Fisheries Research 110 (2011) 149–159

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Species composition and bycatches of a new crustacean trawl in Chile

Dante Queirolo[a,*], Karim Erzini[b], Carlos F. Hurtado[a], Erick Gaete[a], Milagrosa C. Soriguer[c]

[a] Escuela de Ciencias del Mar, Facultad de Recursos Naturales, Pontificia Universidad Católica de Valparaíso, P.O. Box 1020, Avenida Altamirano 1480, Valparaíso, Chile
[b] Centro de Ciências do Mar (CCMAR), Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal
[c] Departamento de Biología, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Avda. República Saharahui, 11510 Puerto Real, Cádiz, Spain

ARTICLE INFO

Article history:
Received 18 November 2010
Received in revised form 15 March 2011
Accepted 3 April 2011

Keywords:
Crustacean trawl
Catch composition
Bycatch
Chile

ABSTRACT

The species composition and bycatches of a new trawl for crustaceans (*Heterocarpus reedi*, *Cervimunida johni* and *Pleuroncodes monodon*) was studied in central Chile between 2007 and 2009. The spatial and temporal variations of the catch composition were analyzed using univariate and multivariate comparison techniques. In 289 trawl hauls, 72 taxa were recorded, with target species accounting for most of the catch, while the bycatch consisted mainly of *Merluccius gayi*, *Hippoglossina macrops*, *Coelorinchus aconcagua*, *Epigonus crassicaudus* and *Platymera gaudichaudii*. 14 species of elasmobranchs were identified, and at least one of these species was present in 50% of the hauls made. The classification and ordination methods showed the existence of three groups, each one associated with a target species, with no significant spatial and temporal effects. The information obtained in this study represents the basis for setting targets in order to reduce the bycatch captured by this trawl. The focused strategy on the most recurring and sensitive species for these fisheries is also discussed.

1. Introduction

The incidental catch of non-target species (termed as "bycatch") represents 40.4% of the total marine catch (Davies et al., 2009) and largely determines the catch that is thrown away at sea ("discards"). Kelleher (2005) estimated the fishery discards at more than 7 million tons, of which 27% corresponds to discarding in shrimp trawl fisheries. Thus, the bottom trawl fisheries, particularly those of crustaceans, are characterized by selectivity problems due to the diversity of species affected. Although the bycatches are generally unavoidable (Borges et al., 2001), it is possible to use technological solutions to effectively reduce it. For this, Kennelly and Broadhurst (2002) note that the quantification of bycatch and identification of the main bycatch species of concern are key steps to successfully address this issue.

Many studies have dealt with the bycatch in fisheries (Andrew and Pepperell, 1992; Kennelly, 1995; Hall et al., 2000), with a special interest in some groups of sensitive species like elasmobranchs (Stobutzki et al., 2002; Carbonell et al., 2003; Coelho and Erzini, 2008; Baeta et al., 2010). Although these species may not occur commonly, it may be difficult to take mitigating measures (Hall, 1996; Hall et al., 2000). In many cases, especially in crustacean trawl fisheries, the problem is that the bycatch represents the highest proportion of the catch (Saila, 1983; Andrew and Pepperell, 1992; Stobutzki et al., 2001; Manjarrés et al., 2008; Tonks et al., 2008; Góngora et al., 2009).

Nylon shrimp (*Heterocarpus reedi*, Bahamonde, 1955), yellow squat lobster (*Cervimunida johni*, Porter, 1903), and red squat lobster (*Pleuroncodes monodon*, Milne Edwards, 1837) are exploited by trawl fisheries along a large part of the Chilean coast (26° and 38° S). Overall, the annual catch quota for these resources amounts to 10,550 ton (D.E. SUBPESCA No. 1675/2008). Zilleruelo et al. (2007) report that the bycatches of these fisheries are, respectively, 23, 10 and 8%, with *Merluccius gayi* the species accounting for the largest proportion. However, the overall number of species present in the catch is high, with 149 taxa identified by Acuña et al. (2005) in hauls made between 1994 and 2004.

It is a fact that worldwide trawl fisheries are being pressured to demonstrate a higher ecological sustainability (Tonks et al., 2008). This represents a big challenge, in particular to those fisheries where catches are characterized by a wide range of species. In this context, construction deficiencies (thick twines, heavy materials, and small meshes) determine a poor performance of traditional trawl nets used in crustacean fisheries in Chile (Melo et al., 2008), so a new design has been requested by the authority (Undersecretariat of Fisheries) and is under evaluation. In order to direct future studies of bycatch mitigation of the new trawl, the current study

* Corresponding author. Present address: Centro Andaluz de Ciencia y Tecnología Marinas (CACYTMAR), Universidad de Cádiz, Campus Río San Pedro, 11510 Puerto Real, Cádiz, Spain. Tel.: +34 956016290; fax: +34 956016747.
E-mail address: dante.queirolo@ucv.cl (D. Queirolo).

0165-7836/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.fishres.2011.04.001

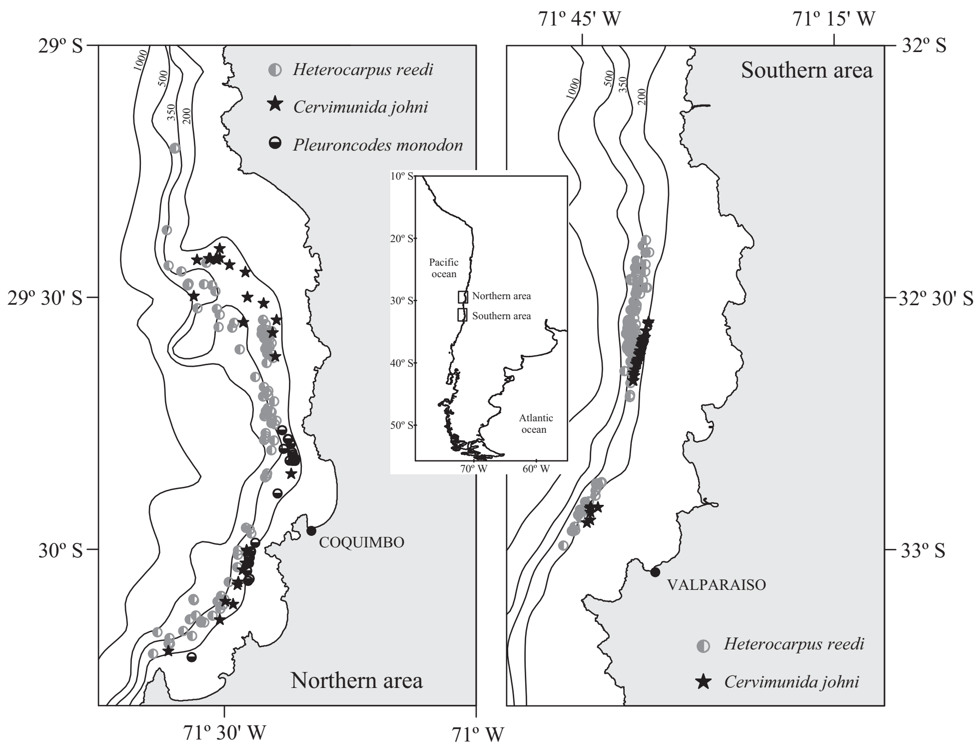

Fig. 1. Fishing areas and tow locations.

was undertaken to (i) quantify the bycatches, and (ii) identify the main bycatch species of concern in three crustaceans trawl fisheries of Chile.

2. Materials and methods

A total of 289 hauls were made in two traditional areas of fleet operation in central Chile (Fig. 1); (a) between 29°12′ and 30°14′ S (northern area), and (b) 32°23′ and 33°00′ S (southern area), during 32 fishing trips, during three periods (spring 2007, winter-spring 2008 and winter 2009). Hauls were made during day time from 7:00 to 19:00 at depths between 140 and 450 m (Table 1). Depending on the three target species, each fisherman decided the fishing area according to season, depth, bottom type and the results of recent hauls. The duration of each haul varied between 0.4 and 2.5 h while trawl speed fluctuated between 1.7 and 2.3 knots depending on weather conditions and sea bottom features. Six vessels of the commercial fleet were utilized in order to achieve a better representativeness of the results. These vessels, which represent 30% of the total fleet, have an engine power that ranges from 325 to 450 HP. All vessels used basically the same design and trawl configuration, which consists of a net with two panels of 28.8 m headrope and 32 m footrope with sweeps and bridles of 1 and 5 m, respectively. The nets were made of knotted polyethylene (PE); 80 mm mesh size on the upper panel (72 mm inner mesh size), 54 mm in the lower panel (47 mm inner mesh size) and 56 mm at the codend (47 mm inner mesh size) (Fig. 2). This net was described and its performance tested by Melo et al. (2008) and Queirolo et al. (2009a).

The catch of each haul was quantified and identified to the lowest possible taxonomical level. In several cases the catch of small species was large, requiring sub-sampling to estimate the number of individuals. The total weight of each species was obtained as the product of the number and the average weight of standard trays (55 cm × 40 cm × 25 cm). The relative contribution of each taxa (number and weight) was determined according to the total catch and the bycatch. In the same way, the average catch rate per hour was determined. In this case, the relationship between the operation area and the year was analyzed using a two-factor ANOVA ($\alpha = 0.05$).

