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Codend Mesh Selectivity of *Uroteuthis (Photololigo) duvauceli* (d'Orbigny, 1848)

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The Indian squid, *Uroteuthis (Photololigo) duvauceli* (d'Orbigny, 1848) is an important resource exploited by trawlers along the northwest coast of India. The size selectivity for this species in two trawl systems *viz.*, semi-pelagic and bottom trawls and in four mesh sizes (40, 50, 60 and 70 mm) was estimated using covered codend method. The L_{25}, L_{50}, L_{75}, selection range, selection factor and selection ratio for each codend were estimated. The L_{50} values of *Uroteuthis (Photololigo) duvauceli* for the 40 and 60 mm diamond mesh codend attached to the bottom trawl were 7.90 ± 0.16 and 12.02 ± 0.21 cm dorsal mantle length (DML) respectively and the selection factors worked out to be 1.98 and 2.00. The L_{50} values of *Uroteuthis (Photololigo) duvauceli* for the 50 and 70 mm diamond mesh codend attached to the semi-pelagic trawlnet was 9.38 ± 0.12 and 16.36 ± 0.19 cm DML respectively. The selection factors derived were 1.88 and 2.34 respectively for 50 and 60 mm mesh size. In codend mesh sizes of 40 and 50 mm, 65.78 and 80.39% of the individuals caught respectively were below the size at first maturity. In 60 mm mesh size, 40.07% of the individuals was below the size at first maturity while in 70 mm mesh size all the individuals caught were below the length at first maturity.

Key words: Codend, selectivity, square mesh, semi-pelagic, bottom trawl, Indian squid

The Indian squid, *Uroteuthis (Photololigo) duvauceli* (d'Orbigny, 1848) is an important cephalopod resource, mostly landed by trawlers along the northwest coast of India operating in the near shore waters up to a depth of 50 m. The species contributed 35 % by weight of cephalopods landed; while the export values from Gujarat were at Rs. 1586.8 million during 2006-07 (Anon, 2007; Mohanraj *et al.*, 2009).

Veraval in Gujarat state has the largest fishing harbour in this region with more than 3500 trawlers in the size range of 13 to 15.5 m L_{OA} (Anon, 2006). The traditional trawlers operate trawl nets with codend mesh size ranging from 10 to 20 mm, even though the legal codend mesh size to be used is 40 mm square mesh (Anon, 2003). The trawl fishery along the Gujarat coast is showing signs of decline with decreasing catch per unit effort (Mathai *et al.*, 2003) and change in composition of harvested resources (Vivekanandan *et al.*, 2005; Bhathal & Pauly, 2008). The quantity and diversity of incidental catches generated by the trawlers is also high (Pravin & Manohardoss, 1996; Zynudheen *et al.*, 2004). There are no restrictions on the minimum landing size for *Uroteuthis (Photololigo) duvauceli* along the Indian waters. The average length at first sexual maturity (LFM) for the squid along the west coast of India is worked out to be 122 mm dorsal mantle length (DML) for males and 128 mm DML for females (Meiyappan *et al.*, 2000; Meiyappan & Mohamed, 2003).

The sustained exploitation of any marine living population requires management interventions, among which the regulation of codend mesh size is one of the most

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appealing due to its conceptual simplicity and ease of implementation in experimental frameworks (Reeves *et al.*, 1992; Ragonese & Bianchini, 2006). Codend is the part from which the major escapement of fish takes place in a trawl net (Beverton, 1963) and hence information, on the selectivity of different trawl codend mesh size for a species will be an important input for management.

In the last decade a large number of studies have been conducted on the codend selectivity of trawls and as a result many of the technical problems and factors affecting the selection process were elucidated (Holst *et al.*, 2002; Madsen & Holst, 2002; Madsen, 2007). Though a lot of information is available on codend selection process for finfish, those related to codend selectivity for cephalopods are relatively less. Codend selectivity of European squid (*Loligo vulgaris*) and Broadtail shortfin squid (*Illex coindetii*) in fishtrawls with three codend meshsizes by Fonseca *et al.* (2002) along Portuguese waters, the relation between the mesh circumference and the shape of *Loligo* sp. by Matsushita & Ali (1997), codend selectivity parameters for squid in Australian waters by Liu *et al.* (1985) and for *Loligo forbesi* by Hastie (1996) are some of the studies reported on the codend selection for cephalopods.

