sapidus	A	0.6
	Corbula patagonica	M	0.6
	Crepidula sp.	M	0.6
	Corystoides chilensis	C	0.6
	Hepatus pudibundus	A	0.6
	Heterosquilla platensis	A	0.6
	Leucippa pentagona	C	0.6
	Lithophaga patagonica	M	0.6
	Pinnotheres sp.	C	0.6
	Pododesmus rudis	M	0.6
	Polystira formosissima	M	0.6
	Portunus spinicarpus	C	0.6
	Prunum martini	M	0.6
	Pteria hirundo	M	0.6
	Transenpitar americana	M	0.6
	Scyllarides deceptor	A	0.6

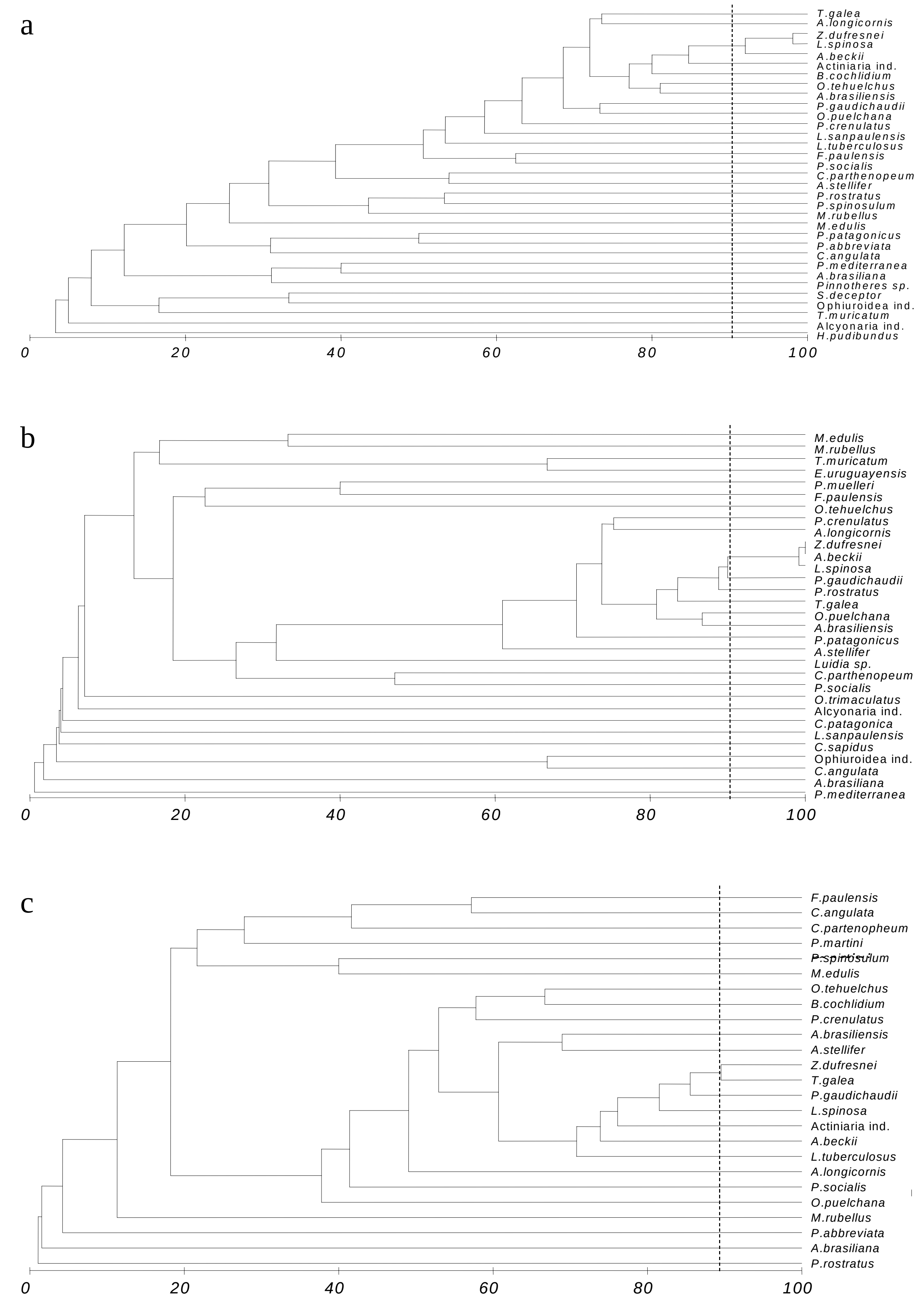

Fig. 2 - Species dendrogram (UPGMA). Dotted vertical line represents the 90% of similarity between species: a) September 2000, b) November 2000 and c) May 2001.

already observed for Argentinean waters were also found in the Uruguayan continental shelf: *A. brasiliana* and the actinia *Antholoba achates* (Luzzatto & Pastorino 2006) and *Libinia spinosa* with *A. achates* (Acuña *et al*. 2003).

Even if in the last years the number of vessels in the fishery of "caracol fino" has substantially diminished, the fishery is still open and the bottom is still heavily trawled. Fishing gears alters seafloor habitats and understanding the extent of these impacts, and the effects on populations of living marine resources, is needed to properly manage current and future levels of fishing effort (Auster *et al*. 1996). The knowledge of the macroinvertebrate diversity results essential for a sustainable fisheries management and the development of potentially valuable resources. Because of the lack of pristine sites, where the use of active fishing is prohibited, no empirical studies that could demonstrate population level effects of bottom trawling, have been conducted so far. If marine fisheries management is to evolve toward an ecosystem or habitat management approach, experiments are required on the effects of habitat change, both anthropogenic and natural (Auster *et al*. 1996). According to the current gap in the knowledge of macrobenthic diversity in the Uruguayan continental shelf, further investigations concerning unexplored bathymetric gradients with systematic samplings and experiments are strongly recommended.

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