Univariate and multivariate analyses of the catch composition were made following the approaches of Stergiou and Pollard (1994), Stergiou et al. (2002), Labropoulou and Papaconstantinou (2004), and Stergiou et al. (2006). Clustering (average groups) was based on the Bray–Curtis similarity index (Field et al., 1982) applied to overall abundance and biomass data taking into account the 15 combinations of target species, year and area. The data were standardized according to the duration of the haul and square root transformed in order to avoid over-dispersion. Furthermore, multidimensional scaling (MDS) was used for ordination analysis with the same data used in the cluster analysis. In order to verify the accurate presentation in two dimensions, the stress rate was used as a contrast. Here, values lower than 0.1 mean a good data representation (Carr, 1997). *K*-Dominance curves (Lambshead et al., 1983), based on catch numbers and weights, were used as a graphical representation of the percentage cumulative abundance (*y*-axis) and the species rank in logarithmic scale (*x*-axis).

The catch composition of each haul was analyzed by using the following parameters: taxa number (S), abundance ($n\,h^{-1}$), dominance (λ), species diversity (H'), evenness (J'), and richness (d). The dominance was expressed through Simpson index (Krebs, 1989):

$$\lambda = \sum p_i^2$$

the species diversity through the Shannon–Wiener index (Hurlbert, 1978):

$$H' = -\sum_{i=1}^{S} p_i \log_2(p_i)$$

Table 1
Haul summary information. The values in the parentheses show the standard deviation.

Target species	Hauls (*n*)		Mean depth (m)		Mean haul duration (h)	
	North	South	North	South	North	South
Heterocarpus reedi	98	100	355 (56.8)	327 (63.6)	1.54 (0.83)	1.03 (0.72)
Cervimunida johni	30	35	264 (43.7)	211 (22.7)	1.16 (0.69)	0.59 (0.41)
Pleuroncodes monodon	26		185 (44.3)	–	0.91 (0.45)	–
Total	154	135	309 (84.3)	297 (75.7)	1.36 (0.79)	0.92 (0.68)

the evenness (Pielou, 1966):

$$J' = \frac{H'}{\log(S)}$$

and species richness through (Margalef, 1968):

$$d = \frac{S-1}{\ln N}$$

Here, p_i is the proportion of the total sample belonging to the *i*th species, and *N* is the number of individuals of the total sample. Before using parametric tests for the analysis, the normality of data was analyzed through the Kolmogorov–Smirnov test and the homocedasticity through the Levene test. In the cases where data did not meet the required assumptions, it was $\log(x+1)$ transformed (Sokal and Rohlf, 1981). Subsequently, analysis of the variance was carried out in order to determine possible differences of the indexes used according to the target species of the catch. In this case, the Fisher test was used to identify the least significant differences (LSD).

The analyses of diversity, clustering, non metric multidimensional scaling and *K*-dominance curves indexes were done using the PRIMER algorithms (Plymouth Marine Laboratory), while statistical analyses were carried out using the SPSS v11.0 software.

3. Results

The total catch in 289 hauls, equivalent to 333 h of trawling, was 199,041 kg and 14,024,914 individuals from 72 taxa (35 families), with 47 taxa identified to the species level (Table 2, Appendix A). The Galatheidae and Pandalidae families represented 82% by weight and 97% in number. In general, 20% of the taxa represented more than 90% of the bycatch in number and weight, with the teleostei families Epigonidae, Macrouridae, Merlucciidae and Paralichthyidae accounting for the highest proportion (Table 2).

In northern area, the contributions of teleostei, invertebrates, elasmobranchs, and myxini to the bycatch were 89.0, 9.5, 1.3 and 0.2%, respectively. The families Merlucciidae, Paralichthyidae, Calappidae, and Epigonidae represented the 95% of the total. If we consider the number of individuals in the bycatch, the highest contribution was teleostei (82.5%), followed by invertebrates (17.1%), while elasmobranchs (0.3%) and myxini (<0.1%) contributed small proportions.

In the southern area, the contributions of teleostei, invertebrates, elasmobranchs and myxini were 83.2, 9.6, 7.1 and 0.1%, respectively. The Merlucciidae, Macrouridae, Paralichthyidae, Ommastrephidae, and Epigonidae families accounted for 90% of the total bycatch. In numbers, bycatch was dominated by teleostei (86.9%), with smaller contributions by invertebrates (12.4%), elasmobranchs (0.6%), and myxini (<0.1%) (Table 2).

In 198 hauls targeting *H. reedi*, a total of 60 taxa were registered. In the northern area, the total number of taxa was 36, with 15 invertebrates, 11 teleostei, 9 elasmobranchs and 1 myxini. In the southern area the number of taxa increases to 59, with 23 invertebrates, 19 teleostei, 16 elasmobranchs and 1 myxini (Table 3). The target species represented 76.1% and 73.4% of the total catch in weight of northern and southern areas, respectively

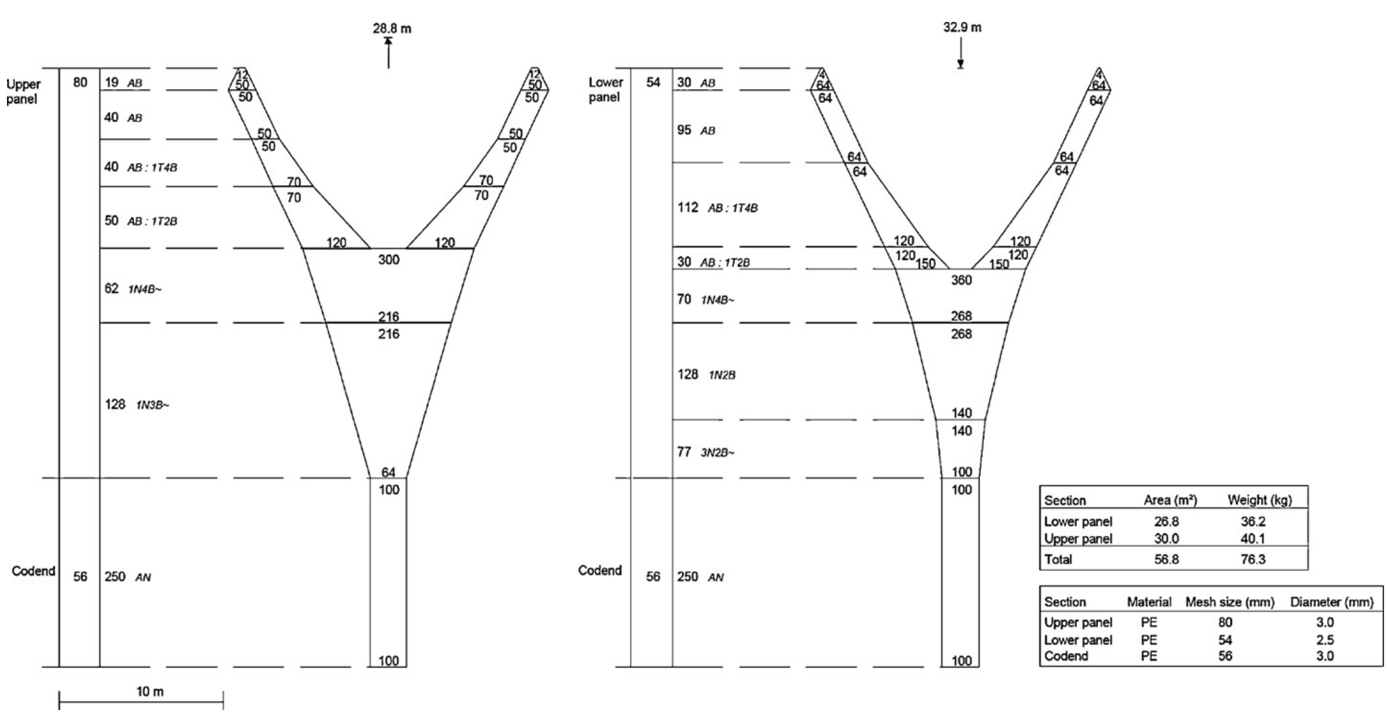

Fig. 2. Design of the crustacean trawl used during experimental fishing.

Table 2
Families caught in the northern and southern areas as target and bycatch. PWTC: percentage with respect to total catch in weight, PWBC: percentage with respect to bycatch in weight, PNTC: percentage with respect to total catch in number, PNBC: percentage with respect to bycatch in number.

