ESTIMATES OF MORTALITY AND YIELD PER RECRUIT OF 'GHOL' *PSEUDOSCIAENA DIACANTHUS* (LACEPEDE)

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ABSTRACT

The mortality rate and yield per recruit of 'ghol', *Pseudosciaena diacanthus*, are estimated from the age composition of catches of the bull-trawlers of the New India Fisheries Ltd., Bombay, for the years 1958 to 1961.

The annual mortality rate estimated from (1) catch per unit effort data and (2) the average catch curve of 1958-'61 lies roughly between 0.55 and 0.60 and the instantaneous mortality rate between 0.83 and 0.87. Since the fishery for 'ghol' was at the beginning stage with only two pairs of bull-trawlers operating commercially, the estimated total mortality rate ($Z=0.83$) is regarded as practically equal to natural mortality rate (M).

The yield per recruit Yw/R for various levels of fishing mortality (F) were calculated with $M=0.83$ and the maximum value of Yw/R was found at a value of $F=0.6$, which shows that the catch from the stock can be stepped up considerably over the present level. Before deciding to step up the catches of 'ghol' by expanding the trawl fishery, it is necessary to have estimates of fishing mortality generated by the 'dol' nets and gill nets on this fish.

Pseudosciaena diacanthus (Lacepede), locally known as 'ghol', is a highly esteemed and commercially important sciaenid fish which forms 5-6% of the catches of the trawlers in Bombay and Saurashtra waters (Rao, K. V. S., 1965; Rao, K. V. *et al.*, 1966). Investigations on the fishery and biology of this important fish were started by the present author in 1958 and the results of these investigations have been dealt in earlier papers (Rao, 1961, 1963, 1965 and 1966). In the present paper the mortality rate and yield per recruit are estimated from the age composition of 'ghol' catches of the bull-trawlers of the New India Fisheries Ltd., Bombay, for the years 1958 to 1961.

MATERIAL AND METHODS

During the period 1958-'61, when observations on 'ghol' catches were undertaken by the author, the two pairs of bull-trawlers of New India Fisheries Ltd., Bombay, fished in the area extending from Bombay to Kutch (Rao, 1965). At the time of unloading of the catches by the bull-trawlers, random samples

(50-100 numbers) of 'ghol' were measured and the length measurements arranged in size groups of 5 cm. The samples of each month were pooled and the length frequency distributions so obtained raised to the monthly catches of 'ghol' in the trawlers. From this the annual size compositions of the catches in terms of numbers per 100 hours of trawling were estimated. It is assumed in the present account that the species from Bombay and Saurashtra waters form a homogenous stock.

During the period 1958-'61, scale samples from 1152 fish (5.0 - 120.0 cm in length) were studied and the number of growth rings in each scale sample determined. From this an age-length key was prepared. Using this key the annual size compositions of the catches per 100 hours of trawling, were converted into the age compositions. From the age composition, estimate of total mortality was made according to the usual formula:

$$N_t = N_o e^{-Z_t}$$

Taking logarithms and rearranging the terms, we get

$$Z_t = \log_e N_o - \log_e N_t$$

where, N_t = the number of fish at age 't', N_o = the number when t=o and Z=the instantaneous total mortality rate. The value of Z can be estimated by the least squares method when more than two values of N_t are available. The catch per 100 hours trawling is used for N_t, as the true number of fish at age 't' cannot be estimated directly by catch sampling. The annual survival rate (s) may be obtained by dividing N_t by N_o. = (1-s) gives the annual mortality rate (a).

The total instantaneous mortality rate Z was estimated in two ways:

(1) From the catch per unit effort of the same year-class during successive ages (Ricker, 1958) and

(2) From the average catch curve of 1958-'61. In this the data of age composition of the catch per 100 trawling hours in different years were summed up and averaged (Beverton and Holt, 1957).

