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Alternative codends to reduce bycatch in Chilean crustacean trawl fisheries

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ABSTRACT

This study was conducted to determine the reduction in bycatch and the loss of target catch in trawl hauls for three commercial crustacean species (yellow squat lobster, *Cervimunida johni*, nylon shrimp, *Heterocarpus reedi*, and red squat lobster, *Pleuroncodes monodon*) in central Chile. Two experiments were carried out using the covered codend method; the first used different mesh sizes (56 and 70 mm, knot-centre to knot-centre) and shapes (diamond and square), and the second tested different reduction devices (escape panel and sorting grid). We analysed the escape proportions of the species caught and the size frequency distributions of the target species and Chilean hake (*Merluccius gayi*), the main commercial bycatch species. The results demonstrate that it is feasible to significantly reduce bycatch while keeping losses within acceptable ranges. In particular, the best option for yellow squat lobster was the combination of a 70-mm diamond mesh with an escape panel that reduced non-target and target catches by 48% and 7%, respectively. For nylon shrimp, the best option was the use of a 56-mm diamond mesh with a sorting grid that reduced non-target and target catches by 41% and 11%, respectively. Although the results for red squat lobster were not as promising, they will help to guide future research.

1. Introduction

Chilean crustacean fisheries mainly target the yellow squat lobster (*Cervimunida johni*), the nylon shrimp (*Heterocarpus reedi*), and the red squat lobster (*Pleuroncodes monodon*). These species are caught between 26° and 38°S off the Chilean coast at depths of 100–500 m. The fishery units have been declared "fully exploited" (squat lobsters in the northern area and nylon shrimp) or "in recovery" (squat lobsters in the southern area). As a result, different management measures have been established, such as restricted access, annual catch quotas with spatial and temporal distributions, maximum catches per vessel owner, and spatial and temporal closures for each species. Together, these bottom-trawl fisheries are responsible for 10,550 ton of the annual catch quota (D.E. SUBPESCA N°1675/2008). The commercial fleet consists of 25 vessels that use traditional two-panel trawl nets constructed of knotted polyamide (PA). Construction deficiencies, such as thick twines, heavy materials and small meshes (50 mm knot-centre to knot-centre), result in the poor functional and selective performance of traditional trawl nets (Melo et al., 2008). For these reasons, a new design, mandated by the fisheries authorities, is under evaluation (Queirolo et al., 2009).

Most crustacean fisheries worldwide have a common problem due to the bycatch of a large number of species and, consequently, a high number of discards (Broadhurst et al., 2002a). In the crustacean fisheries in Chile, there are no official records of discards (Cerda et al., 2009), although the scale of the bycatch problem can be inferred from the catch composition. Zilleruelo et al. (2007) reported that the bycatches in these fisheries range between 8% and 23% according to the target species; Chilean hake (*Merluccius gayi*) accounts for the largest proportion, followed by bigeye flounder (*Hippoglossina macrops*), aconcagua grenadier (*Coelorinchus aconcagua*), and armed box crab (*Platymera gaudichaudii*). Acuña et al. (2007, 2009) obtained similar results.

Although the bycatch in these fisheries is relatively low compared to many other crustacean fisheries, effort must be placed on reducing the impact of trawling on the ecosystem, starting by reducing bycatch. It is possible to identify three groups of technological improvements that contribute towards reducing the bycatch of crustacean trawl fisheries: (i) modifying structures and components of the trawl nets, such as bridles and footropes, among others (Hannah and Jones, 2000; Queirolo et al., 2009), (ii) changing the size and shape of meshes (Campos et al., 2003; Guijarro and Massutí, 2006; Krag et al., 2008; Sala and Lucchetti, 2010), and (iii)

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Table 1
Summary of experiments carried out according to target species. The number of hauls is in parentheses. D: diamond mesh; S: square mesh, 56 and 70 are mesh size (knot-centre to knot-centre) in mm.

Experiment	Yellow squat lobster	Nylon shrimp	Red squat lobster
1	D56 (12)	D56 (13)	D56 (6)
	D70 (12)	S56 (15)	D70 (10)
	S70 (15)	D70 (17)	
Area	29°30′–32°40′S	29°35′–32°40′S	29°50′–30°15′S
Depth (m)	160–300	220–430	110–250
Tow duration ± S.D. (h)	0.40 ± 0.12	0.52 ± 0.11	0.45 ± 0.12
2	D56 (12)	D56 (19)	
	D56+Panel (14)	D56+Panel (21)	
	D70+Panel (11)	D56+Grid (7)	
Area	29°50′–32°40′S	29°30′–32°40′S	
Depth (m)	170–280	260–430	
Tow duration ± S.D. (h)	0.52 ± 0.14	0.61 ± 0.17	

installing mechanical or behavioural escape devices such as panels or grids (Isaksen et al., 1992; Broadhurst and Kennelly, 1996; Fonseca et al., 2005; Hannah and Jones, 2007; Briggs, 2010). These can be used individually or by combining the selective properties of each one.