Family/other	Northern area						Southern area					
	Weight (kg)	PWTC	PWBC	Number (n)	PNTC	PNBC	Weight (kg)	PWTC	PWBC	Number (n)	PNTC	PNBC
Mixini												
Myxinidae	31.2	0.03	0.16	52	<0.01	0.04	22.2	0.02	0.14	37	<0.01	0.02
Elasmobranchs												
Scyliorhinidae	142.1	0.13	0.74	225	<0.01	0.17	112.7	0.13	0.72	179	<0.01	0.08
Dalatiidae	1.1	<0.01	0.01	2	<0.01	<0.01	196.7	0.22	1.26	233	<0.01	0.10
Etmopteridae	59.5	0.05	0.31	122	<0.01	0.09	50.5	0.06	0.32	92	<0.01	0.04
Order Squaliformes	19.2	0.02	0.10	40	<0.01	0.03	15.4	0.02	0.10	32	<0.01	0.01
Somniosidae	5.6	0.01	0.03	11	<0.01	0.01	105.2	0.12	0.68	169	<0.01	0.07
Arhynchobatidae	2.5	<0.01	0.01	5	<0.01	<0.01	135.5	0.15	0.87	374	0.01	0.16
Rajidae	6.7	0.01	0.03	4	<0.01	<0.01	308.1	0.34	1.98	355	0.01	0.15
Torpedinidae	9.9	0.01	0.05	2	<0.01	<0.01	160.2	0.18	1.03	29	<0.01	0.01
Teleostei												
Notacanthidae							1.4	<0.01	0.01	20	<0.01	0.01
Ophichthidae	54.3	0.05	0.28	105	<0.01	0.08	29.9	0.03	0.19	56	<0.01	0.02
Alepocephalidae							0.1	<0.01	<0.01	1	<0.01	<0.01
Sternoptychidae	0.1	<0.01	<0.01	8	<0.01	0.01	0.2	<0.01	<0.01	9	<0.01	<0.01
Stomiidae							0.1	<0.01	<0.01	1	<0.01	<0.01
Macrouridae	274.5	0.25	1.43	11,220	0.15	8.66	3777.9	4.22	24.25	156,144	2.46	66.03
Merlucciidae	10,445.4	9.53	54.55	41,465	0.54	32.02	6170.4	6.90	39.61	26,349	0.42	11.14
Moridae							8.8	<0.01	0.06	584	0.01	0.25
Ophidiidae	7.5	0.01	0.04	21	<0.01	0.02	99.2	0.11	0.64	333	0.01	0.14
Berycidae							0.6	0.01	<0.01	2	<0.01	<0.01
Epigonidae	929.6	0.85	4.85	2707	0.04	2.09	805.5	0.90	5.17	2312	0.04	0.98
Zoarcidae	9.2	0.01	0.05	23	<0.01	0.02	10.6	0.01	0.07	26	<0.01	0.01
Paralichthyidae	5325.9	4.86	27.81	51,296	0.67	39.61	2060.7	2.30	13.23	19,621	0.31	8.30
Invertebrates												
Class Porifera	0.5	0.01	0.01	31	<0.01	0.02	0.1	<0.01	<0.01	7	<0.01	<0.01
Class Anthozoa	0.1	0.01	0.01	1	0.01	0.01	0.2	<0.01	<0.01	21	<0.01	0.01
Limopsidae							0.1	<0.01	<0.01	2	<0.01	<0.01
Buccinidae		<0.01			<0.01		1.5	<0.01	0.01	75	<0.01	0.03
Class Gastropoda	15.1	0.01	0.08	93	<0.01	0.07	0.5	<0.01	<0.01	3	<0.01	<0.01
Trochidae							1.4	<0.01	0.01	70	<0.01	0.03
Octopodidae	10.7	0.01	0.06	65	<0.01	0.05	28.4	0.03	0.18	172	<0.01	0.07
Ommastrephidae	209.4	0.19	1.09	13	<0.01	0.01	1022.2	1.14	6.56	64	<0.01	0.03
Calappidae	1440.0	1.31	7.52	16,098	0.21	12.43	132.5	0.15	0.85	1474	0.02	0.62
Cancridae	36.6	0.03	0.19	424	0.01	0.33	21.1	0.02	0.14	245	<0.01	0.10
Epialtidae	2.4	<0.01	<0.01	6	<0.01	<0.01	7.2	0.01	0.05	107	<0.01	0.05
Galatheidae*	41,699.5	38.05	-	975,445	12.69	-	33,458.5	37.41	-	626,251	9.88	-
Order Decapoda	21.3	0.02	0.11	251	<0.01	0.19	11.6	0.01	0.07	137	<0.01	0.06
Paguridae							0.5	<0.01	<0.01	48	<0.01	0.02
Pandalidae*	48,755.5	44.48		6,584,513	85.63		40,400.3	45.17		5,472,708	86.38	
Platyxanthidae	2.4	<0.01	0.01	30	<0.01	0.02						
Solenoceridae	20.1	0.02	0.10	2010	0.03	1.55	263.2	0.29	1.69	26,321	0.42	11.13
Squillidae	66.7	0.06	0.35	3181	0.04	2.46	14.3	0.02	0.09	678	0.01	0.29
Order Asteroidea	0.1	<0.01	<0.01	1	<0.01	<0.01	1.3	<0.01	0.01	100	<0.01	0.04
Order Echinoidea							0.1	<0.01	<0.01	3	<0.01	<0.01
Total	109,604.4			7,689,470			89,436.5			6,335,444		

The * denotes families of the target species.

(Fig. 3). The average catch rate of *H. reedi* in the northern area was 331.5 kg h^{-1}, while it was higher in the south area, reaching 422.9 kg h^{-1} (Table 3). ANOVA results showed that the year and the operation area had significant effects ($p < 0.05$) on the average catch rate of *H. reedi* (Table 4).

In both areas, the second species in relative importance by weight was *M. gayi* (11.5% in the north and 7.9% in the south), followed by *Hippoglossina macrops* (5.9%) in the northern area and *Coelorinchus aconcagua* (5.6%) in the southern area (Fig. 3). Regarding frequency of occurrence, only three species were present in more than 70% of the hauls made in the northern area: *M. gayi* (100%), *Platymera gaudichaudii* (94%) and *H. macrops* (86%). In terms of their catch rate, *M. gayi* with 77.7 kg h^{-1} and 296.3 n h^{-1}, followed by *H. macrops* (30.4 kg h^{-1} and 280.5 n h^{-1}) and *C. johni* (20.9 kg h^{-1} and 392.5 n h^{-1}) are noteworthy (Table 3).

In the southern area, a larger number of species with high frequency of occurrence was recorded. These species were *M. gayi* (99%), *C. johni* (86%), *H. macrops* (85%), *P. gaudichaudii* (81%), *Epigonus crassicaudus* (80%) and *C. aconcagua* (70%). The highest average catch rates by weight correspond to *M. gayi* (54.4 kg h^{-1}), *C. aconcagua* (47.8 kg h^{-1}), and *Dosidicus gigas* (36.7 kg h^{-1}). In number, Macrouridae (*C. aconcagua* 1986.2 n h^{-1} and *Coelorinchus* sp. 895 n h^{-1}), followed by *Haliporoides diomedeae* (629.7 n h^{-1}), *C. johni* (437.2 n h^{-1}) and *M. gayi* (235.9 n h^{-1}) are noteworthy (Table 3).

Of the most frequent species that constitute the bycatch of *H. reedi*, only three species show significant differences ($p < 0.05$) in their average catch rates by weight. For *C. aconcagua* and *H. macrops* the fishing area and year are significant factors, although with different tendencies for each species (Table 4). On the other hand, for *P. gaudichaudii* only the fishing area effect was significant. The average catch rates were much higher ($p < 0.05$) in the northern area (Table 4).

In 65 hauls targeting *C. johni*, a total of 24 taxa were registered. In the northern area, the number of taxa was 20, with 8 invertebrates, 7 teleostei, 4 elasmobranchs and 1 myxini. In the south, the number of taxa was 15, with 7 invertebrates, 6 teleostei and 2 elasmobranchs (Table 5). The target species represented 85.3 and

Table 3
The occurrence and average catch rates of species in hauls targeting *Heterocarpus reedi*, by area.