Estimations of the yield per recruit at different levels of fishing mortality were also made using the formula of Beverton and Holt (1957) simplified by Ricker (1958):

$$\frac{Yw}{R} = Fe^{-M(t_{p1}-t_p)} W_\infty \left(\frac{1}{F+M} - \frac{3e^{-K(t_{p1}-t_o)}}{F+M+K} + \frac{3e^{-2K(t_{p1}-t_o)}}{F+M+2K} - \frac{e^{-3K(t_{p1}-t_o)}}{F+M+3K} \right)$$

where,

Yw/R = Yield per recruit

F = instantaneous fishing mortality coefficient

M = instantaneous natural mortality coefficient

t_{pl} = age of recruitment (average age at which the fish become vulnerable to trawl)

t_p = age at which the fish become vulnerable to some common type of fishing

$W\infty$ = the average weight of the fish of a brood when its average asymptotic length is $l\infty$

K = $-\log e^k$, where k is the slope of the Walford line (catabolic coefficient in von Bertalanffy's equation).

Estimations of Annual Mortality Rates

The annual size compositions of the 'ghol' catches in terms of number per 100 hours of trawling for the years 1958, 1959, 1960 and 1961 are given in Table 1. The age-length key is given in Table 2 while the annual age compositions of 'ghol' landings are given in Table 3.

(1) *From the catch per unit effort data*— In Table 4 are given the catches of 'ghol' in numbers by the bull-trawlers per 100 hours of trawling (c/f) at successive ages in 1958, 1959, 1960 and 1961. The survival rates of individual year-classes may be estimated from the ratios of c/f in successive seasons of the respective year-classes. It may be seen from the table that the number of fish at age III in 1958, 1959 and 1960 is less than that of age IV fish in 1959, 1960 and 1961 respectively. This discrepancy is observed during the three periods consistently and this is due to age III fish being not fully recruited to bull-trawling. Omitting these survival rates for age III/IV fish, the mean annual survival rate (s) for the other year-classes during the periods 1958-59, 1959-'60 and 1960-'61 are 0.4785, 0.4471 and 0.3286 respectively. The average of the three values is 0.4181.

The mean survival rate (s), annual mortality rate (a) and the instantaneous total annual mortality rate (Z) of the year-classes are given below:

		s	a=(1-s)	Z
	1958-'59	0.4785	0.5215	0.74
	1959-'60	0.4471	0.5529	0.81
	1960-'61	0.3286	0.6714	1.11
Average for the period	1958-'61	0.4181	0.5819	0.87

(2) *From the average catch curve of* 1958-'61— In Fig. 1 are plotted the natural logarithms of the average number of 'ghol' per 100 hours of trawling during the period 1958-'61 (ordinate) against the different ages (abscissa) and a regression line was fitted by the method of least squares using the equation $Y=a+b\,x$, where Y=nat. log. numbers per 100 hours trawling, x=age in years, a=a constant and b=the slope. The slope (b) of the regression line which is the numerical

TABLE 1. *Estimated total number and number per 100 hours of trawling of* P. diacanthus *in the catches of the bull-trawlers of New India Fisheries Ltd., Bombay, during the years 1958—'61*

Year	1958		1959		1960		1961	
Size group (cm)	Total	Number per 100 hrs trawling	Total	Number per 100 hrs trawling	Total	Number per 100 hrs trawling	Total	Number per 100 hrs trawling
20- 24	—	—	28.04	0.65	—	—	120.19	2.60
25- 29	348.74	6.88	4653.29	108.25	931.48	18.37	3603.07	78.07
30- 34	2030.73	40.10	16103.55	374.62	7756.56	152.98	12561.85	272.20
35- 39	1351.50	26.69	10716.39	249.30	5815.61	114.70	11240.06	243.56
40- 44	4825.93	95.31	8320.49	193.56	2871.45	56.63	8182.53	177.30
45- 49	2877.06	56.82	9305.62	216.47	7303.73	144.05	12225.73	264.91
50- 54	3756.78	74.19	5566.07	129.48	5253.83	103.62	6672.76	144.59
55- 59	2482.31	49.02	1642.38	38.20	1136.87	22.42	4457.95	96.59
60- 64	1726.20	34.09	1550.81	36.07	892.39	17.60	4953.11	107.32
65- 69	667.85	13.19	2668.92	62.08	2105.16	41.52	2817.53	61.05
70- 74	1112.62	21.97	2371.65	55.17	2636.08	52.00	1159.50	25.12
75- 79	1564.81	30.90	1342.14	31.22	2839.29	56.00	1117.76	24.22
80- 84	2646.09	52.26	2674.33	62.21	5519.70	108.86	1400.97	30.36
85- 89	4960.87	97.98	4807.05	111.82	7919.45	156.19	4494.60	97.39
90- 94	5720.25	112.98	3402.04	79.14	9379.24	185.00	6844.93	148.32
95- 99	4313.11	85.18	2590.09	60.25	6613.82	130.44	3182.04	68.95
100-104	382.21	7.54	801.28	18.64	806.25	15.90	1187.93	25.74
105-109	63.80	1.26	104.62	2.43	98.64	1.94	209.78	4.54