The specific objective of our study was to quantify the bycatch reduction due to the use of (i) different mesh sizes and shapes in the extension and in the codend, and (ii) escape devices in the extension. Two experiments were conducted in the nylon shrimp and yellow squat lobster fisheries. In the case of the red squat lobster fishery, only the mesh size effect was evaluated.

2. Materials and methods

Two experiments were performed in traditional fishing areas (29°30′–32°40′S) (Table 1). The first consisted of the use of different mesh sizes and shapes in the extension and codend in 100 hauls in December 2008. In the second experiment, the use of escape devices was evaluated in 84 hauls between June and July 2009. The trawl used during the trials was the prototype designed by Melo et al. (2008); approximately 42 m long from the wing tips to the codend, with 28.8 m of headrope and 32.9 m of footrope. This two-panel bottom trawl is entirely constructed of knotted polyethylene (PE) netting, with an 80-mm mesh size in the upper panel and a 56-mm mesh in the lower panel (knot-centre to knot-centre). Different mesh sizes, shapes and escape devices for the codend were selected, taking the target species into account. Three commercial trawl vessels were involved (300–320 kW), each using 1-m sweeps and 5-m bridles, according to the results obtained by Queirolo et al. (2009). The hauls were made between 06:30 and 20:00 at depths between 110 and 430 m, with a towing duration of between 15 and 70 min, depending on the experiment and the target species (Table 1). The average speed was 2.0 knots (±0.11 knots).

Both experiments used the covered codend method. The cover was made of knotted polyamide 32-mm mesh (27.04 ± 0.86 mm in internal size), with dimensions 1.5 times larger and wider than the extension and codend, following Stewart and Robertson (1985). To avoid the masking effect, 12 kites were attached to the cover, following the design principle described by Madsen et al. (2001) and the specifications of He (2007). Each kite had a trapezoidal shape, with lengths of 30 and 60 cm on its parallel sides and a height of 30 cm.

2.1. Experiment 1

The 56- and 70-mm diamond meshes (D56 and D70) were tested for the three target species, with the former used as a reference (Fig. 1). In addition, the 70-mm square mesh (S70) was also tested on yellow squat lobster, while the 56-mm square mesh (S56) was tested on nylon shrimp. In the case of red squat lobster, it was only possible to test the diamond mesh due to the low catch quota allocated for this study. The codends were made of knotted PE with a total length of ~12.2 m (10.0 m extension and 2.2 m codend). The internal sizes of the mesh were measured in the N direction using an ICES gauge with 4 kg tension on wet netting: 46.83 ± 1.58 mm (D56), 45.95 ± 1.09 mm (S56), 63.86 ± 1.81 mm (D70), and 63.17 ± 1.75 mm (S70).

2.2. Experiment 2

In the case of yellow squat lobster, two configurations were tested and compared with respect to the reference codend (D56), corresponding to the diamond mesh codends with escape panels (D56+P and D70+P) (Fig. 1). The escape panel consisted of a square mesh section made of 80-mm PE (69.25 ± 1.27 mm of internal size), located on the upper panel, 1 m from the start of the extension. The escape panel dimensions were 40 bar in width and 75 bar in length.

For nylon shrimp, the two configurations tested were 56-mm diamond mesh codends with an escape panel (D56+P) and with a sorting grid (D56+G) (Table 1). The escape panel was similar to that used for experiment 1, while the sorting grid was a Nordmøre-type grid made of steel (1.2 m high × 0.8 m wide). The internal bars of the grid had an 8-mm diameter with a separation of 35 mm between bars. The grid was installed at an angle of 45° and was located 2 m from the forward end of the extension. A guide funnel was used to ensure contact of the catch with the grid. In both experiments, the codends tested were changed after two or three hauls, and the order of use of each codend was randomized.

2.3. Data collected and statistical analyses

After each haul, the codend and the cover were emptied separately, and the catch was placed in trays. When the catch was large, the weight of each species (cw_i) in a haul was estimated based on the average weight of a tray (w) and the total number of trays (t), according to $cw_i = w_i t_i$. The catch, in number (cn_i), was estimated according to $cn_i = d_i cw_i$, where d is the number of individuals per weight unit in a representative sample.

All species other than the target species were considered bycatch. The escape proportions between the codends tested were analysed using linear-mixed models (LMM) for both target and non-target species. The analyses considered only those species with sufficient numbers of individuals caught and that occurred in at least 30% of the hauls made with each configuration. The LMMs were applied using the restricted maximum likelihood (REML) method to identify the significance of any differences in escape proportions. All models included the fixed factor of ‘codend configuration’ and the random effect of ‘days’, and the ‘total catch’ per