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STUDIES ON GILL NET SELECTIVITY

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The theoretical models pertaining to the selectivity of gill nets proposed by Holt (1957) and Olsen (1959) are examined, especially with regard to the various assumptions inherent in the models. The validity of the models with respect to the validity of the assumptions has been tested. The selectivity of a gill net of a given mesh size as purely a function of the girth of fish alone is aiso critically examined.

Introduction

The importance of accurate catch statistics in the estimation of certain characteristics of fish populations is very well known. A significant factor that has to be reckoned with before the utilisation of any data is the selectivity of the nets used in the capture of fish. Certain types of gears, such as gill nets, are particularly selective and in such cases the assessment of selectivity, and the adjustment of data for the effects of such selectivity, are very important. Mc Combie and fry (1960), Von Brandt (1955), Holt (1957), Hodgson (1933) etc. have contributed to the knowledge on the selectivity of gill nets. Some of the important facts of the subject covered by these workers are the escape mechanism, the theoretical derivation of the selection ogive, the changes in the ogive parameters with changes in mesh sizes and the hydro-dynamies of the gear components. Despite these important studies, it should be stated, that quantitative data on the selection parameters of the gear are comparatively few probably because of the difficulties in experimentation.

Among the important theoretical models pertaining to the selectivity of gill nets are those of Holt (1957) and Olsen (1959). Several assumptions are inherent in these models which it is the object of this study to examine and also to test the validity of the models themselves with respect to the validity of the assumptions. In addition, it has been critically examined as to whether the selectivity of a gill net of a given mesh size is purely a function of the girth of fish alone, irrespective of its shape. Certain selectivity characteristics of gill nets used have been estimated for two species of *Cyprinids, Barbus dubius* and *Barbus carnaticus*, the two dominant species represented in the experimental gill net catches which provided the basic data for this study.

Material and Methods

The present study is based mainly on the data collected during fishing experiments conducted by this Institute at the Krishnarajasagar reservoir details of which experiments are available in a report (Gulbadamov, 1960). Experimental fishing in this reservoir was conducted during the months June to August, 1960 with gill nets of mesh bar sizes 1½", 2", 2½", 3", 3½", 4", 4½" and 5". The bulk of catches was constituted by the two species, *B. dubius* and *B. carnaticus* which alone have been considered in the analysis presented in this account. The measurements of the mesh bar are made from knot centre to knot centre by measuring the distance between several knots, from which a single mesh bar size is computed. The girth measurement used in this study was that taken at the deepest portion of the fish. In addition to the data mentioned above some published results of Olsen (1959) where used for comparison and verification.

One of the assumptions underlying the estimation of parameters in Holt's model (1957) is that the standard deviations of the distributions for two adjacent mesh sizes are equal. This assumption is tested in respect of the data for *B. dubius* and *B. carnaticus* (Table I).

TABLE 1

Calculated species-wise means and variances and tests for equality of means and homogeneity of variances

Mesh / Calculated	1½"		2"		2½"		3"		3½"	
	B. dubius	*B. Carnaticus*	*B. dubius*	*B. Carnaticus*	*B. dubius*	*B. Carnaticus*	*B. dubius*	*B. Carnaticus*	*B. dubius*	*B. Carnaticus*
Mean	199.67	197.14	238.17	244.59	290.68	290.51	321.97	340.91	339.28	356.43
Variance (s^2)	1025.75	418.13	1593.86	854.42	1453.25	636.39	2654.07	663.42	1492.06	1114.28
d.f.	29	13	251	193	168	88	128	21	27	6
$w = s^2 / n$	34.19	29.87	5.53	4.36	8.60	7.15	20.57	30.16	53.29	159.18
/d/(difference in means)	2.53		6.42		0.17		18.94		17.15	
$C=\frac{s_1^2/n_1}{s_1^2/n_1+s_2^2/n_2}$	0.534		0.559		0.546		0.405		0.251	
$V=\frac{/d/}{\sqrt{w_1+w_2}}$	0.316		2.041		0.043		2.659		1.176	
V at 2% level	72.40		2.53		2.53		2.40		72.60	

Bartlett's test

	d. f.	C	M	M/C	From the χ^2 table 5%	1%
B. dubius	4	1.0073	24.800	24.620		
B. carnaticus	4	1.0254	5.039	4.914	9.488	15.086

Note :—d. f. : degrees of freedom

C : correction factor used $= 1+\frac{1}{-3\,(k-1)}$

M : N log $N^{-1\,k}$

Where $N = \frac{k}{z}$

Testing within the species indicated that in respect of *B. dubius*, in most of the cases the variances and hence standard deviations of distributions for two adjacent mesh sizes were significantly different at 5% level Beverton also was recorded to have pointed out that the "spread of the selection curves increases with the size of the mesh, which weakens one of Holts assumptions", (Mc Combie and Fry, 1960). In case of *B. carnaticus*, however, it is observed that the assumption of equality of variances holds good (Table I).