Group	Species	Northern area			Southern area		
		Hauls (%)	CPUE (kg h^{-1}) ± (S.E.)	CPUE (n h^{-1}) ± (S.E.)	Hauls (%)	CPUE (kg h^{-1}) ± (S.E.)	CPUE (n h^{-1}) ± (S.E.)
Mixini	*Eptatretus polytrema*				24.0	1.16 (0.18)	1.93 (0.3)
Elasmobranchs	*Halaelurus canescens*	39.8	1.90 (0.25)	3.03 (0.38)	34.0	3.51 (0.72)	5.51 (1.17)
	Centroscyllium nigrum				18.0	8.53 (2.37)	9.22 (2.31)
	Aculeola nigra	29.6	1.32 (0.29)	2.74 (0.62)	35.0	1.58 (0.22)	2.83 (0.37)
	Order Squaliformes				3.0	2.63 (1.18)	5.49 (2.47)
	Centroselachus crepidater	3.1	1.84 (0.75)	3.51 (1.57)	41.0	2.63 (0.29)	4.29 (0.48)
	Bathyraja sp.				16.0	1.80 (0.33)	6.28 (0.88)
	Psammobatis rudis				35.0	2.16 (0.29)	5.36 (0.77)
	Dipturus trachyderma				9.0	3.28 (1.28)	2.65 (0.48)
	Family Rajidae				5.0	1.63 (0.62)	7.07 (2.21)
	Gurgesiella furvescens				23.0	1.39 (0.34)	5.11 (0.92)
	Zearaja chilensis	2.0	1.70 (0.25)	0.55 (0.08)	32.0	6.04 (0.93)	2.08 (0.33)
	Torpedo tremens	2.0	5.76 (3.01)	1.12 (0.51)	20.0	5.31 (1.05)	1.39 (0.15)
Teleostei	*Ophichthus remiger*	25.5	1.16 (0.16)	1.72 (0.32)	30.0	1.33 (0.25)	2.53 (0.51)
	Coelorinchus aconcagua	42.9	2.93 (0.61)	121.76 (25.72)	70.0	47.83 (5.64)	1986.24 (234.55)
	Coelorinchus chilensis				15.0	1.67 (0.73)	35.82 (14.79)
	Coelorinchus sp.	5.1	5.60 (5.39)	215.86 (206.28)	27.0	21.29 (3.27)	895.03 (127.6)
	Merluccius gayi	100.0	77.71 (18.25)	296.33 (65.58)	99.0	54.41 (7.23)	235.87 (30.71)
	Brotulotaenia sp.				30.0	3.58 (0.66)	11.95 (2.22)
	Genypterus maculatus				2.0	1.17 (0.74)	4.80 (2.86)
	Epigonus crassicaudus	29.6	19.28 (6.34)	56.15 (18.32)	80.0	15.40 (4.11)	44.52 (12.36)
	Lycenchelys scaurus	6.1	3.16 (0.97)	7.90 (2.43)	2.0	13.21 (12.87)	32.88 (32.33)
	Hippoglossina macrops	85.7	30.38 (3.01)	280.45 (28.49)	85.0	18.83 (2.09)	180.58 (20.16)
Invertebrates	*Dosidicus gigas*	7.1	12.96 (4.93)	0.80 (0.31)	30.0	36.75 (5.73)	2.27 (0.35)
	Platymera gaudichaudii	93.9	7.85 (0.83)	89.05 (9.21)	81.0	1.48 (0.18)	16.05 (1.94)
	Cervimunida johni	38.8	20.87 (6.89)	392.53 (128.97)	86.0	23.23 (5.36)	437.23 (100.24)
	Pleuroncodes monodon	10.2	2.70 (1.4)	75.78 (39.31)			
	*Heterocarpus reedi**	100.0	331.53 (21.63)	44661.00 (2955.79)	100.0	422.93 (23.31)	57512.56 (3195.6)
	Haliporoides diomedeae	8.2	1.55 (1.03)	155.21 (103.02)	25.0	6.30 (1.27)	629.65 (127.94)
	Pterygosquilla armata	35.7	1.06 (0.23)	50.39 (11.26)			

The * denotes the target species.
Only those with a mean CPUE greater than 1 kg h^{-1} and ocurrence greater than 1 are included.

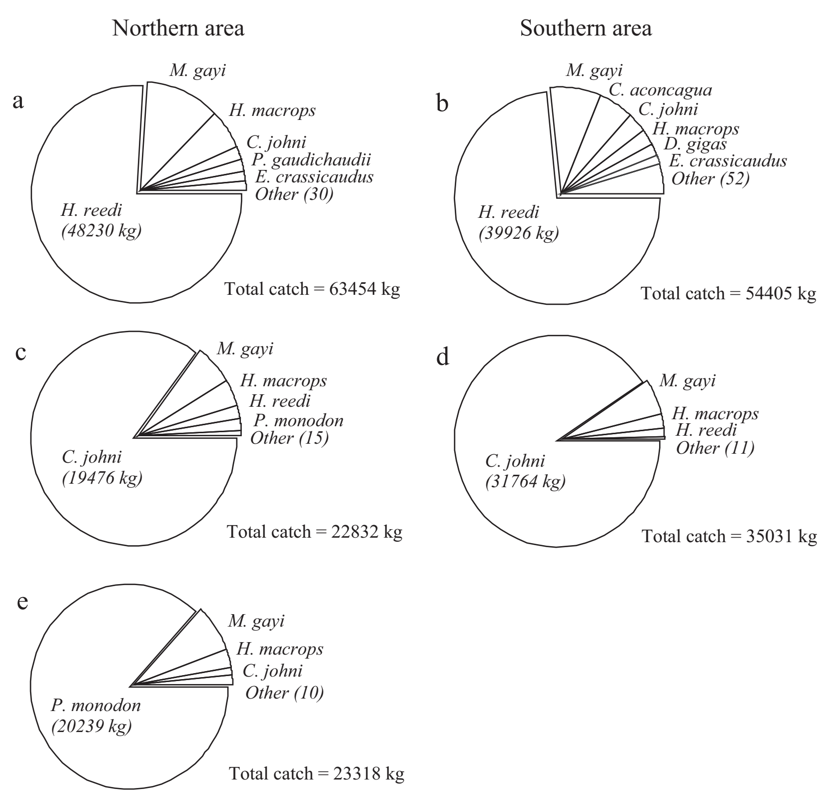

Fig. 3. Relative contribution of species to the total catch by area and target species (a, b: *Heterocarpus reedi*; c, d: *Cervimunida johni*; e: *Pleuroncodes monodon*).

Table 4
Results of the two-factor ANOVA of catch rate (kg h^{-1}) of the most frequent species caught in hauls targeting *Heterocarpus reedi*; testing for differences between areas and years.

Species	Area		Year		Area * year	
	F	*p*-Value	*F*	*p*-Value	*F*	*p*-Value
Aculeola nigra	0.69	0.411	0.29	0.751	0.33	0.567
Cervimunida johni	0.02	0.879	0.71	0.493	0.16	0.856
Coelorinchus aconcagua	29.95	<0.001	15.04	<0.001		
Epigonus crassicaudus	0.13	0.724	0.25	0.775	2.94	0.089
Halaelurus canescens	1.70	0.197	1.91	0.156	1.61	0.208
Heterocarpus reedi	15.33	<0.001	7.49	0.001	0.11	0.892
Hippoglossina macrops	65.18	<0.001	16.73	<0.001	35.84	<0.001
Merluccius gayi	0.04	0.836	0.01	0.991	1.97	0.142
Ophichthus remiger	3.37	0.072	1.76	0.182	1.93	0.171
Platymera gaudichaudii	7.13	0.008	1.77	0.173	1.78	0.172

Table 5
Occurrence and average catch rates of species in hauls targeting *Cervimunida johni*, by area.

		Northern area			Southern area		
		Hauls (%)	CPUE (kg h^{-1}) ± (S.E.)	CPUE (n h^{-1}) ± (S.E.)	Hauls (%)	CPUE (kg h^{-1}) ± (S.E.)	CPUE (n h^{-1}) ± (S.E.)
Mixini	*Eptatretus polytrema*	6.7	30.14 (23.85)	50.24 (39.76)			
Elasmobranchs	*Halaelurus canescens*	6.7	6.09 (4.63)	9.73 (7.42)			
	Aculeola nigra	16.7	1.99 (0.57)	3.66 (1.27)			
Teleostei	*Ophichthus remiger*	40.0	2.77 (0.89)	5.35 (1.75)	14.3	1.33 (0.46)	2.59 (0.89)
	Lucigadus nigromaculatus	10.0	4.85 (3.22)	192.54 (126.86)			
	Merluccius gayi	93.3	54.21 (13.71)	216.79 (55.47)	100.0	118.28 (18.35)	541.94 (94.33)
	Brotulotaenia sp.	13.3	1.58 (0.63)	5.26 (2.08)			
	Epigonus crassicaudus	6.7	4.52 (3.89)	13.81 (11.9)			
	Hippoglossina macrops	96.7	33.43 (7.25)	320.20 (69.67)	100.0	43.64 (5.34)	415.03 (51.12)
Invertebrates	*Dosidicus gigas*				5.7	47.85 (15.95)	3.00 (1.01)
	Platymera gaudichaudii	76.7	3.08 (2.48)	36.11 (29.26)	80.0	2.10 (0.47)	23.58 (5.12)
	*Cervimunida johni**	100.0	676.59 (112.26)	12,673.85 (2100.95)	100.0	1854.24 (177.92)	34,667.50 (3338.87)
	Pleuroncodes monodon	30.0	56.79 (33.99)	1596.73 (956.03)			
	Heterocarpus reedi	73.3	29.23 (7.41)	3954.65 (1002.42)	62.9	42.41 (7.65)	5727.32 (1037.91)

The * denotes the target species.
Only those with a mean CPUE greater than 1 kg h^{-1} and occurrence greater than 1 are included.

90.7% of the total catch by weight in the northern and southern areas, respectively (Fig. 3). The average catch rate was 676.6 kg h^{-1} in the northern area, and slightly higher in the south, reaching 1855.2 kg h^{-1} (Table 5). Using ANOVA, it was determined that fishing area, operation year and the interaction between the two factors have a significant effect ($p < 0.05$) on average catch rates (Table 6).

As in the case of *H. reedi,* the second species in relative importance by weight to *C. johni* was *M. gayi* in both areas (6.1 and 5.4%, respectively), followed by *H. macrops* (4.1 and 5.4%), while the remaining species presented a low individual contribution (Fig. 3). However, in terms of frequency of occurrence, four species (*H. macrops*, *M. gayi*, *P. gaudichaudii* and *H. reedi*) were present in more that 70% of hauls made in the northern area. Regarding the average catch rate by weight, *P. monodon* with 56.8 kg h^{-1}, followed by *M. gayi* (54.2 kg h^{-1}) and *H. macrops* (33.4 kg h^{-1}) are noteworthy. In the hauls targeting *H. reedi* and *P. monodon*, invertebrates were the most important by number, with 3954.6 and 1596.7 n h^{-1}, while *H. macrops* (320.2 n h^{-1}) and *M. gayi* (216.8 n h^{-1}) presented the highest values in teleostei (Table 5).