TABLE 2. *Frequency distribution of rings in the scales of ghol,* Pseudosciaena diacanthus (*Lacepede*)

Size group in cm*	Number of fish examined	Number of rings in the scales								
		0	I	II	III	IV	V	VI	VII	VIII
5- 9	2	2								
10-14	26	26								
15-19	78	78								
20-24	65	65								
25-29	31	26	5							
30-34	29	21	8							
35-39	36	10	26							
40-44	33	2	31							
45-49	42	—	42							
50-54	33		32	1						
55-59	33		21	12						
60-64	23		6	17						
65-69	35		3	32						
70-74	38		2	34	2					
75-79	39			16	23					
80-84	58			7	40	11				
85-89	103			3	32	68				
90-94	144				2	109	33			
95-99	144					34	109	1		
100-104	91					1	64	25	1	
105-109	47						10	25	11	1
110-114	16							6	8	2
115-119	4								3	1
120-124	2									2
Total	1152	230	176	122	99	223	216	57	23	6

* Total length in cm from tip of the snout to tip of the longest ray of caudal fin.

TABLE 3. *Annual age composition (number per 100 hours of trawling in each age group) of* P. diacanthus *in the catches of the bull-trawlers of New India Fisheries Ltd., Bombay, for the years 1958'-61*

Age	I	II	III	IV	V	VI	VII
1958	293	99	88	181	96	4	1
1959	867	175	100	160	78	11	1
1960	451	150	162	295	153	7	1
1961	932	214	69	199	106	10	2
Average for 1958-'61	636	160	105	209	109	8	2
Nat. log of average numbers	6.4552	5.0752	4.6540	5.3424	4.6914	2.0794	0.6931

TABLE 4. *Catch per 100 hours (c/f) of trawling (numbers) for* P. diacanthus *during 1958, 1959, 1960 and 1961 and the survival rates (S) estimated from this. (Data from the bull-trawlers of New India Fisheries Ltd., Bombay)*

Age	1958 c/f	S	1959 c/f	S	1960 c/f	S	1961 c/f
I	293		867		451		932
		0.5972		0.1730		0.4745	
II	99		175		150		214
		1.0000		0.9257		0.4600	
III	88		100		162		69
		-1.8181		-2.9500		-1.2283	
IV	181		160		295		199
		0.4309		0.9562		0.3593	
V	96		78		153		106
		0.1145		0.0897		0.0654	
VI	4		11		7		10
		0.2500		0.0909		0.2857	
VII	1		1		1		2
Mean survival rate (excluding (S) for age III/IV)		0.4785		0.4471		0.3286	

value of the instantaneous total mortality coefficient (Z), was found to be 0.83. From Ricker's table (Ricker, 1958) the annual survival rate (s) and mortality rate (a) were found out to be 0.4360 and 0.5640 respectively. This values are close to those found by the other method. Beverton and Holt (1957) are of the opinion that if there are sufficient data, by plotting the mean catch per unit effort of each age group over a period of years, the influence of fluctuations in recruitment can be effectively eliminated.

The annual mortality rate of 'ghol' by taking into account both the methods lies roughly between 0.55 and 0.60 and the instantaneous mortality rate between 0.83 and 0.87. Since the fishery for 'ghol' was only at the beginning stage and the number of trawlers operated commercially during this period was only 2 pairs, the estimated total mortality rate (Z) may be regarded as practically equal to the natural mortality rate (M). The yield per recruit may be estimated giving M (instantaneous natural mortality coefficient) the value of 0.83.