The assumption that the mean length or girth is directly proportional to the mesh size in the form $lm = K\,\theta$ (where 'lm' is the mean length ; θ the mesh bar size and 'k' a constant) was examined in respect of both the species *B. dubius* and *B. carnaticus* and found that the relationship between mean length or girth and mesh bar size for both the species, was of the form $lm = d' + k'\,\theta$, $gm = d + K\,\theta$ where lm and gm are mean length and mean girth respectively ; θ is the mesh bar size ; d, d' , K and K' are constants.

The models of Holt (1957) and Olsen (1959) are as given below :

$$\text{Holts : } C_L = nP_L\, pm\, e^{-(L-Lm)^2} / 2\sigma^2 \qquad \text{— (1)}$$

$$\text{Olsen's : } C_L = nP_L\; P.\,V.\; e^{f(L)} \qquad \text{— (2)}$$

where in (1) 'C_L' is the number of fish of length 'L' caught ; 'n' is the duration of fishing or number of hauls ; 'Lm' is the modal length ; 'P_L' is the number of fish of length 'L' liable to capture ; pm is the fishing power of the mesh in question with respect to the fish caught in modal numbers ; 'e' is the base of natural logarithm and 'σ' is the standard deviation of length distribution. In (2), other symbols being the same as in (1), 'P' is the fishing power of the fishing unit referred to a length Lm, the mean selection length, which is the length of fish for which that particular net is most efficient ; 'V' is the vulnerability of the species ; f(L) is a function of length 'L' that being $-u(L-Lm)^3 - v(L-Lm)^2$ where 'u' and 'v' are constants. It may be mentioned that Olsen's (1959) model is a generalisation of Holt's (1957) model. While estimating parameters the assumptions made in Olsen's (1959) model are more or less same as those used in Holt's (1957) model.

Due to reasons elaborated earlier, in the present analysis the assumption of proportionality of the mean length to the mesh size has been relaxed to the from $lm = d + k\,\theta$ —(3) for both the models and formulae have been obtained to get the estimates of the required parameters, as shown below, in respect of *B. carnaticus* which satisfies the assumption of equality of variances. In respect of *B. dubius* where the assumption regarding the equality of variances is found to be invalid; no further estimates of parameters have been made.

Let A, B and C denote three gill nets in the ascending order of their mesh sizes, where the mesh sizes of two consecutive nets differ slightly. Taking the pair A, B with regard to Holt's (1957) model after simplification we have as per the assumptions $\frac{pmA}{pmB} = 1$ and $\sigma A = \sigma B$.,

$$\text{Log}\frac{CLB}{CLA} = \frac{(LmB - LmA)}{2} \quad L + \frac{L^2mA - L^2mB}{2}$$

which is of the form

$$Y = a_1 + b_1, X \text{ where}$$

$$a_1 = \frac{l^2mA - L^2mB,}{2} \quad b_1 = \frac{(LmB - LmA)}{2}$$

From the above it follows that

$$LmA + LmB = \frac{-2a_1}{b_1} \quad — \quad (4)$$

we have $Lmb - LmA = K(\theta B - \theta A) = Kd$ — (5)

where 'k' and 'd' are constants and $d = \theta B - \theta A$

(3), (4) and (5) finally give

$$-\frac{a_1}{b_1} = d + \frac{K}{2} \quad (\theta A + \theta B) \quad — \quad (6)$$

Similarly for the pair B, C we have

$$-\frac{a_2}{b_2} = d + \left(\frac{K}{2}\right) \quad (\theta B + \theta C) \quad — \quad (6')$$

Hence

$$\frac{a_1}{b_1} - \frac{a_2}{b_2} = \left(\frac{K}{2}\right) \quad (\theta C - \theta A) \quad — \quad (7)$$

and

$$d = -(\tfrac{1}{2}) \left[\frac{a_1}{b_1} + \frac{a_2}{b_2} + \frac{K}{2} \quad (\theta A + 2\theta B + \theta C)\right] \quad — \quad (8)$$

The parameters 'k' and 'd' can be estimated from (7) and (8).