In the southern area, the most recurrent species were *M. gayi* (100%), *H. macrops* (100%) and *P. gaudichaudii* (80%). In terms of average catch rate, *M. gayi* with 118.3 kg h^{-1} and 541.9 n h^{-1}, followed by *D. gigas* (47.9 kg h^{-1} and 3 n h^{-1}), *H. macrops* (43.6 kg h^{-1} and 415 n h^{-1}) and *H. reedi* (42.4 kg h^{-1} and 5727.3 n h^{-1}) are noteworthy (Table 5). Of the most frequent species that constitute the bycatch, only *M. gayi* showed significant differences ($p < 0.05$) in average catch rates by weight among years (Table 6), presenting its lowest magnitude in 2008.

The third target species of this study was *P. monodon*, whose 26 hauls were made exclusively in the northern area, and where a total of 14 taxa were recorded. Here 10 were invertebrates, 3 teleostei and 1 elasmobranch. The target species represented 86.8% of the total catch by weight (Fig. 3), showing an average catch rate of 892.2 kg h^{-1} (Table 7), with no significant differences between years (Table 8).

As in previous cases, *M. gayi* is the second species in relative importance by weight with 7.6% of the total catch, followed by *H. macrops* (2.9%) (Fig. 3). Along with *P. monodon*, only three species (*M. gayi*, *H. macrops* and *P. gaudichaudii*) presented a high fre-

Table 6
Results of two-factor ANOVA of catch rate (kg h^{-1}) of the most frequent species caught in hauls targeting *Cervimunida johni*; testing for differences between areas and years.

Species	Area		Year		Area * year	
	F	*p*-Value	*F*	*p*-Value	*F*	*p*-Value
Cervimunida johni	15.40	<0.001	9.43	<0.001	6.38	<0.001
Heterocarpus reedi	2.30	0.137	2.13	0.133	0.07	0.934
Hippoglossina macrops	1.26	0.266	0.15	0.860	0.65	0.527
Merluccius gayi	3.30	0.074	3.40	0.041	0.64	0.531
Platymera gaudichaudii	0.54	0.467	1.61	0.211	1.57	0.219

Table 7
Occurrence and average catch rates of species in hauls targeting *Pleuroncodes monodon* in the northern area.

Group	Species	Northern area		
		Hauls (%)	CPUE ($kg\,h^{-1}$) ± (S.E.)	CPUE ($n\,h^{-1}$) ± (S.E.)
Elasmobranchs	*Halaelurus canescens*	7.7	1.34 (0.75)	1.67 (0.27)
Teleostei	*Ophichthus remiger*	11.5	1.00 (0.46)	1.92 (0.93)
	Merluccius gayi	100.0	92.43 (18.8)	369.37 (76.41)
	Hippoglossina macrops	96.2	40.68 (7.38)	435.36 (72.39)
Invertebrates	Class Gastropoda	7.7	5.86 (5.84)	33.58 (32.27)
	Platymera gaudichaudii	73.1	14.82 (4.28)	154.18 (47.43)
	Cervimunida johni	46.2	30.06 (12.11)	562.48 (226.59)
	*Pleuroncodes monodon**	100.0	892.24 (144.5)	24,996.76 (3982.74)
	Order Decapoda	7.7	7.62 (3.97)	89.61 (46.75)
	Heterocarpus reedi	26.9	20.47 (10.15)	2769.85 (1373.59)

The * denotes the target species.
Only those with a mean CPUE greater than 1 $kg\,h^{-1}$ and occurrence greater than 1 are included.

Table 8
Results of the two-factor ANOVA of catch rate ($kg\,h^{-1}$) of the most common species caught in hauls targeting *Pleuroncodes monodon*; testing for differences between years.

Species	Year	
	F	*p*-Value
Cervimunida johni	0.75	0.499
Hippoglossina macrops	4.72	0.021
Merluccius gayi	1.92	0.169
Platymera gaudichaudii	14.03	0.002
Pleuroncodes monodon	2.34	0.119

quency of occurrence (>70%). In terms of average catch rate by weight, *M. gayi* (92.4 $kg\,h^{-1}$), *H. macrops* (43.6 $kg\,h^{-1}$), and *C. johni* (30.1 $kg\,h^{-1}$) are noteworthy. In terms of numbers, the *H. reedi* and *C. johni* invertebrates are the most important with 2,769.8 and 562.5 $n\,h^{-1}$, respectively, while *H. macrops* (435.4 $n\,h^{-1}$) and *M. gayi* (369.4 $n\,h^{-1}$) presented the highest values in teleostei (Table 7). Of the most frequently caught species, only *P. gaudichaudii* and *H. macrops* presented significant differences ($p < 0.05$) in the catch rate between years (Table 8).

The analysis of standardized and transformed catch data (in number and weight), indicates that at a similarity level of 35 and 40%, the 15 target species/year/area combinations can be classified into three main groups, corresponding to the dependent combinations of each target species (Fig. 4a and b). In the same way, groups 1, 2 and 3 correspond to trawls aimed at *H. reedi*, *C. johni* and *P. monodon*, respectively, where there is no pattern of secondary classification related to area and year of operation. The ordination through non-metric multidimensional scaling (MDS) presented a high concordance with clustering results, considering the 15 target species/year/area combinations (Fig. 4c and d). The stress values of the bidimensional analysis were 0.04 and 0.05 for the standardized and transformed abundances in number and weight, respectively. In both cases, the magnitude indicates a correct representation of the information.

The *K*-dominance curves reflect the observed patterns found in the previous analyses, with a high dominance in catch of a few species, and a high participation of target species in number and weight (Fig. 5a–c). When excluding the target species, and considering only the bycatch, it can again be observed that few species dominate the catch (Fig. 5d–f), and in the *C. johni* and *P. monodon* hauls in particular, it can be seen that the *K*-dominance curves are higher compared to the case of *H. reedi* hauls.

Significant differences ($p < 0.05$) in the catch rate and the diversity indexes were found for each of the target species (Table 9). The highest value of number of species, catch rate, dominance and richness was associated to the catch of *H. reedi*, while the diversity and evenness were higher for *C. johni* and *P. monodon* targeted hauls, respectively. The Fisher's LSD test indicates that there are significant differences ($p < 0.05$) in catch rates and diversity indexes in hauls aimed at *H. reedi* in comparison to the other target species (Table 10). In contrast, the same analysis shows that these variables do not differ significantly ($p > 0.05$) between *C. johni* and *P. monodon*.

4. Discussion

This study provides information on the composition of species as well as the magnitude of the bycatch caught by a new experimental trawl that is under assessment by the crustacean trawl fisheries sector of Chile. Although the *Heterocarpus reedi*, *Cervimunida johni* and *Pleuroncodes monodon* target species are managed as independent administrative fishing units, it is recognized that while they partly share their spatial distribution in the studied area, there is stratification in their main areas of abundance, which determines not only the composition but also the contribution of different species in the catch.

Table 9
Ecological parameters and summary of statistical tests by target species.

Parameters	Target species (mean ± standard error)			Statistical tests	
	Heterocarpus reedi	*Cervimunida johni*	*Pleuroncodes monodon*	Levene statistic	*F*
Hauls	198	65	26	2,286[a]	2,286[a]
Number of taxa (*S*)	10.90 (±0.38)	5.81 (±0.18)	5.26 (±0.25)	22.67 (<0.001)	41.86 (<0.001)
Catch rate[b] ($n\,h^{-1}$)	4.63 (±0.02)	4.31 (±0.05)	4.24 (±0.08)	8.79 (<0.001)	31.75 (<0.001)
Dominance (λ)	0.93 (±0.02)	0.78 (±0.02)	0.81 (±0.04)	84.18 (<0.001)	41.32 (<0.001)
Diversity (H')	0.18 (±0.01)	0.42 (±0.03)	0.40 (±0.07)	57.25 (<0.001)	36.33 (<0.001)
Evenness (J')	0.13 (±0.01)	0.28 (±0.01)	0.31 (±0.02)	11.25 (<0.001)	138.79 (<0.001)
Richness (*d*)	0.92 (±0.03)	0.49 (±0.02)	0.44 (±0.02)	17.49 (<0.001)	34.07 (<0.001)

[a] Degree of freedom.
[b] Mean and standard error were calculated using $\log(x \pm 1)$.