Yield per recruit

The values of the parameters t_p I (0.8 year), t_0 (0.30 year), l_∞ (122.14 cm), and K (0.315) were estimated by the present author in an earlier paper (Rao,

1966). Wcc was calculated from the length-weight relationship, and based on the results of earlier studies a value of 0.5 year was given for t_p.

In Table 5 are shown the details of calculation for yield per recruit of 'ghol' for various rates of annual instantaneous fishing mortality coefficients, taking the value of 0.83 as the instantaneous rate of natural mortality. These results are graphically represented in Fig. 2 where the yield per recruit Yw/R values are plotted along the ordinate and the various rates of instantaneous fishing mortality coefficient (F) along the abscissa. As F increases Yw/R also increases till the maximum value is reached at fishing mortality value of 0.60.

REMARKS

Although 'ghol' are landed commercially by other gear besides bull-trawls, the size ranges of the catches of the former and the latter overlap only at the

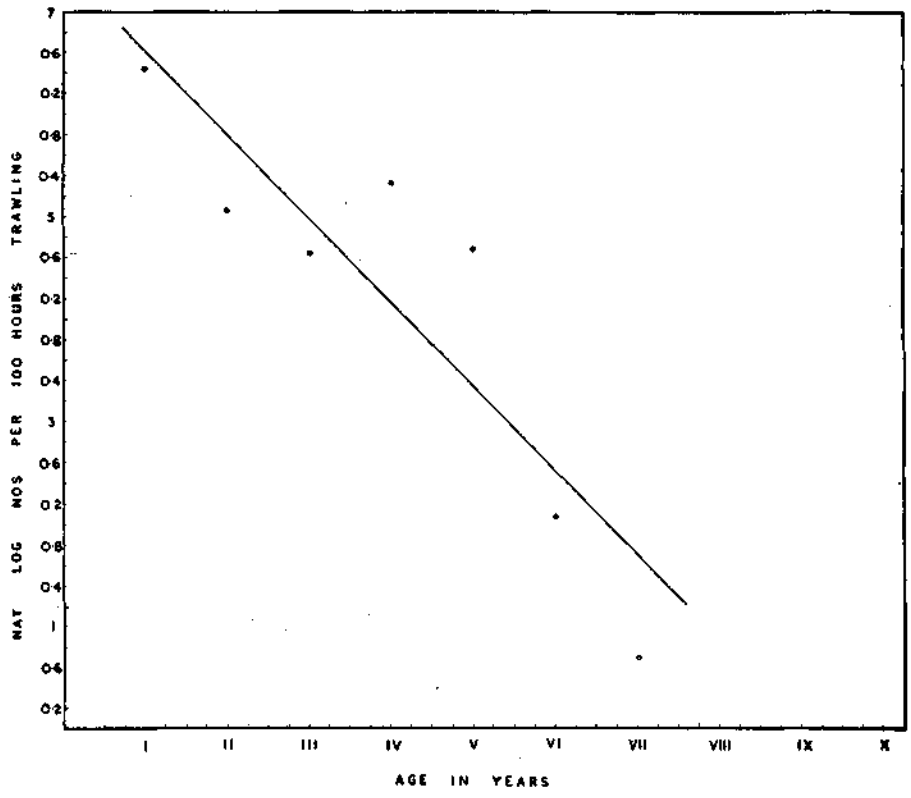

FIG. 1. Natural logarithms of the average number of 'ghol' per 100 hours of trawling during the period 1958-'61 are plotted against the different ages. The slope (b) of the regression line fitted gives the value of the instantaneous total mortality coefficient (Z).

extremes. It is interesting to note that juveniles (2.0-30.0 cm) and larger-sized 'ghol' (90.0 - 120.0 cm) are caught in the 'dol' nets while the middle size groups (40.0 - 90.0 cm) are generally absent. The bulk of the catches of the bull-trawlers consisted of the middle size groups (30.0-99.0 cm) while fish above 100 cm were landed in fewer numbers. In the bottom set gill nets, generally, 'ghol' of 90.0 cm and above are caught. The "Ghol-Dara Fishery" in the Gulf of Kutch consisted of large sized adult 'ghol' (90.0 - 120.0 cm) comprising age groups IV to VIII, those at V and VI dominating the catches (Bhatt *et al.*, 1967).

