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Selectivity of Trawls

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Responsible fishing regime requires that fishing gear should preferentially catch the adult fish at a particular age, which would maximize yield while permitting the juveniles and sub-adults to escape and also minimize the catch of non-targeted and protected organisms. In this review, selectivity characteristics of trawls are discussed in the context of their relevance in conservation of fishery resources, development of selective fishing gears and fisheries management. Different methods used for determining trawl selectivity are discussed along with recent developments related to trawl selectivity such as evolution of selective trawls, use of square mesh in trawl construction, and optimum mesh size determination for multi-species trawl fisheries.

Key words: Trawl selectivity, mean selection length, selection range, selection factor, selective trawl, square mesh panel, optimum mesh size

The property of any fishing gear or method, which causes the probability of capture to vary with the characteristics of fish, is called selectivity. Selectivity mainly depends on the principles of fish capture and on the intrinsic design features of the gear itself. Information on gear selectivity is important in biological investigations, fish stock assessment, fisheries management and fishing gear design and development. In biological investigations and resource assessment surveys, to estimate the true age structure of the population it is necessary to account for the effect of selection of the sampling gear (Sparre *et al.*, 1989). Good fisheries management and responsible fishing regime requires that fishing gear should preferentially catch the adult fish at a particular age, which would maximize yield while permitting the juveniles and sub-adults to escape and also minimize the catch of non-targeted and protected organisms. Selectivity data are required to prescribe optimum mesh size for particular species or species groups to meet the objectives of yield optimization and conservation of resources (Pope *et al.*, 1975; ICNAF, 1983; Sparre *et al.*, 1989; McLennan, 1992; DFO, 1995). Size selectivity in trawls range from average to low, compared to high size selectivity in gill nets, lines and traps (Thompson & Ben-Yami, 1984; Hameed & Boopendranath, 2000). Selectivity characteristics of trawls are discussed here in the context of their relevance in conservation of resource, development of selective fishing gears and fisheries management.

Trawl selectivity characteristics

Literature on trawl selectivity has grown over the past nine decades, beginning with the earlier works by Todd (1911), Davis (1929, 1934), Jensen (1949), Clark (1952), Graham (1954), Thompson & Ben-Yami (1984) and others, with continuous refinement of techniques and analytical procedures. Framework for investigation of selectivity of various fishing gears have been described in several works, e.g. Pope *et al.* (1975), ICNAF (1983), Pauly (1984), Sparre *et al.* (1989), McLennan (1992), DFO (1995), Fryer (1991), Miller & Walsh (1992) and Wileman *et al.* (1996).

Since netting is used in the capture process and retention of the catch in a trawl, mesh size of the netting has the greatest influence on selectivity. Among other intrinsic design features which influence selectivity of trawls are mesh configuration (diamond, square and hexagonal), load on twine, material and thickness of twine, hanging ratio, towing speed, towing duration, use of lastridge ropes in codend and type of ground rig (Brandt, 1963; Clark, 1963; Briggs, 1986). Most of the size selection occurs in the codend and hence codend selection has received greater attention of research workers. Escapes of fish are also known to take place through forward net panels and underneath the ground rope (Ellis, 1963; Clark, 1963; Bennett, 1984; Godo & Walsh, 1992) indicating the importance of studies on whole trawl selection. Typical trawl selection process is given in Fig. 1.

Determination of codend mesh selection

Selectivity of trawls is generally determined by trawl selection experiments. In such experiments, it is assumed that size composition of the fish entering the mouth of trawl is the same as that in the ambient environment. Escapes of fishes that has entered the net, through trawl mesh, determines selectivity.

Measurement of mesh size

Internal mesh size (mesh lumen) measured when the net is wet is most commonly used for selectivity studies (Fig. 2). It is the inside distance between two opposite knots in the same mesh when fully extended in the diagonal direction (Pope *et al.*, 1975). There are two systems of pressure gauges for measuring the mesh size. One is pushed vertically into the mesh and other operates longitudinally. The former type (Westhoff *et al.*, 1962) has been recommended as standard gauge for scientific purposes by ICES and is now widely used for mesh measurement during selectivity studies, with an operating pressure of 4 kg. Average of a number of measurements taken at random on the operative part of the net