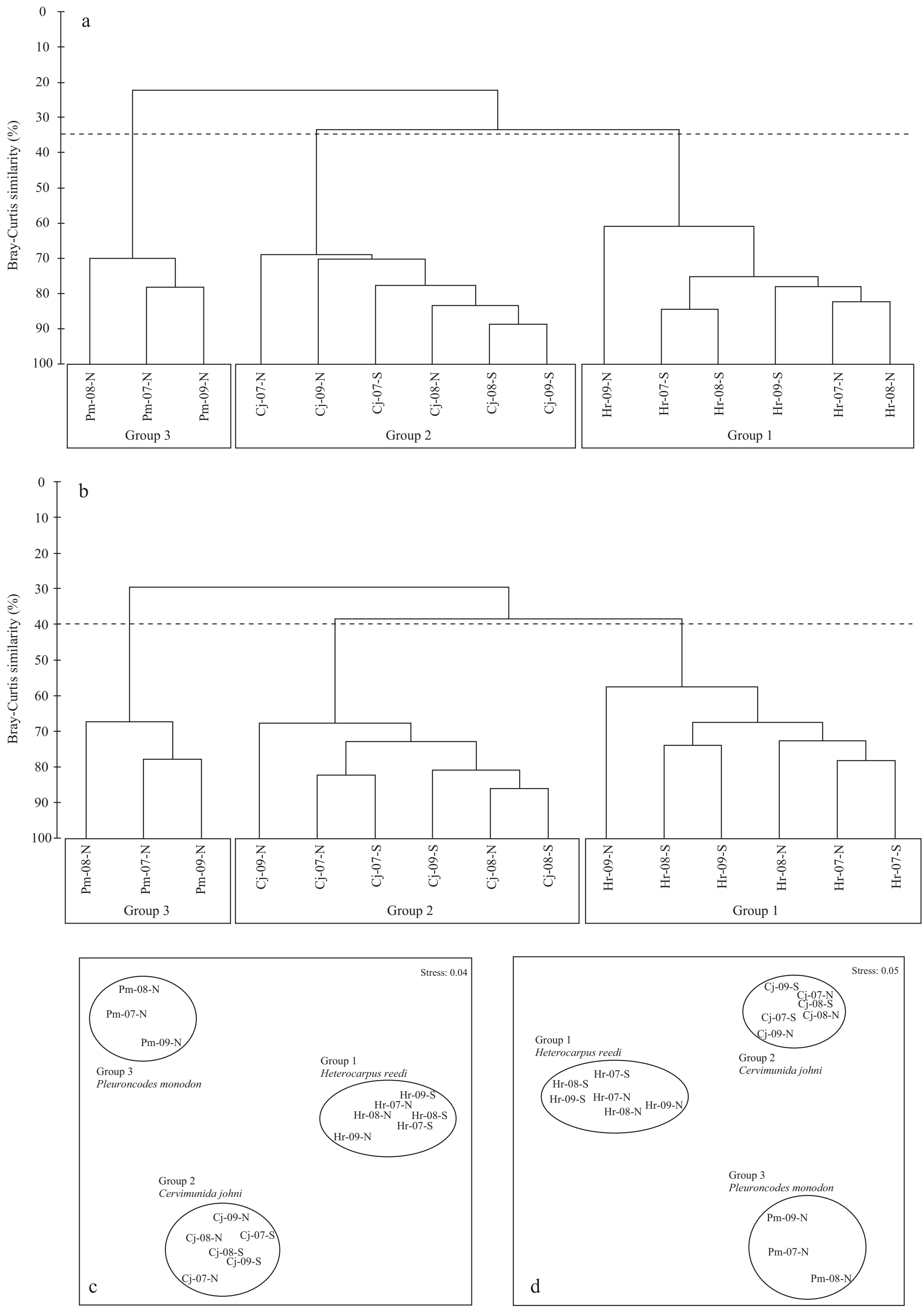

Fig. 4. Dendrogram for group-average clustering and MDS ordination, based on Bray–Curtis similarities between catch in numbers (a, c) and weights (b, d) (standardized and transformed data) for all species per target species/year/fishing area combinations. Hr: *Heterocarpus reedi*; Cj: *Cervimunida johni*; Pm: *Pleuroncodes monodon*; N: north area; S: south area; 07, 08 and 09: years 2007, 2008, and 2009, respectively.

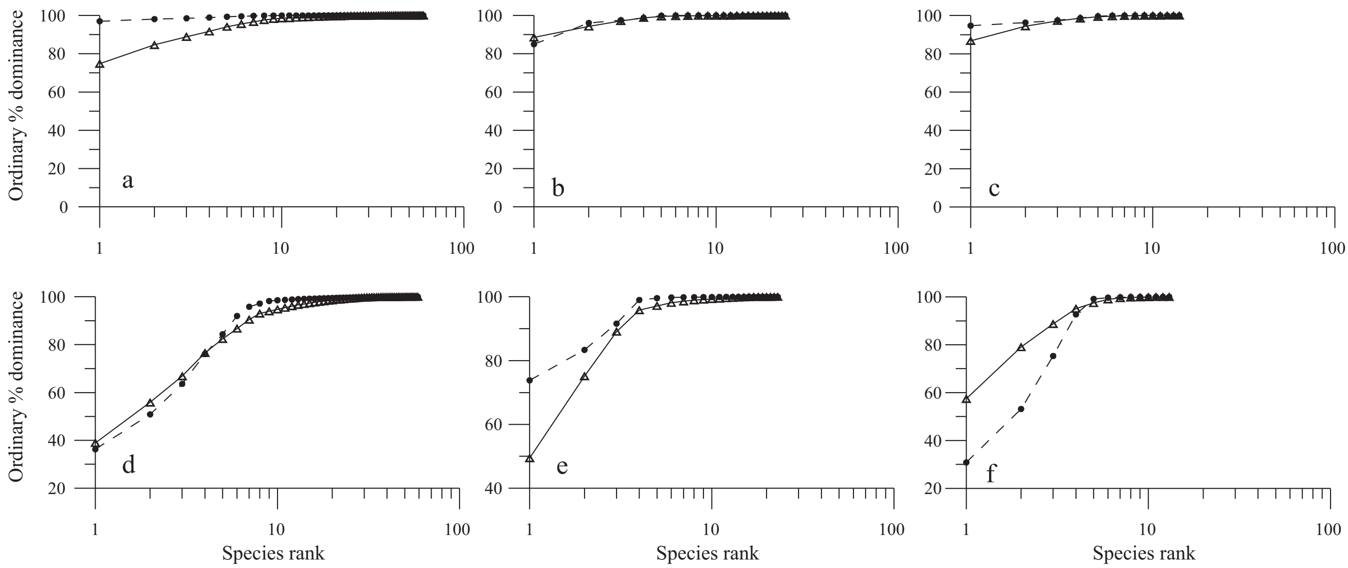

Fig. 5. *K*-Dominance curves based on catch numbers (dashed line) and weights (solid line) for all species in hauls targeting *Heterocarpus reedi* (a and d); *Cervimunida johni* (b and e) and *Pleuroncodes monodon* (c and f). In the upper curves, the target species are considered and the lower curves these species are excluded.

Table 10
Results of Fisher's LSD test. Standard error is in parentheses. Hr: *Heterocarpus reedi*; Cj: *Cervimunida johni*; Pm: *Pleuroncodes monodon*.

Variable	Categories	Mean difference	*p*-Value
Number of taxa (S)	Hr vs Cj	5.09 (±0.69)	<0.001
	Hr vs Pm	5.63 (±0.99)	<0.001
	Cj vs Pm	0.55 (±1.11)	0.604
Catch rate ($n\,h^{-1}$)	Hr vs Cj	0.32 (±0.09)	<0.001
	Hr vs Pm	0.39 (±0.12)	<0.001
	Cj vs Pm	0.07 (±0.12)	0.379
Dominance (λ)	Hr vs Cj	0.14 (±0.06)	<0.001
	Hr vs Pm	0.12 (±0.07)	<0.001
	Cj vs Pm	−0.02 (±0.07)	0.377
Diversity (H')	Hr vs Cj	−0.24 (±0.08)	<0.001
	Hr vs Pm	−0.21 (±0.09)	<0.001
	Cj vs Pm	0.02 (±0.09)	0.672
Evenness (J')	Hr vs Cj	−0.15 (±0.06)	<0.001
	Hr vs Pm	−0.17 (±0.06)	<0.001
	Cj vs Pm	−0.03 (±0.06)	0.109
Richness (d)	Hr vs Cj	0.43 (±0.11)	<0.001
	Hr vs Pm	0.48 (±0.13)	<0.001
	Cj vs Pm	0.05 (±0.14)	0.598

In the hauls made, although 72 taxa were recorded, only a small proportion contributed to the catch in a significant way. Teleostei fish are the ones that contribute with the highest proportion to the bycatch. *M. gayi* is noteworthy by being the main species, according to its high frequency of occurrence (nearly 100% of hauls) and is the highest in individual contribution (8.3% of total catch). However, this result should be considered with caution, since before the dramatic reduction in hake stock during the years 2002–2004, its relative contribution in hauls targeting *H. reedi* fluctuated between 18 and 24% in the 1998–2001 period, more than twice the amount registered in the current study.

For teleostei, the family that contributed with the highest number of species was the Macrouridae, as also reported by Acuña et al. (2005). However, these authors pointed out that the second most important families in contribution were the Stomiidae and Myctophidae, represented in this case particularly by small size species. This difference could be explained by the selectivity of this trawl since the fishing net being tested has a 47 mm mesh size, a much larger size than the one used in previous studies (35 mm). In any case, the selectivity of the trawl is something that must be evaluated in subsequent studies for both the bycatch and the target species, ideally through covered cod-end or twin trawl hauls.

The highest proportion of bycatch is explained by *M. gayi* along with *H. macrops*, *C. aconcagua*, *E. crassicaudus* and *P. gaudichaudii* species, and is consistent with the results obtained in different studies (Arana et al., 2006; Zilleruelo et al., 2007; Acuña et al., 2009). Some of these species presented differences in their catch rates due to the effect of the year and/or fishing area. Nevertheless, the classification and ordination analysis indicates that the composition of the catch for the same target species is similar between years and areas. In this way, the differences in catch rates can be explained by the common variability between hauls, and not by the changes in biomass space-time patterns of the associated fauna and/or the environment conditions (Acuña et al., 2009).

