Overview of Trawl Gear Selectivity Studies and Analysis

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Introduction

The property of any fishing gear or method, which causes the probability of capture to vary with the characteristics of fish, is called selectivity. This happens because the targeted fish populations are heterogeneous in species, age, size and shape, behaviour, habitat, etc., and the physical environment also plays and important role in changing these behavioural characteristics, thus making species differ in their vulnerability to capture.

Selectivity mainly depends on the principles of fishing method used and on the intrinsic design features of the gear itself. Table: 1, shows the variation in size selectivity characteristics of some important fishing gear types.

Table: 1 Size selectivity characteristics of some important fishing gears

Fishing gear system	Size selectivity
Gill nets	High
Hooks and lines	High
Traps	High
Trolling lines	High
Purse seines	Low
Trawl nets	Average to low
Entangling nets	Average to low

Selectivity is expressed as the proportion of catch at each size category retained by the fishing gear, and hence is derived by calculating for each size class, the actual catch as a fraction of the total catch viz., the catch retained by the gear plus the portion that escapes.

Size selectivity of the fishing gear often represented by a selection curve, giving for each size of fish species, the proportion of the population of that size which is caught and retained by the fishing gear, often derived from multiple-hauls.

Significance of fishing gear selectivity

Information on gear selectivity is important in biological investigations, fish stock assessment, fisheries management and fishing gear design and development.

In resource assessment surveys, it is necessary to account for the effect of selection of the sampling gear, to estimate the true age structure of the population

Objectives of fisheries management and responsible fishing regime require that fishing gear should preferentially catch the fish at a particular age/size, which would maximize yield, while permitting the juveniles and sub-adults to escape. Selectivity data are required to prescribe optimum mesh size / hook size for particular species or species groups to meet the objectives of yield optimization and conservation of resources.

Literature on fishing gear selectivity has grown over the past nine decades, beginning with the earlier works by Todd (1911), Baranov (1954), Davis (1929, 1934), Clark (1952), Graham (1954) and others, with continuous refinement of techniques and analytical procedures.

Selectivity characteristics of trawls discussed here is in the context of their relevance in conservation of resource, development of selective fishing gears and fisheries management. General principles and description of trawls and operation are discussed by Brandt (1984), Nedlec (1982), Sainsbury (1996), Boopendranath and Pravin (2005) and others.

Trawl gear selectivity

Trawl is a conical bag net, which is towed through water by one or a pair of fishing vessels. Different accessories keep the mouth of the gear open and the catch entering the mouth gets concentrated at the tail end of the trawlnet called codend.

Since netting/webbing 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. 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, and type of ground rig. Most of the size selection occurs in the codend and hence codend selection has received greater attention of research workers.

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. The measurement of the escapees from the gear is difficult and different methods are used to access it.

Measurement of mesh size

Internal mesh size (mesh lumen) measured when the net is wet is most commonly used for selectivity studies (Fig. 1). It is the inside distance between two opposite knots in the same mesh when fully extended in the diagonal direction (Pope *et al.*, 1975). The standard gauge for scientific purposes by ICES 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 is used and information on twine size, material, construction, whether single or double twine, knotted or knotless, wet or dry, are recorded.

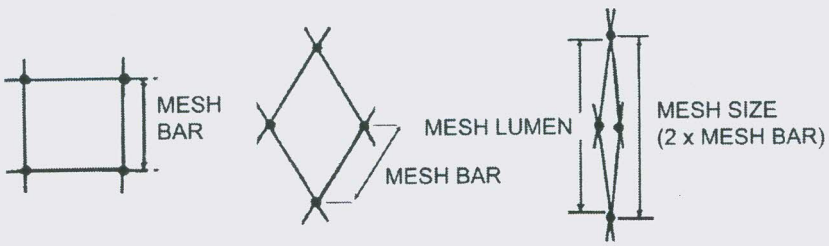

Fig. 1 Mesh measurements

Covered codend method

The length frequency of fishes that has entered the net, and escaped through trawl mesh, determines selectivity and this data may be obtained by attaching a small-meshed (usually 15-20 mm stretched mesh) cover over codend or other parts of the trawl to retain animals escaping trough the trawl (Pope *et al.*, 1975). The masking effect on codend meshes by cover is nullified if the cover dimensions are 1.5, times the length and width of a codend (Fig. 2.). Most of the recent works have used plastic hoops to negate the masking effect of cover on selectivity.