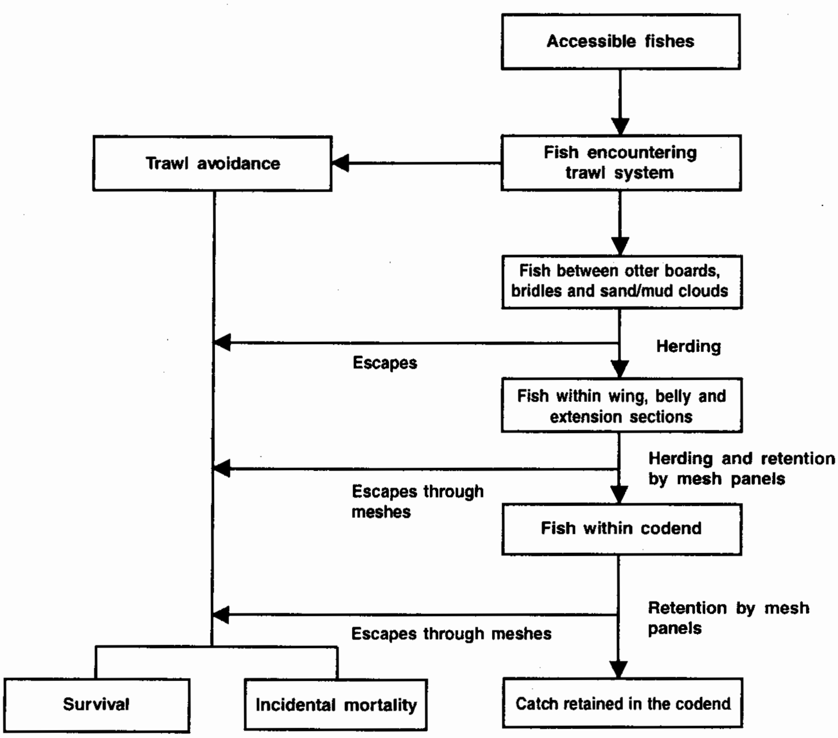

Fig. 1. Trawl selection process

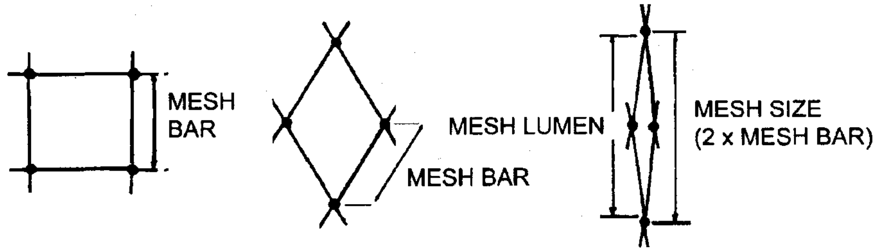

Fig. 2. Mesh measurements

is used and information on twine size, material, construction, whether single or double twine, knotted or knotless, wet or dry, are recorded.

Covered codend method

Selectivity data may be obtained by attaching a small-meshed (usually 15-30 mm stretched mesh) cover over codend or other parts of the trawl to retain animals escaping trough the trawl (Beverton & Holt, 1957; Pope *et al.*, 1975; Jones, 1976). The use of such covers has been criticized on the grounds of its masking effect on codend meshes (Davis, 1934; Pope *et al.*, 1985). Investigations of Stewart & Robertson (1985) have indicated that a cover, which is 1.5 times the length and width of a codend is unlikely to obstruct the codend meshes (Fig. 3.). Use of hoop to keep the cover separated from codend may improve the performance (DFO, 1995).

Covered codend method is a simple method in which a commercially used trawl design can be adapted for the experiment, after substituting the codend. It is possible to use data from each haul to estimate the selection curve.

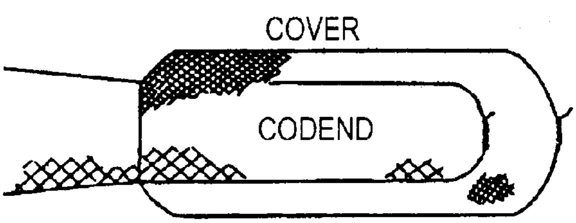

Fig. 3. Schematic diagram of codend and cover

Trouser trawl method

In the trouser trawl method, two codends – one having the mesh size for which the selective properties are to be determined and the other with a much smaller mesh size – are attached to a single trawl. In some cases, a vertical separation panel, which extends from the trouser codends to the trawl mouth, may also be used for best results (Fig. 4). It may be ensured that the openings to the codends are approximately equal to the dimensions of a single codend on a single trawl. The catch in the small mesh codend is taken as sample of the population.