Melo et al. (2007) determine that the biological diversity increases along the latitudinal axis in the area between 29° and 41° S, due to water bodies characteristics. Likewise, Camus (2001) establishes biogeographical units on the continental coastline of Chile, pointing out that the 29° S parallel corresponds to a transition area, and that Coquimbo (ca. 30° S) and also Valparaíso (ca. 33° S) would present a distribution discontinuity. Thus, the northern and southern areas of this study are included in the same biogeographical unit, which could explain the similarity obtained through classification and ordination.

The depth has also been pointed out as responsible for the diversity (Acuña et al., 2005; Melo et al., 2007), and in this case it is associated to the higher number of species captured in hauls targeting *H. reedi*. In this sense, Menares and Sepúlveda (2005) indicate that the apparent segregation of groups can be explained partly by the bathymetry, although the heterogeneity in the nature and distribution of substrates in the research area is a factor that can also influence the composition of certain groups.

The number of species (S) and the richness (d) as descriptive parameters of the composition of the community provide an immediate idea of the biological diversity of a community (Maguran, 1988). In the case of *H. reedi*, the highest average number of taxa was obtained. However, the high abundance of this species and the high catch rates obtained reflect more abundance and less diversity in comparison to the other target species.

Andrade (1987), Acuña et al. (2005), and Melo et al. (2007) identify a high number of species caught by trawls in the central area of Chile, although the results vary significantly in relation to certain taxa. Even though the results of this study show a high similarity with the main taxa pointed out by these authors, we cannot rule out differences due to species identification problems, and also by problems in sub-sampling of occasional or less abundant species (Acuña et al., 2008).

The crustacean trawl fisheries are often associated with high levels of bycatch and discard (Kelleher, 2005), although it is important to emphasize that this situation is not a general rule, since in some shrimp and prawn fisheries, the bycatch/catch ratio is really low (Hall et al., 2000). In this study, a total of 34.727 kg of bycatch was captured, being equivalent to 17.4% of total catch. This situation does not seem to be very serious, but we recognize that it is possible to reduce the bycatch, especially in the case of *H. reedi* whose bycatch was ~25% of the total catch.

Bergmann et al. (2002) note that non-target species of high public appeal such as marine mammals, turtles and sharks, have contributed to increase the awareness of non commercial discards. In this study, a total of 14 elasmobranchs species were caught. This group is characterized by its vulnerable life cycles, low growing rates, late maturity and low fertility rates (Cortés, 2000) and by having higher probabilities of being affected by fishing activities than most teleostei (Stevens et al., 2000; Coelho and Erzini, 2008). Even though the contribution of this group was lower than 1% of the total catch and 7.1% of bycatch, the presence of one or more species in 50% of the hauls is noteworthy. For all these reasons, the continuous pressure of fishing can take the elasmobranchs to a risk level or even to the collapse of their populations. Assuming a precautionary approach, this demands immediate attention in order to reduce unnecessary mortality.

The results obtained in this study suggest that the strategy to reduce the bycatch in these fisheries should be centered on the most commonly occurring and sensitive species and/or groups. The most frequently occurring includes *M. gayi*, *H. macrops*, *C. aconcagua* and *E. crassicaudus*, while elasmobranchs form the most sensitive group. Diverse alternatives to reduce bycatch can be tested. In the front section of the trawl, the reduction of the catch of *M. gayi* was possible by shortening the bridles and sweeps, whereas others species no evidence differences (Queirolo et al., 2009b). Then, alternatives in the rear section of the trawl should be tested, such as square mesh codends and reduction devices (i.e., square mesh panels and sorting grids).

The change of the crustacean trawl nets is already underway in Chile; the fisheries authority has promoted this change and most of the crustacean fleet is committed to improving their practices and to make cleaner catches. Therefore, this study is a key element to define objective selection of catches, essential information for conservation and management of these fisheries. Future studies will be needed to test options for bycatch mitigation.

Acknowledgements

This work was partially funded by the Fisheries Research Fund (FIP) under projects FIP No. 2006-20: ‘Rediseño de redes de arrastre de crustáceos’ and FIP No. 2008-26: ‘Evaluación del desempeño operacional de una nueva red de arrastre para la pesquería de crustáceos demersales’. We thank Mauricio Ahumada, Teófilo Melo, Roberto Escobar, Ivonne Montenegro, José Merino and Víctor Zamora for their collaboration and Alejandro Karstegl (SUBPESCA) for the support that has given in these projects. We also express our appreciation to José A. Hernando for their helpful suggestions and criticisms. Special thanks to the Centro Andaluz de Ciencia y Tecnología Marinas (CACYTMAR) for the logistic support. Dante Queirolo is also grateful for the fellowship awarded by the Comisión Nacional de Investigación Científica y Tecnológica (CONICYT, Programa Becas Chile). We would also like to thank the anonymous referees for helpful suggestions, constructive comments and critical reading of the manuscript.

Appendix A.

Checklist of taxa from northern (29°12′–30°14′) and southern (32°23′–33°00′) areas.

Order	Family	Taxa
Myxini		
Myxiniformes	Myxinidae	*Eptatretus polytrema*
Elasmobranchs		
Carcharhiniformes	Scyliorhinidae	*Halaelurus canescens*
Carcharhiniformes	Scyliorhinidae	*Schroederichthys chilensis*
Squaliformes	Dalatiidae	*Centroscyllium granulatum*
Squaliformes	Dalatiidae	*Centroscyllium nigrum*
Squaliformes	Etmopteridae	*Aculeola nigra*
Squaliformes	Order Squaliformes	Order Squaliformes
Squaliformes	Somniosidae	*Centroselachus crepidater*
Squaliformes	Somniosidae	*Proscymnodon macracanthus*
Rajiformes	Arhynchobatidae	*Bathyraja magellanica*
Rajiformes	Arhynchobatidae	*Bathyraja peruana*
Rajiformes	Arhynchobatidae	*Bathyraja* sp.
Rajiformes	Arhynchobatidae	*Psammobatis rudis*
Rajiformes	Rajidae	*Dipturus trachyderma*
Rajiformes	Rajidae	Family Rajidae
Rajiformes	Rajidae	*Gurgesiella furvescens*
Rajiformes	Rajidae	*Zearaja chilensis*
Torpediniformes	Torpedinidae	*Torpedo tremens*
Teleosts		
Albuliformes	Notacanthidae	*Notacanthus sexspinis*
Anguilliformes	Ophichthidae	*Ophichthus remiger*
Osmeriformes	Alepocephalidae	*Binghamichthys aphos*
Stomiiformes	Sternoptychidae	*Argyropelecus gigas*
Stomiiformes	Stomiidae	*Chauliodus sloani*
Gadiformes	Macrouridae	*Coelorinchus aconcagua*
Gadiformes	Macrouridae	*Coelorinchus chilensis*
Gadiformes	Macrouridae	*Coelorinchus* sp.
Gadiformes	Macrouridae	*Lucigadus nigromaculatus*
Gadiformes	Macrouridae	*Trachyrincus villegai*
Gadiformes	Merlucciidae	*Merluccius gayi*
Gadiformes	Moridae	Family Moridae
Gadiformes	Moridae	*Notophycis marginata*
Ophidiiformes	Ophidiidae	*Brotulotaenia* sp.
Ophidiiformes	Ophidiidae	*Genypterus blacodes*
Ophidiiformes	Ophidiidae	*Genypterus maculatus*
Beryciformes	Berycidae	*Beryx splendens*
Perciformes	Epigonidae	*Epigonus crassicaudus*
Perciformes	Zoarcidae	*Lycenchelys scaurus*
Pleuronectiformes	Paralichthyidae	*Hippoglossina macrops*
Invertebrates		
Porifera		
Phylum Porifera	Phylum Porifera	Phylum Porifera
Cnidaria		
Class Anthozoa	Class Anthozoa	Class Anthozoa
Mollusca		
Arcoida	Limopsidae	*Limopsis marionensis*
Class Gastropoda	Buccinidae	*Aeneator fontainei*
Class Gastropoda	Buccinidae	*Aeneator loisae*
Class Gastropoda	Class Gastropoda	Class Gastropoda
Class Gastropoda	Trochidae	*Bathybembix humboldti*
Octopoda	Octopodidae	*Octopus* sp.
Oegopsida	Ommastrephidae	*Dosidicus gigas*
Crustacea		
Decapoda	Calappidae	*Platymera gaudichaudii*
Decapoda	Cancridae	*Cancer porteri*
Decapoda	Epialtidae	*Libidoclaea granaria*
Decapoda	Galatheidae	*Cervimunida johni*
Decapoda	Galatheidae	*Pleuroncodes monodon*
Decapoda	Galatheidae	*Munida propinqua*
Decapoda	Order Decapoda	Order Decapoda
Decapoda	Paguridae	*Pagurus* sp.
Decapoda	Pandalidae	*Heterocarpus reedi*
Decapoda	Platyxanthidae	*Homalaspis plana*
Decapoda	Solenoceridae	*Haliporoides diomedeae*
Stomatopoda	Squillidae	Family Squillidae
Stomatopoda	Squillidae	*Pterygosquilla armata*
Echinodermata		
Echinoidea	Order Echinoidea	Order Echinoidea
Class Asteroidea	Order Asteroidea	Order Asteroidea

References

Acuña, E., Villarroel, J.C., Andrade, M., Cortés, A., 2005. Fauna acompañante en pesquerías de arrastre de crustáceos de Chile: implicancias y desafíos desde la perspectiva de la biodiversidad. Figueroa, E. (Ed.), Biodiversidad Marina: valoración, usos y perspectivas ¿hacia dónde va Chile? Editorial Universitaria, Santiago de Chile, 586 pp.