Similar procedure in Olsen's model, yields estimates for 'k' and 'd' as follows :

Here $\log \frac{C_{LB}}{C_{LA}} = a_1 \quad L^2 + b_1 L + c_1$ — (9)

were $a_1 = 3^u (LmB - LmA)$

$$b_1 = -(LmB - LmA) \quad [3^u (LmB - LmA) \quad -2v]$$

$$c_1 = (LmB - LmA) \quad [u (L^2mB + LmB \; LmA + L^2mA) - v \; (LmB + LmA)]$$

In the usual notation then we have

$$a_1 = 3.ukd \quad — \quad (10)$$

$$b_1 = \frac{2a_1 v}{3u} - a_1 \quad (LmB + LmA)$$

Thus

$$LmB+LmA = \frac{2v}{3u} - \frac{b_1}{a_1} \qquad — \qquad (11)$$

From (3) and (11) it follows :

$$\frac{b_1}{2a_1} = \left(\frac{v}{3^u} - d\right) - \left(\frac{K}{2}\right)(\theta B + \theta A) \qquad — \qquad (12)$$

$$\text{Now } c_1 = \frac{b_1^2}{4a_1} - \frac{v^2}{a_1} k^2 d^2 + \frac{a_1}{12} k^2 d^2$$

which gives

$$v = \pm \sqrt{\frac{(b_1^2 - 12 ^a{}_1 c_1 + a_1^2 k^2 d^2}{12 k^2 d^2}} \qquad — \qquad (13)$$

when a_1 is small a_1^2 is negligible. Then

$$v = \pm \sqrt{\frac{b_1^2 - 4 a_1 c_1}{2kd}} \qquad — \qquad (13')$$

The model implicitly assumes positive values for v. Hence from (12), (13) and (13′) we have

$$\frac{-b_1}{2a_1} + \sqrt{\frac{b_1^2 - 12 a_1 c_1 + a^2{}_1 k^2 d^2}{12 a_1^2}} = d + \frac{K}{2} (\theta B + \theta A) \qquad — \qquad (14)$$

and

$$\frac{-b_1 + \sqrt{b^2{}_1 - 4 a_1 c_1}}{2a_1} = d + \left(\frac{K}{2}\right) (\theta B + \theta A) \qquad — \qquad (14')$$

Similar expressions can be derived for the pair B, C which together with (14) or (14′) yield the estimates for 'k' and 'd'. From the estimates of 'k' and 'd' estimates for mean lengths follow from (3). Parameters 'k' and 'd' were estimated from formulae (7) and (8) shown above, for *B. carnaticus* (Table II). It is noteworthy that considering 'u' and 'v' in Olsen's (1959) model to be constants the equation (12) showed that the relation between variable $\frac{b}{2a}$ and the corresponding sum of mesh sizes was linear where the intercept was $\left(\frac{v}{3u} - d\right)$. But the calculated value of $\frac{b}{2a}$ and the values of their respective sums of mesh sizes for the pairs AB, BC and CA gave negative value for 'k' which would be contradictory to the assumption that both lm and θ would decrease or increase simultaneously. In the light of this, 'u' and 'v' were expressed as functions of 'a', 'b' and 'c' and the equations (14) and (14′) were derived. For Olsen's (1959) data estimates of 'k' and 'd' based on (14′)

were calculated and the corresponding estimates for mean lengths were also made. Side by side the estimates of these parameters by Olsen (1959) were also given for comparison (Table III).

TABLE II

Numbers of *B. carnaticus* caught in the nets of mesh sizes 2" (A), 2½" and 3" (C)

Nets Girth (g) m. m.	A	B	C	log B/A	log C/B
185	1				
195	1				
205	19				
215	24				
225	22				
235	28				
245	19				
255	32	10		−1.16315	
265	10	11		0.09531	
275	13	14		0.07411	
285	11	9		−0.20068	
295	4	18	1	1.50408	−2.89037
305	5	10	2	0.69315	−1.60944
315	2	5	4	0.91629	−0.22315
325	3	5	1	0.51083	−1.60944
335		2	2		0.00000
345		3	1		−1.09861
355		2	5		0.91629
365			3		
375			3		

Pairs of nets	r*	d. f.*	a	b	a/b
AB	0.704	6	−6.38859	0.23077	276.837975
BC	0.774	5	−15.63088	0.0452314	345.575860
When d = 0	k	LmA	LmB		LmC
AB	4.827166	245.22	306.53		
BC	4.9473996	—	314.16		376.99
Combined AB & BC	k = 4.8872828	248.27	310.34		372.41
When d ≠ 0 = −32.582515 ; AB, BC	5.412432	242.36	311.11		379.84

r* is the correlation coefficient beteen log B/A (log C/A) with the corresponding girths.
d. f.* denotes the corresponding degrees of freedom for 'r'.