In the Indian scenario, selectivity parameters of 20, 30 and 40 mm square mesh codends for the Indian squid were estimated by Kunjipalu *et al.* (2001). No other study exists on the selectivity of squids in trawls with meshsizes larger than 40 mm along the Indian waters (Boopendranath & Pravin, 2005; Kunjipalu *et al.*, 1994; Varghese *et al.*, 1996). This study is an attempt to derive the selectivity parameters of trawl codends with mesh sizes of 40, 50, 60 and 70 mm for *Uroteuthis* (*Photololigo*) *duvauceli* along the northwest coast of India.

Materials and Methods

Trawl selectivity experiments were carried out onboard the Central Institute of Fisheries Technology, research trawler, MFV Sagarkripa (L_{OA} 15.5 m, 124 HP, stern trawler), from October 2005 to May 2006. The study was carried out in the commercial fishing grounds off Veraval, Gujarat, India in the depth zone of 20-45 m. The overall dimensions and installed engine power of the vessel were similar to that of the commercial vessels operating in the region. An 18 m semi-pelagic trawl net (18 m RMT 8P) and 34 m high opening bottom trawl (HOBT) were used for the study.

Four different codend mesh sizes were employed for the study *viz.*, 70 and 50 mm diamond mesh codends (nominal mesh size) with the semi-pelagic trawl designated as SP70 and SP50 respectively. BT60 and BT40 corresponded to 60 and 40 mm diamond mesh codends (nominal mesh size) in the bottom trawl. The details regarding the experimental nets and the operations carried out are given in Table 1. The 70 and 60 mm mesh codends were made of 1.5 mm dia HDPE twine while the 50 and 40 mm mesh codends were of 1.2 mm dia Sapphire™ (Garware, 2010) webbing.

The mean mesh size for the experimental codends was determined by measuring 60 randomly selected meshes using a calibrated wedge. The mean mesh sizes in mm for the different codends were 70 ± 2.05, 60 ± 0.89, 50 ± 1.02 and 40 ± 0.57 respectively.

Covered-codend method as described by Wileman *et al.* (1996) was used to estimate the selectivity of the different codends. A proportionately 30% larger (by length and breadth) codend cover made of polyamide (PA) was used to minimize the masking effect of the codend by the cover (Wileman *et al.*, 1996; Lök *et al.*, 1997). The experimental trawling operations were carried out during day time and uniform shooting and hauling procedures were adopted for the entire fishing operations. The duration of a single tow varied from 1.5 to 2.0 hours and the speed of trawling varied from 2.0 to 2.2 knots for the bottom trawling which was same as

Table 1. Details of experimental trawl nets and trawling operations

Codend Types (Code)	Type of operation	Codend material (Type and Diameter)	Codend mesh size (mm) and shape	No. of valid hauls	Specifications of net and otter boards
SP70	Semi-pelagic *trawling*	HDPE *twisted* 1.5 mm dia	70 *(diamond)*	16	*18 m RMT 8P semi-*pelagic trawl fitted with Suberkrub otterboards
SP50	Semi-pelagic Trawling	Sapphire™ 1.2 mm dia	50 (Diamond)	9	(115x89 cm; 90 kg each)
BT60	Bottom Trawling	HDPE twisted 1.5 mm dia	60 (Diamond)	11	34 m Bottom trawl fitted with V-form otterboards
BT40	Bottom Trawling	Sapphire™ 1.2 mm dia	40 (Diamond)	13	(79x136 cm; 85 kg each)

the commercial operations. For the semi-pelagic trawling experiments (Semi-pelagic trawling is not practiced commercially), the trawling speed varied from 2.4 to 2.6 knots. At the end of each tow, the catch from the cover and codend were kept separately and after sorting, individual species were weighed and the DML measured to the nearest 0.5 cm. Since sex wise classification of the catches was not carried out, the LFM for *Uroteuthis (Photololigo) duvauceli* was taken as 122 mm, corresponding to the LFM of males for assessing the proportion of species above and below the LFM.

Uroteuthis (Photololigo) duvauceli encountered in the codend and cover for the respective codend under study was first pooled and the data were analyzed for each codend separately. The factors that can influence the selection properties like the time of the haul, season and variation in codend catch were considered to be constant for estimating the selectivity of the codends (Stewart & Robertson, 1985; Carlucci *et al.*, 2006). Logistic selection curve was fitted based on the model r (l) = exp (a + bl)/[1 + exp (a + bl)], where r (l) is the probability that a squid of length l entering the net is retained by the trawl net and the parameters a and b, are the intercept and the slope coefficients respectively. Selectivity parameters were estimated using the coefficients a and b derived by maximum likelihood method (Wileman *et al.*, 1996; Ragonese *et al.*, 2002). The R-function code by Millar (2003) using the package *nlm*, which is the built-in numerical optimizer in R-software (Ihaka & Gentleman, 1996; R Core team, 2008) was used for the analysis. The length at 25, 50 and 75% retentions, represented as L_{25}, L_{50} and L_{75} respectively, selection range (SR), selection factor (SF) and selection ratio were also calculated for the different codends. The calculations of SF and SR were based on the nominal mesh sizes.