Acuña, E., Alarcón, R., Cid, L., Cortés, A., Cubillos, L., Godø, O., León, R., López, V., Pérez, E., Rodríguez, P., 2008. Estandarización de procedimientos metodológicos para la evaluación de crustáceos demersales a través del método de área barrida. Informes Técnicos FIP. FIP-IT/2006-19, 326 pp.

Acuña, E., Alarcón, R., Arancibia, H., Cortés, A., Cid, L., Cubillos, L., León, R., 2009. Evaluación directa de langostino colorado y langostino amarillo entre la II y VIII Regiones, año 2008. Informes Técnicos FIP. FIP-IT/2008-16, 420 pp.

Andrade, H., 1987. Distribución batimétrica y geográfica de macro-invertebrados del talud continental de Chile central. Cienc. Tec. Mar, CONA 11, 61–94.

Andrew, N.L., Pepperell, J.G., 1992. The by-catch of shrimp trawl fisheries. Oceanogr. Mar. Biol. Annu. Rev. 30, 527–565.

Arana, P., Ahumada, M., Guerrero, A., Melo, T., Queirolo, D., Barbieri, M.A., Bahamonde, R., Canales, C., Quiroz, J.C., 2006. Evaluación directa de camarón nailon y gamba entre la II y VIII Regiones, año 2005. Informes Técnicos FIP. FIP-IT/2005-08, 368 pp.

Baeta, F., Batista, M., Maia, A., Costa, M.J., Cabral, H., 2010. Elasmobranch bycatch in a trammel net fishery in the Portuguese west coast. Fish. Res. 102, 123–129.

Bergmann, M., Wieczorek, S.K., Moore, P.G., Atkinson, R.J.A., 2002. Discard composition of the *Nephrops* fishery in the Clyde Sea area. Scotland Fish. Res. 57, 169–183.

Borges, T.C., Erzini, K., Bentes, L., Costa, M.E., Gonçalves, J.M.S., Lino, P.G., Pais, C., Ribeiro, J., 2001. By-catch and discarding practices in five Algarve (southern Portugal) métiers. J. Appl. Ichthyol. 17 (3), 104–114.

Camus, P.A., 2001. Biogeografía marina de Chile continental. Rev. Chil. Hist. Nat. 74, 587–617.

Carbonell, A., Alemany, F., Merella, P., Quetglas, A., Románc, E., 2003. The by-catch of sharks in the western Mediterranean (Balearic Islands) trawl fishery. Fish. Res. 6, 7–18.

Carr, M.R., 1997. PRIMER User Manual. Plymouth Marine Laboratory, 36 pp. + appendices.

Coelho, R., Erzini, K., 2008. Effects of fishing methods on deep water shark species caught as by-catch off southern Portugal. Hydrobiologia 606, 187–193.

Cortés, E., 2000. Life history patterns and correlations in sharks. Rev. Fish. Sci. 8, 299–344.

Davies, R.W.D., Cripps, S.J., Nickson, A., Porter, G., 2009. Defining and estimating global marine fisheries bycatch. Mar. Pol. 33, 661–672.

Field, J.G., Clarke, K.R., Warwick, R.M., 1982. A practical strategy for analysis of multispecies distribution patterns. Mar. Ecol. Prog. Ser. 8, 37–52.

Góngora, M.E., Bovcon, N.D., Cochia, P.D., 2009. Ictiofauna capturada incidentalmente en la pesquería de langostino patagónico Pleoticus muelleri Bate, 1888. Rev. Biol. Mar. Oceanogr. 44 (3), 583–593.

Hall, M.A., 1996. On bycatches. Rev. Fish Biol. Fish. 6 (3), 319–352.

Hall, M.A., Alverson, D., Metuzals, K., 2000. By-catch: problems and solutions. Mar. Poll. Bull. 41 (1–6), 204–219.

Hurlbert, S.H., 1978. The measurement of niche overlap and some relatives. Ecology 59, 67–77.

Kelleher, K., 2005. Discards in the world's marine fisheries. An update. FAO Fish. Tech. Pap. No. 470, 131 pp.

Kennelly, S.J., 1995. The issue of bycatch in Australia's demersal trawl fisheries. Rev. Fish Biol. Fish. 5 (2), 213–234.

Kennelly, S.J., Broadhurst, M.K., 2002. By-catch begone: changes in the philosophy of fishing technology. Fish Fish. 3, 340–355.

Krebs, C.J., 1989. Ecological Methodology. Harper and Row, New York.

Labropoulou, M., Papaconstantinou, C., 2004. Community structure and diversity of demersal fish assemblages: the role of fishery. Sci. Mar. 68 (1), 215–226.

Lambshead, P.J.D., Platt, H.M., Shaw, K.M., 1983. The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. J. Nat. Hist. 17, 859–874.

Maguran, A.E., 1988. Ecological Diversity and its Measurement. Croom Helm, London.

Manjarrés, L., Duarte, L.O., Altamar, J., Escobar, F., García, C., Cuello, F., 2008. Effects of using bycatch reduction devices on the Colombian Caribbean Sea shrimp fishery. Cienc. Mar. 34 (2), 223–238.

Margalef, R., 1968. Perspectives in Ecological Theory. University of Chicago Press, Chicago, Illinois.

Melo, T., Silva, N., Muñoz, P., Díaz-Naveas, J., Sellanes, J., Bravo, A., Lamilla, J., Sepúlveda, J., Vögler, R., Guerrero, Y., Bustamante, C., Alarcón, M.A., Queirolo, D., Hurtado, F., Gaete, E., Rojas, P., Montenegro, I., Escobar, R., Zamora, V., 2007. Caracterización del fondo marino entre la III y X Regiones. Informes Técnicos FIP. FIP-IT/2005-61, 287 pp.

Melo, T., Hurtado, C., Queirolo, D., Gaete, E., Montenegro, I., Zamora, V., Merino, J., Escobar, R., 2008. Rediseño de las redes de arrastre de crustáceos. Informes Técnicos FIP. FIP-IT/2006-20, 144 pp.

Menares, B., Sepúlveda, J.I., 2005. Grupos recurrentes de peces y crustáceos demersales en la zona centro-sur de Chile. Invest. Mar. (Valparaíso) 33 (1), 91–100.

Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. J. Theor. Biol. 13, 131–144.

Queirolo, D., DeLouche, H., Hurtado, C., 2009a. Comparison between dynamic simulation and physical model testing of new trawl design for Chilean crustacean fisheries. Fish. Res. 97, 86–94.

Queirolo, D., Ahumada, M., Gaete, E., Zamora, V., Escobar, R., Montenegro, I., Merino, J., 2009b. Improved interspecific selectivity of nylon shrimp (*Heterocarpus reedi*) trawling in Chile. Lat. Am. J. Aquat. Res. 37 (2), 221–230.

Saila, S.B., 1983. Importance and assessment of discards in commercial fisheries. FAO Fish. Circ. No. 765, 62 pp.

Sokal, R.R., Rohlf, F.J., 1981. Biometry: The Principles and Practice of Statistics in Biological Research. Freeman, San Francisco.

Stergiou, K.I., Pollard, D.A., 1994. A spatial analysis of the commercial fisheries catches from the Greek Aegean Sea. Fish. Res. 20 (2–3), 109–135.

Stergiou, K.I., Moutopoulos, D.K., Erzini, K., 2002. Gill net and longlines fisheries in Cyclades waters (Aegean Sea): species composition and gear competition. Fish. Res. 57, 25–38.

Stergiou, K.I., Moutopoulos, D.K., Soriguer, M.C., Puente, E., Lino, P.G., Zabala, C., Monteiro, P., Errazkin, L.A., Erzini, K., 2006. Trammel net catch species composition, catch rates and métiers in southern European waters: a multivariate approach. Fish. Res. 79 (1–2), 170–182.

Stevens, J.D., Bonfil, R., Dulvy, N.K., Walker, P.A., 2000. The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. ICES J. Mar. Sci. 57, 476–494.

Stobutzki, I.C., Miller, M., Brewer, D., 2001. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. Environ. Conserv. 28, 167–181.

Stobutzki, I.C., Miller, M., Heales, D.S., Brewer, D.T., 2002. Sustainability of elasmobranch caught as bycatch in a tropical prawn (shrimp) trawl fishery. Fish. Bull. 100, 800–821.

Tonks, M.L., Griffiths, S.P., Heales, D.S., Brewer, D.T., Dell, Q., 2008. Species composition and temporal variation of prawn trawl bycatch in the Joseph Bonaparte Gulf, northwestern Australia. Fish. Res. 89, 276–293.

Zilleruelo, M., Bravo, C., Párraga, D., Montenegro, C., 2007. Investigación situación pesquería crustáceos año 2006. Informe Técnico SUBPESCA/IFOP, 134 pp.