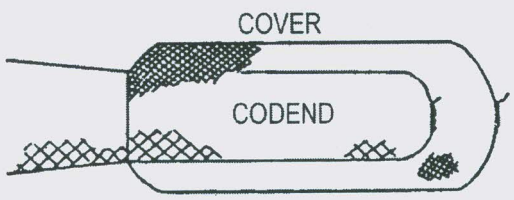

Fig.2 Schematic diagram of codend and cover

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. The catch in the small mesh codend is considered 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 different factors.

The SELECT methodology developed by Millar & Walsh (1992) helps in deriving selection parameters for 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 trawl 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. The analytical procedures of all these methods are similar to trouser trawl method and the comparison is shown in Table: 2.

Table 2 Comparative advantages and disadvantages of different methods used for trawl selectivity studies

ADVANTAGES	DISADVANTAGES
Covered codend method	
• Commercially used trawl design can be used for the experiment, by inserting a cover. • Data from each haul can be used to estimate the selection curve.	• Use of cover of size less than 1.5 times the codend may have a masking effect, affect fish behaviour or gear performance and hence selectivity. • Extra drag of the cover distorts the shape of the net near the codend mouth.
Trouser trawl method	
• Commercial trawl fitted with trouser codend can be used for experiments and no special rigging required. • Free from any bias due to masking effect caused from the use of a cover.	• Reduced dimensions of each side of the trawl may affect fish behaviour • The assumption of 50:50 split between the codends may not be met and specialized techniques are required to analyze data
Twin trawl and Parallel hauls method	
• Both the control gear and the experimental gear is fished at the same time on adjacent grounds • Gives reasonable simulation of commercial fishing situations and indicates immediate gain or loss in catch	• Requires a vessel with facilities for twin trawling/double rig trawling or two vessels for operations. • The experimental and control nets may not encounter the same populations despite proximity of nets.
Alternate Hauls	
• No special rigging required for	• Because each tow takes place under

operations. • **Free from any bias caused from the use of a cover.**	**different conditions and at different times, the population estimate from a small mesh codend may not accurately represent the population encountered by the test codend.** • **Large number of tows required**

Selection ogive

Selection curve for trawls giving proportion retained for each length class, normally assumes a sigmoid form (Fig. 3). It is either fitted by eye or plotted by using conventional statistical methods such as probit or logit analysis. 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. The logistic model is commonly used to describe trawl selection ogive.

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

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 for each species.

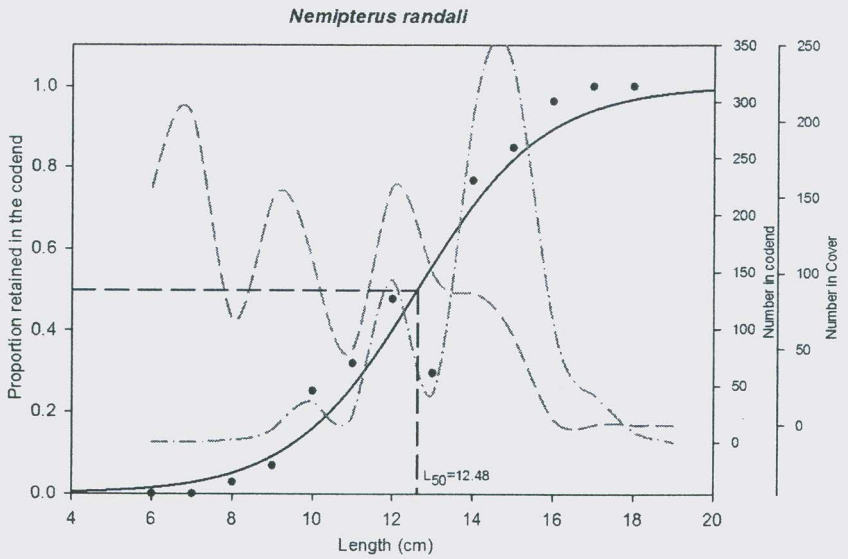

Fig. 3 Typical selection curve for trawls

Another sigmoid curve model frequently used is Robert's curve, which is mathematically more complex, but allows for asymmetry. Methods of analysis used to fit the data to the selected curve model are weighted least squares and maximum likelihood estimation and SELECT methodology proposed by Miller (1992).