Results and Discussion

The results of the estimated selectivity curves and the regression parameters (with standard errors and variance matrix values) of the curves are shown in Table 2. The pooled selectivity ogives and the length frequency distributions of the squids retained and escaped from the different codends are also shown along with the selectivity curves in the Fig. 1, 2, 3 and 4.

For semi-pelagic trawl (SP70), total of 16 valid hauls were considered for the analysis and the mean DML ± SE at 50% retention probability and SR were 16.36 ± 0.19 and 3.38 ± 0.21 cm respectively. The SF and selection ratio were 2.34 and 0.48

Table 2. Selection parameters of *Uroteuthis (Photololigo) duvauceli* obtained from pooled data in the two trawling system with different meshsizes. 25% retention lengths (L_{25}), 50% (L_{50}) and 75% retention lengths (L_{75}), selection range (SR), Selection factor (SF), regression parameters (a and b), their standard errors (in brackets), variance matrix values (R_{11}, R_{12} and R_{22}) and number of fish in the codend and cover from all the hauls in different codends.

Parameters	Codend Types (Code)			
	BT40	**SP50**	**BT60**	**SP70**
No. of hauls	13	9	11	16
L_{50}	7.90 (0.16)	9.38 (0.12)	12.02 (0.21)	16.36 (0.19)
L_{25}	5.98 (0.19)	7.99 (0.19)	9.78 (0.22)	14.67 (0.18)
L_{75}	9.83 (0.20)	10.77 (0.15)	14.27 (0.29)	18.05 (0.26)
a	- 4.51	- 7.43	- 5.87	- 10.63
b	0.57	0.79	0.49	0.65
SR	3.85 (0.23)	2.77 (0.23)	4.49 (0.28)	3.38 (0.21)
SF	1.98	1.88	2.00	2.34
S ratio	0.96	0.55	0.75	0.48
R_{11}	0.075	0.431	0.126	0.406
R_{12}	- 0.009	- 0.043	- 0.011	- 0.026
R_{22}	0.001	0.004	0.001	0.002
Codend	488	408	282	195
< LFM	321 (65.78 %)	328 (80.39 %)	113 (40.07 %)	0 (0.00 %)
> LFM	167 (34.22 %)	80 (19.61 %)	169 (59.93 %)	195 (100 %)
Cover	502	333	863	647
< LFM	498 (99.20 %)	326 (97.90 %)	807 (93.51 %)	443 (68.47 %)
> LFM	4 (00.80 %)	7 (2.10 %)	56 (06.49 %)	204 (31.53 %)

respectively. This is the first report of selectivity of 70 mm codend mesh for *Uroteuthis* spp. and hence comparisons could not be made with similar studies. Codend selectivity of related species in the Scottish waters *viz.*, *Loligo forbesi* for 75 mm diamond

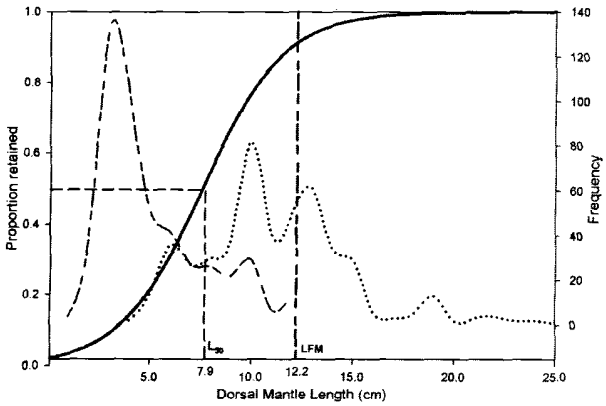

Fig. 1. Selection curve and length frequency distribution of *Uroteuthis (Photololigo) duvauceli* in 40 mm diamond mesh codend (BT40). Pooled selectivity curve (thick continuous line), length frequency distribution of the population retained in the codend (dotted line), population entering the cover (dashed thin line), L_{50} and length at first maturity (LFM) (dashed thick line).