In the trouser trawl experiment, an initial assumption used for calculation of selectivity is that fish encountering the gear enters either side with equal probability. This assumption of 50:50 split is not always satisfied due to differences in sampling area, water flow through small and large meshes, herding effect or by chance factors (Pope *et al.*, 1975; Walsh *et al.*, 1992) as indicated by unequal catch of large fishes in the two codends. When equal split assumption is seen to be violated, the catch in the small mesh is adjusted by the ratio of large fish in the two codends (Pope *et al.*, 1975). In a recent development, Millar & Walsh (1992) have developed a new statistical model for analysis of trouser trawl data even when 50:50 split assumption is violated, without the need for modifying the data.

Twin trawl, parallel haul and alternate haul method

Two trawls of similar design and rigging differing only in codend meshes are operated either in parallel tows from one or two vessels or in alternate tows from the same vessel, in the same fishing ground maintaining the operating parameters unchanged during successive operations, to facilitate statistical comparison of size composition. The assumption used here is that the expected number of fish encountering both the trawls is the same. Analytical procedures are similar to trouser trawl method.

Selection ogive

Selection curve for trawls giving proportion retained for each length class, normally assumes a sigmoid form (Fig. 5). It is either fitted by eye or plotted by using statistical methods. It may extend over a range of length of fish. The young fish, which begins to grow into selection range, suffer only little fishing mortality. As the fish grow larger, the chance of escaping from the net become increasingly less and eventually they grow too large to escape. Different models are used for fitting trawl selection curves. Weighted Least Squares and Maximum Likelihood method are used to fit the observed data to the curve, of which maximum likelihood method is seen to give better results (DFO, 1995). Another method is the SELECT methodology proposed by Miller & Walsh (1992), which gives accurate selectivity estimates even when the fishing efficiencies are not equal.

Mean selection length, selection range and selection factor

The results of trawl selectivity experiments are often presented in terms of three parameters, viz., mean selection length, selection range and selection factor.

An estimate of the mean size at first capture or mean selection length is given by the length at which 50 per cent of the fish entering the trawl is retained by the gear (50% retention length) (Fig. 5). Selection curves differ in their sharpness depending on whether selection occurs over small or wide range of sizes. This is usually measured by the selection range, which is the difference between the 25% and 75% retention lengths (L25 and L75) (Fig. 5). The mean selection length is generally proportional to the mesh size of the codend over a certain

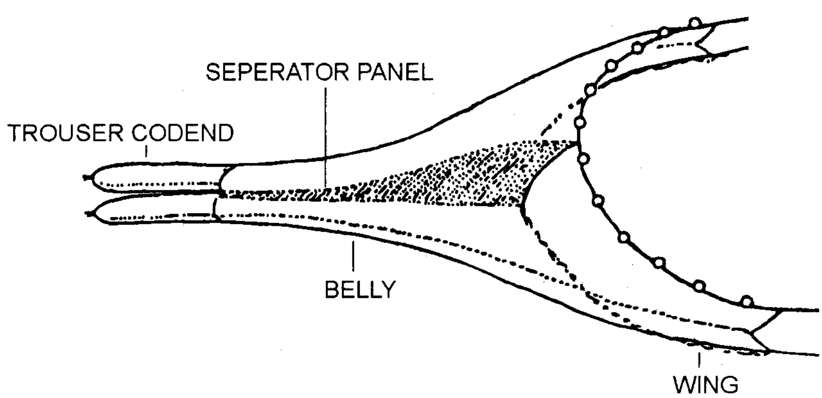

Fig. 4. Schematic diagram of trouser trawl with vertical separation panel

range. The proportionality constant is called selection factor (SF).

Mean selection length = SF x mesh size

The mean selection length can thus be calculated for any specified mesh size once the value of selection factor for particular species of fish and the type of material is determined through selectivity experiments. However, in many cases, selection factor is dependent on the mesh size (Liu, 1985). Selection factor is used for comparison of selective properties of different materials and their construction (McCracken, 1963; Brandt, 1963). Selection factor is generally related to overall shape of the fish; slender fish have high selection factor while bulky, tall-bodied fish have low selection factor.

Logistic curve

The logistic curve is a simple and symmetrical model, which is commonly used to describe trawl selection ogive (Sparre *et al.*, 1989):

$$SL = 1/\ 1+\exp(S1-S2*L)$$

Where SL is the function of the ogive defining for each length L, the fraction of fish retained in the codend; S1 and S2 are constants determined by linear least square estimation or maximum likelihood estimation from observed length frequencies for each species. L50, L25, L75, selection range, selection factor are calculated as below:

$$L50 = (S1/\ S2)$$
$$L25 = (S1 - \ln 3)\ /\ S2$$
$$L75 = (S1 + \ln 3)\ /\ S2$$
$$\text{Selection range} = L75 - L25$$
$$\text{Selection factor} = L50\ /\ \text{Mesh size}$$

Selectivity parameters reported for some fishes caught in Indian waters, obtained using covered codend experiments and logistic model are given in Table 1.