It may, therefore, be seen that in the size range 30.0-90.0 cm fishing mortality cannot be generated by the gear other than the trawls and inasmuch as only two pairs of bull-trawlers and four exploratory trawlers of Govt. of India, Deep Sea Fishing Station, Bombay, were operating during the period referred to here, fishing mortality during the period referred to may be regarded as negligible. To that extent the assumption that the total instantaneous mortality rate estimated is equal to total instantaneous natural mortality rate is justified.

The estimated yield per recruit at present is only of theoretical interest but would be useful when the fishery develops further to a stage where a measurable level of fishing mortality exists. However, the finding that the yield per recruit attains the maximum value only at a fairly high level of fishing mortality (0.60) shows that the catch from the stock can be stepped up considerably over the present level.

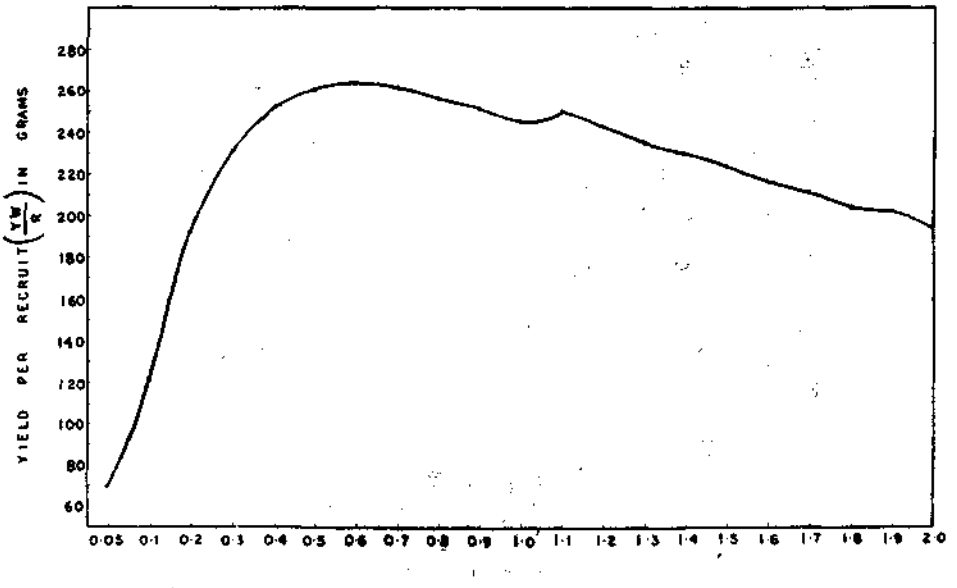

FIG. 2. Yield per recruit of 'ghol' Yw/R at various levels of fishing mortality (F) taking the value of 0.83 as the instantaneous rate of mortality (M).

TABLE 5. *Details of calculation of yield per recruit of* P. diacanthus

$$\frac{Yw}{R} = Fe^{-M(t_p\,1-t_p)} \quad W_\infty \left[\frac{1}{F+M} - \frac{3e^{-K(t_p\,1-t_0)}}{F+M+K} + \frac{3e^{-2K(t_p\,1-t_0)}}{F+M+2K} - \frac{e^{-3K(t_p\,1-t_0)}}{F+M+3K} \right]$$

$t_0 = 0.30$ year
$t_p = 0.50$ year
$t_p\,1 = 0.80$ year
$l_\infty = 122.14$ cm
$W_\infty = 17.54$ kg
$K = 0.315$
$M = 0.83$
$t_\lambda = 8$ years

$K = 0.315$
$2K = 0.630$
$3K = 0.945$

$t_p\,1-t_0 = 0.5$ year
$K\,(t_p\,1-t_0) = 0.1575$
$2K\,(t_p\,1-t_0) = 0.315$
$3K\,(t_p\,1-t_0) = 0.4725$