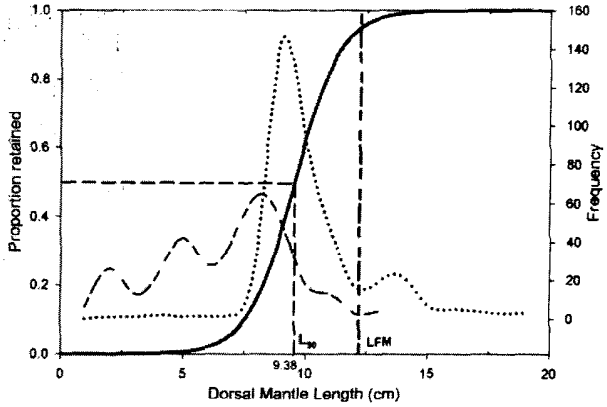

Fig. 2. Selection curve and length frequency distribution of *Uroteuthis (Photololigo) duvauceli* in 50 mm diamond mesh codend (SP50). Pooled selectivity curve (thick continuous line), length frequency distribution of the population retained in the codend (dotted line), population entering the cover (dashed thin line), L_{50} and length at first maturity (LFM) (dashed thick line).

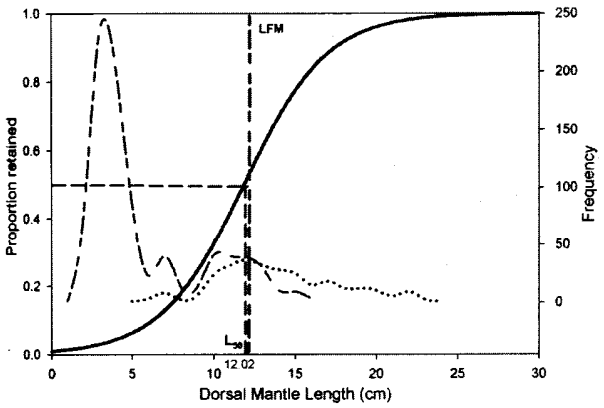

Fig. 3. Selection curve and length frequency distribution of *Uroteuthis (Photololigo) duvauceli* in 60 mm diamond mesh codend (BT60). Pooled selectivity curve (thick continuous line), length frequency distribution of the population retained in the codend (dotted line), population entering the cover (dashed thin line), L_{50} and length at first maturity (LFM) (dashed thick line).

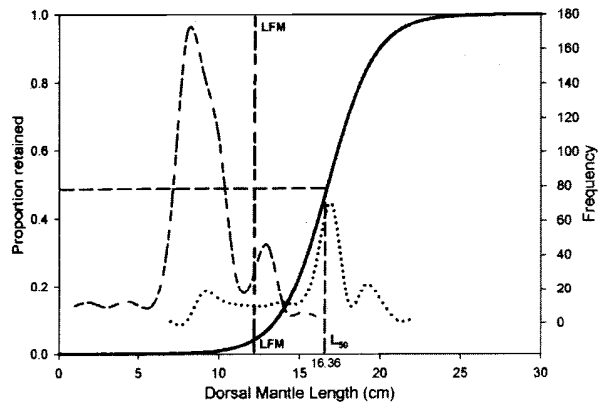

Fig. 4. Selection curve and length frequency distribution of *Uroteuthis (Photololigo) duvauceli* in 70 mm diamond mesh codend (SP70). Pooled selectivity curve (thick continuous line), length frequency distribution of the population retained in the codend (dotted line), population entering the cover (dashed thin line), L_{50} and length at first maturity (LFM) (dashed thick line).

mesh codend using three research vessels with estimated L_{50} of 14.6, 13.9 and 14.9 respectively was reported by Hastie (1996). The L_{50} value for *Uroteuthis* spp. was higher in 70 mm diamond mesh codend than in 75 mm double braided meshes for *Loligo forbesi* (Hastie, 1996). Use of double braided twines (Özbilgin & Tosunoglu, 2003; Sala *et al.*, 2007) and difference in morphology of the species (Matsushita & Ali, 1997; Tosunoglu, 2007) can be the reasons for comparatively lower selectivity of 75 mm braided mesh than 70 mm codend mesh used in the present study. For the European squid, selectivity parameters estimated for 80 and 90 mm mesh size codends had L_{50} of 9.7 and 11.4 cm respectively and SF of 1.3 for both codends (Foneska *et al.*, 2002). For the broadtail shortfin squid, the L_{50} and SF estimated for the 65 mm mesh size were 9.5 cm and 1.5 respectively. The much lower values for the L_{50} and SF in comparison to mesh sizes used in the present study can be due to the double polyethylene twine used in the codend (Özbilgin & Tosunoglu, 2003).