Robert's curve

Another sigmoid curve model frequently used for trawl selection is Robert's curve, which is mathematically more complex, but allows for asymmetry (Millar, 1991). The asymmetry is accomplished by using a third parameter S in addition to the two parameters S1 and S2 used in logistic equation. When S=1, the curve is equivalent to logistic curve.

$$SL = (1/\ 1+\exp(S1-S2*L))^{1/s}$$

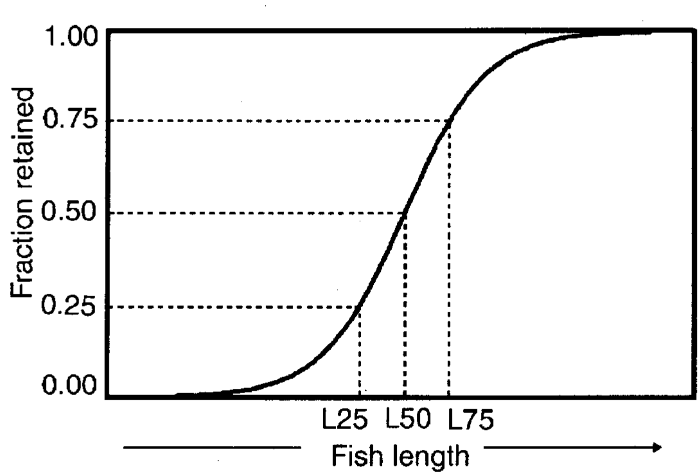

Fig. 5. Typical selection curve for trawls

Table 1. Selectivity parameters reported for some species caught in Indian seas

Species	TL/ FL	Codend mesh size (mm) / mesh type	L25, mm	L50, mm	L75, mm	Sel. range	Sel. factor	Reference
Caranx para	TL	40 S	109	120	132	23	3.01	Kunjipalu *et al.* (2001)
Dussumieria acuta	TL	20 D	63	78	94	31	3.88	Varghese *et al.* (1996)
Dussumieria acuta	TL	20 S	67	81	96	29	4.07	Varghese *et al.* (1996)
Dussumeiria acuta	TL	30 S	89	98	107	17	3.27	Kunjipalu *et al.* (2001)
Johnius borneensis	TL	40 D	107	111	116	9	2.78	Liu *et al.* (1985)
Johnius borneensis	TL	55 D	155	168	180	25	3.05	Liu *et al.* (1985)
Lacatrius lactarius	TL	25 S	59	69	80	21	2.77	Kunjipalu *et al.* (2001)
Leiognathus bindus	FL	40 D	59	63	67	8	1.58	Silvestre *et al.* (1986)
Leiognathus equulus	FL	78 D	122	142	162	40	1.82	Pauly (1984)
Leiognathus leuciscus	FL	40 D	61	68	75	14	1.70	Silvestre *et al.* (1986)
Lutjanus vitta	TL	100 D	240	252	263	23	2.52	Liu *et al.* (1985)
Metapenaeus dobsoni	TL	20 D	34	50	66	32	2.49	Varghese *et al.* (1996)
Metapenaeus dobsoni	TL	20 S	45	58	72	27	2.94	Varghese *et al.* (1996)
Metapenaeus dobsoni	TL	30 S	54	61	69	16	2.05	Kunjipalu *et al.* (2001)
Lutjanus lineolatus	TL	40 S	52	71	91	39	1.78	Silvestre *et al.* (1986)
Nemipterus japonicus	TL	30 S	84	101	118	33	3.4	Kunjipalu *et al.* (1994)
Nemipterus japonicus	FL	40 D	82	91	100	18	2.26	Silvestre *et al.* (1986)
Nemipterus japonicus	FL	40 D	117	132	147	30	3.3	Jones (1976)
Nemipterus nematophorus	FL	40 D	69	80	91	22	1.99	Silvestre *et al.* (1986)
Parapeaneopsis stylifera	TL	20 D	33	42	55	22	2.12	Varghese *et al.* (1996)
Parapeaneopsis stylifera	TL	20 S	42	53	66	24	2.62	Varghese *et al.* (1996)
Parapeaneopsis stylifera	TL	30 S	55	64	73	17	2.13	Kunjipalu *et al.* (2001)
Pentaprion longimanus	FL	40 D	71	83	89	18	2.08	Silveste *et al.* (1986)
Pentaprion longimanus	TL	55 D	99	115	120	21	2.09	Liu *et al.* (1985)
Pomadasys hasta	TL	100 D	223	251	271	48	2.51	Liu *et al.* (1985)
Priacanthus hamrur	TL	100 D	178	192	205	27	1.92	Liu *et al.* (1985)
Saurida tumbil	TL	30 D	110	124	140	30	4.2	Kunjipalu *et al.* (1994)
Saurida tumbil	TL	30 S	115	132	150	35	4.4	Kunjipalu *et al.* (1994)
Saurida tumbil	FL	40 D	60	74	89	19	1.86	Silveste *et al.* (1986)
Saurida micropectoralis	FL	55 D	97	153	213	116	2.78	Liu *et al.* (1985)
Saurida micropectoralis	FL	100 D	253	274	295	42	2.74	Liu *et al.* (1985)
Saurida undosquamis	TL	40 D	86	96	106	20	2.4	Silvestre *et al.* (1986)
Saurida undosquamis	TL	100 D	215	258	301	86	2.8	Liu *et al.* (1985)
Sphyraena forsteri	FL	55 D	152	168	185	33	3.05	Liu *et al.* (1985)
Stolephorus indicus	TL	40 D	92	103	115	23	2.58	Silvestre *et al.* (1986)
Terapon theraps	TL	55 D	117	126	134	17	2.28	Liu *et al.* (1985)
Thryssa purava	TL	20 D	52	67	79	28	3.37	Varghese *et al.* (1996)
Thryssa purava	TL	20 S	49	68	85	35	3.39	Varghese *et al.* (1996)
Upeneus sulphureus	FL	40 D	84	94	103	19	2.34	Silvestre *et al.* (1986)