$e^{-K(t_p\,1-t_0)} = 0.8538$
$e^{-2K(t_p\,1-t_0)} = 0.7299$
$e^{-3K(t_p\,1-t_0)} = 0.6231$
$-3e^{-K(t_p\,1-t_0)} = -2.5614$
$+3e^{-2K(t_p\,1-t_0)} = 2.1897$

$$A = \left[\frac{1}{F+M} - \frac{3e^{-K(t_p\,1-t_0)}}{F+M+K} + \frac{3e^{-2K(t_p\,1-t_0)}}{F+M+2K} - \frac{e^{-3K(t_p\,1-t_0)}}{F+M+3K} \right]$$

$e^{-M(t_p\,1-t_p)} = 0.78$

$B = Fe^{-M(t_p\,1-t_p)}$

TABLE 5. (*Continued*)

F	F + M	$\frac{1}{F+M}$	$3e^{\frac{-K(t_p\ 1-t_o)}{F+M+K}}$	$3e^{\frac{-2K(t_p\ 1-t_o)}{F+M+2K}}$	$e^{\frac{-3K(t_p\ 1-t_o)}{F+M+3K}}$	A	$W\alpha A$	B	$\frac{Yw}{R} = (W\alpha A)B$ Kg
0.05	0.88	1.1363	2.1434	1.4501	0.3414	0.1016	1.7820	0.039	0.0694
0.10	0.93	1.0752	2.0573	1.4036	0.3323	0.0892	1.5645	0.078	0.1220
0.20	1.030	0.9708	1.9043	1.3190	0.3154	0.0701	1.2295	0.156	0.1918
0.30	1.130	0.8849	1.7725	1.2441	0.3002	0.0563	0.9875	0.234	0.2310
0.40	1.230	0.8130	1.6578	1.1772	0.2864	0.0460	0.8068	0.312	0.2517
0.50	1.330	0.7518	1.5570	1.1171	0.2738	0.0381	0.6682	0.390	0.2605
0.60	1.430	0.6993	1.4678	1.0629	0.2623	0.0321	0.5630	0.468	0.2634
0.70	1.530	0.6535	1.3882	1.0137	0.2517	0.0273	0.4788	0.546	0.2614
0.80	1.630	0.6134	1.3169	0.9688	0.2419	0.0234	0.4104	0.624	0.2560
0.90	1.730	0.5780	1.2525	0.9278	0.2329	0.0204	0.3578	0.702	0.2511
1.00	1.830	0.5464	1.1941	0.8901	0.2245	0.0179	0.3139	0.780	0.2448
1.10	1.930	0.5181	1.1409	0.8553	0.2159	0.0166	0.2911	0.858	0.2497
1.20	2.030	0.4926	1.0922	0.8231	0.2087	0.0148	0.2595	0.936	0.2428
1.30	2.130	0.4694	1.0476	0.7933	0.2019	0.0132	0.2315	1.014	0.2347
1.40	2.230	0.4484	1.0064	0.7656	0.1956	0.0120	0.2104	1.092	0.2297
1.50	2.330	0.4291	0.9683	0.7397	0.1896	0.0109	0.1911	1.170	0.2235
1.60	2.430	0.4115	0.9331	0.7155	0.1840	0.0099	0.1736	1.248	0.2166
1.70	2.530	0.3952	0.9003	0.6929	0.1787	0.0091	0.1596	1.326	0.2116
1.80	2.63	0.3802	0.8697	0.6716	0.1738	0.0083	0.1455	1.404	0.2042
1.90	2.73	0.3663	0.8411	0.6516	0.1690	0.0078	0.1368	1.482	0.2027
2.00	2.83	0.3533	0.8144	0.6328	0.1646	0.0071	0.1245	1.560	0.1942

It is to be remembered that in these calculations of yield per recruit, the entire life span of the fish has been taken into consideration and so it is not quite correct to say that the fishing mortality (F) is at present zero. There is already a considerable fishery of 'ghol' by 'Dol' nets and gill nets with associated 'F', the magnitude of which is not known. Hence it is necessary to have estimates of the magnitude of 'F' generated by the 'Dol' nets and gill nets on this fish before deciding to step up the catches of 'ghol' with the introduction of further bull-trawling or otter-trawling.

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