For calculating the selectivity parameters of semi-pelagic trawl (SP50) codend, data from 9 hauls were used. The L_{50} and SR were 9.38 ± 0.12 and 2.77 ± 0.23 cm respectively. The SF and the selection ratio were 1.88 and 0.55 respectively. In the case of bottom trawling, the L_{50} values were 12.02 ± 0.21 and 7.90 ± 0.16 cm respectively for the BT60 (11 hauls) and BT40 (13 hauls) trawl codends. The SR for BT60 was 4.49 ± 0.28 cm and for BT40 it was 3.85 ± 0.23 cm. The SF for the BT60 and BT40 codends were 2.00 and 1.98, while the selection ratios were 0.75 and 0.96 respectively. The L_{50} value for 40 mm square mesh codend for *Loligo* spp. off Cochin was reported to be 8.32 cm (Kunjipalu *et al.*, 2001). In the present study the L_{50} of diamond mesh codend of 40 mm was 7.9 cm, lower than that of the square mesh codend of 40 mm reported by Kunjipalu *et al.* (2001). Even though the results of the studies of Kunjipalu *et al.* (2001) cannot be directly compared with the present study, the values obtained were in general agreement with the reports that square mesh codends were more selective than the diamond shaped mesh codends (Briggs, 1992; Thorsteinsson, 1992; Tokaç *et al.*, 1998; Bahamon *et al.*, 2006; Bullough *et al.*, 2007).

The selectivity of 70 mm diamond mesh codend *viz.*, L_{50} of 16.36 ± 0.19 was higher than the 60 mm diamond mesh codend with L_{50} of 12.02 ± 0.21, which was very close to the LFM of 12.2 cm for this species. The L_{50}

values for the 50 and 40 mm diamond mesh codends, which were 9.38 ± 0.12 and 7.9 ± 0.16 cm respectively, were lower than the LFM of *Uroteuthis (Photololigo) duvauceli.*

In the semi-pelagic trawlnet with 70 mm codend, out of the total 842 individuals which entered the codend, 76.84% escaped and all the escapees had DML higher than the LFM. In the case of the 60 mm diamond mesh codend attached to the bottom trawl, of the 1145 individuals that entered the codend, 75.37% escaped and 59.93% of the individuals retained had lengths greater than the LFM. In 50 mm diamond mesh codend attached to the semi-pelagic trawl net, 44.94% of the individuals which entered the codend escaped and 80.39% of the individuals retained in codend had lengths lower than LFM while only 19.61% of the individuals had L_{50} lengths above the LFM. In the case of 40 mm diamond mesh codend attached to the bottom trawl, 50.70% of the individuals had escaped. In the retained catch, 65.78% was below the LFM.

A percentage increase of 42.66 and 19.66 respectively in the L_{50} and selection factor was observed when the codend mesh size increased from 50 to 70 mm in the semi-pelagic trawl. In the demersal trawls an increase in mesh size from 40 to 60 mm caused an increase in the L_{50} by 34.28% and the selection factor by 1%.

Taking into account the retention and the escapement pattern of individuals from the different codends studied, it was noticed that 60 mm diamond meshes allow half of the proportion of the individuals below the LFM to escape and the escapement of individuals with lengths above the LFM accounted to only 6.49 % (Table 2). So a codend mesh size of 60 mm can be used in bottom trawls targeted for cephalopods for selective fishing to maintain the reproductive potentiality of *Uroteuthis (Photololigo) duvauceli* along northwest coast of India.

The study demonstrated that the mesh sizes presently used (15-20 mm diamond meshes) in trawls by the fishermen are grossly insufficient for the conservation of *Uroteuthis (Photololigo) duvauceli* resource along the north west coast of India. Hooped codend covers were not used in this study and so the results may be biased due to some masking effect by the cover and hence the results have to be interpreted with caution (Madsen & Holst, 2002). Fonseca *et al.* (2002) suggested that the soft bodied nature of the squids help in their easy escapement from the codend by squeezing through the meshes. Escape from the smaller mesh may lead to abrasion and skin lesions in the juvenile squid which is the main reason for mortality (Yang *et al.*, 1986). The use of large mesh codends can result in more live escapees than from small mesh codends. The survival of juvenile squids escaping the codends also needs to be studied before recommending an optimum mesh size for conservation of squid resources along Gujarat coast.

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