TL: Total length; FL: Fork length ; D: Diamond mesh; S: Square mesh

Recent advances related to trawl selectivity

Among the recent developments related to trawl selectivity could be mentioned, (i) evolution of selective trawls, (ii) use of square mesh panels and codend in trawl construction, (iii) optimum mesh size determination for multi-species trawl fisheries.

Selective trawls

Over the last thirty years much research has been done on the development of selective trawls. In selective trawl, differences in size selection are made use of, to separate the catch components by installation of specially designed sorting panels or rigid devices (FAO, 1973; Watson & McVea, 1977; Watson & Seidel, 1980; Main & Sangster, 1982; Watson, 1989; Prado, 1997). Selective trawls helps to reduce man-hours spend on sorting the catch and to reduce the volume of undesirable bycatch of non-target species and juveniles as for instance in shrimp trawling.

Square mesh panels and codends

Selectivity experiments using square mesh codends have shown that square meshes are more selective for many species than conventional diamond meshes (Robertson, 1983; Robertson & Stewart, 1988; Walsh *et al.*, 1992; Varghese *et al.* 1996). The main reason for improved selectivity is that square mesh remains open all along the codend, whereas diamond meshes tend to distort due to longitudinal and transverse tension on mesh bars depending on catch size, current and other factors. In the case of flat fishes where selection is related to width rather girth of fish, square mesh codend is seen to be less effective in releasing young ones (Walsh *et al.*, 1992).

Optimum mesh size for multi-species trawl fisheries

While determination of optimum mesh size for single species fisheries is relatively simple once the population parameters are known and selectivity data are collected, it is more complicated in multi-species fisheries. Currently available analytical procedures for determination of optimum overall mesh size for multi-species trawl fisheries are (i) the 'abundance weighted average' method (Sinoda *et al.*, 1979), (ii) the 'iterative aggregate yield' method, (Sainsbury, 1984) and (iii) 'aggregate yield response surface' procedure (Silvestre, 1986). The first one utilizes the relative abundance and, optionally the relative market value of the species constituting the fisheries in determining the optimum overall mesh size. The other two methods estimate the mesh size providing the greatest yield, based on Beverton & Holt (1957) yield model for single species population.

There is global interest in methods for improving the size and species selectivity of commercial trawl gears, in order to reduce unintentional fishing mortality and impacts of fishing systems and to conserve fishery resources. It is often necessary to distinguish between gear dependent (intrinsic) selection and gear-independent (extrinsic) selection, as the process of selection may begin to operate even before fish come into contact with the fishing gear (Parrish, 1963). Studies on intrinsic gear selection have mainly focused on independent effect of particular gear parameters such as mesh size of the codend of trawl. Total gear selection obtained from the combined effect of different gear characteristics, which are useful in the development of selective and efficient fishing gear design, are much less understood.

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