Mean selection length, selection range and selection factor

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

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. 3). Selection curve 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. 3). The mean selection length is generally proportional to the mesh size of the codend over a certain range. The proportionality constant is called selection factor (SF).

Estimation of selectivity parameters

The logistic curve model for trawl selectivity is:

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

The above equation can be rewritten as $\ln (1/SL - 1) = S1 - S2*L$ which represents a straight line, where S1 and S2 represents intercept (a) and slope (b); $\ln (1/SL - 1)$ is natural logarithm of (1/SL-1); SL is fraction retained for mid-length class L. Regression of mid-length class and observed values of fraction retained (SL-obs) obtained from selectivity experiments, gives the S1 (Y-intercept) and S2 (slope), which can then be used to fit the logistic curve that fits to the observations. L50, L25, L75, and selection range are calculated as below:

$L50 = (S1/ S2)$

$L25 = (S1 - \ln 3) / S2$

$L75 = (S1 + \ln 3) / S2$

Selection range = L75 – L25

Recent advances related to trawl selectivity

Trawl selectivity has been evolving in the recent years to , (i) development of selective trawls, (ii) use of square mesh panels and codend in trawl construction, (iii) optimum mesh size determination for multi-species trawl fisheries, (iv) use of morphometric measurements of fish to determine gear selectivity.

Selective trawls

A large number of studies for development of selective trawls have been carried out, by incorporating different technical devices to improve both species and size selection. 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.

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. 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. Significant improvements were observed in case of square mesh panels inserted in the codend.

Optimum mesh size for multi-species trawl fisheries

Determination of optimum mesh size for single species fisheries is relativity simple once the population parameters are known. However derivation of optimum mesh size is often very complicated in multi-species fisheries like in the tropics. 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.

Conclusions

Fishery resources are harvested by a wide variety of gear types. There is global interest in methods for improving the size and species selectivity of commercial fishing gears, to reduce unintentional fishing mortality and impacts of fishing systems. 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 meet the fishing gear. 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 and hence studies to find behaviour responses of fishes to different stimuli are very essential.

Selection parameters for a large number of species are now available in the Indian scenario, many states have incorporated suitable mesh sizes in their respective Marine Fisheries Regulations Acts. Demonstrations on the efficacy of improving selection using gear based technical measures and involvement of fishers in all stages of decision making will help in adoption of stipulated mesh sizes in the fishery.

Data collection methodology

- Once the trawlnet is hauled, sort, weigh and label the catches to the lowest taxonomic resolution possible, separately, for codend and cover. Measure the length of the individual species, for which selectivity parameters are to be determined. Measure total length or fork length for finfishes, carapace length for crustaceans and mantle length for cephalopods, to the nearest unit below.
- Whenever the catch from either the experimental codend or cover is too large to measure, a representative random sample not less than 30% is taken. Data from sub-samples must be proportionately scaled up to the size of total catch.
- The data can be grouped into appropriate length classes and tabulated, separately for codend and cover.
- If the male and female has differential growth rate, it is better to separate the sexes, before measurement.
- In case of BRDs or any other specialized designs, the catches in the codend, and from the different covers, needs to be collected separately, measured and tabulated.
- If the study intends to consider different operational parameters that affect selectivity like vessel speed, depth of operation, sea state, etc., then the parameters need to be factored in for analysis.

- The trawlnet and the cover should be checked regularly for damage, since any damage to the webbing, may skew the estimates of the selection parameters.

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Open source software

FiSAT II VER 1.1.0 Fish Stock Assessment Software

FiSAT II VER 1.1.0 Fish Stock Assessment Software has routines to determine selectivity of trawl. http://www.fao.org/fi/statist/fisoft/fisat/downloads.htm

Licensed software

ConStat, Denmark

The **CC 2000 program** from ConStat, Grønspættevej 10, DK-9800 Hjørring, Denmark. Features include five selectivity curves (Logistic, Probit, C-LogLog, LogLog and Richards curve), Covered Codend and Trouser Trawl/Twin Trawl experiments; correct adjustment for sub-sampling. *(Check availability)*

In-built excel routines for determination of selection parameters