The linear forms (6) and (14) would be satisfied by data provided, the models and other assumptions fit the data, thus providing an indirect check over the models considered and assumptions made. In case there were more than two sets of equations of the type (6) and (14) then least squares method would yield better estimates of 'k' and 'd'. However, in practice, absence of proper spread of frequency distribution, is generally observable in the catches of some gill nets. In such cases, data from a group of three nets having close mesh size for which proper spread of frequency distributions is found would give better estimates of 'k' and 'd'. As the present procedure gives a single estimate for both 'k' and 'd' for series of mesh sizes no direct comparison for estimates of 'k' and 'd' as in the case of Holt's and Olsen's methods is possible. However, in this instance, difference between theoretical and observed frequency distributions tested by χ^2 method would point out the admissibility of estimates of 'k' and 'd'. Moreover, these estimates being based on catches from more than one pair of mesh sizes may probably be considered superior to estimates as suggested by Holt (1967) and Olsen (1959). The approximation envisaged in the equation (14′) would be advantageous and time saving whenever $\frac{a^2}{12}$ is found to be relatively small. When this approximation is made the left hand side of (14′) resolves merely into a root of quadratic equation $ax^2+bx+c=0$ with one restriction that the discriminant b^2-4ac of the above equation should always be positive, since otherwise 'v' will assume imaginary values, which in turn is due to negative values of 'a'. This fact also could be used as a primary cheek before proceeding to further calculations.

TABLE III

Comparison among the estimates of 'k', 'u', 'v', LmA, LmB and LmC obtained from the present* method and Olsen's (1959) method

Pairs	Method	d	k	u	v
AB	Present	-1.046678	4.959595	-0.000162	0.055701
,,	Olsen	Zero	4.792200	-0.000168	0.057645
BC	Present	-1.046678	4.001608	-0.001608	0.045647
,,	Olsen	Zero	4.799500	-0.001662	0.047446
		LmA	LmB	LmC	
AB, BC	Present	28.58	31.25	34.93	
AB, BC and CA	Olsen	28.59	31.17	34.72	

* For the present method (14′) was used, as the value of $a^2/12$ was found to be negligible.

From table II it is interesting to note that the estimates of mean girths based on (3) are found to be closer to those based on Lm=k for the species *B. carnaticus*. Similar comparisons for the values of 'u' and 'v, are made (Table III) as stated above. However, regarding the constants 'u' and 'v' the data (Olsen 1959) clearly demonstrated, as seen by using (12), that they might be different for different mesh sizes. Further, the equations for 'u' and 'v' were found to be functions of 'a', 'b' and 'c' where the functions need not be invariants. As such, an attempt to have a common 'u' and 'v' for different meshes might vitiate the theoretical frequency distribution as envisaged by (2). Hence, it would be worth trying to have some kind of weighted estimates for u and v for each mesh size under consideration.

Mean girth and mesh size relationship between species

The mean girths and variances for *Barbus dubius* and *B. carnaticus* were estimated (Table I). Tests of significance for the equality of variances between the two species for given mesh size indicated that the variances for *B. dubius* were always greater than those for *B. carnaticus* expect in respect of mesh far sizes $1\frac{1}{2}''$ and $3''$. Differences in mean girths of these species for each mesh size were then tested and found not to be significant at 2% level except in case of 3″ mesh where the difference was found to be significant at that level. The test used was based on that of Welch (1947) which gives due considerarion to the levels of significance. For testing homogeneity of variances Bartlett test was used for variances of girth distribution in all mesh sizes for each species individually and it was found that in the case of *B. carnaticus* null hypothesis was not rejected at 5% level whereas in the case of *B. dubius* the null hypothesis was rejected even at 1% level.

The assumption that the girth measurements of fish gilled in particular mesh size would belong to a single population in the statistical sense, irrespective of the differences in species of the gilled fishes is critically examined in respect of *B. dubius* and *B. carnaticus*. It has been found from this study that such an assumption is incorrect atleast as far as the above species are concerned. Though the differences in mean girths of these two species caught in identical mesh sizes are not found to be significant at 2% level the differences in the variances are found to be significant. This indicates that the spread of the selection curve for the two fishes is different, the selection curve for *B. dubius* having a wider spread than that of *B. carnaticus*. This may probably be attributed to a factor associated with the shape of the fish gilled which emphasizes the importance of the 'shape factor' in mesh selectivity studies.

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