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Estimated mortalities and potential yield of freshwater shark *(Wallago attu)* from the 'Dhir beel' (riverine floodplain lake) ecosystem of the Brahmaputra basin, Assam, India

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ABSTRACT

The annual instantaneous natural mortality as well as the total mortality rates and the potential yield of *Wallago attu* (Bloch and Schneider) were estimated from the 'Dhir beel' ecosystem of the Brahmaputra basin, Assam, India. The instantaneous natural mortality (M) as estimated by different methods was found to be 0.83 (Pauly) and 1.15 (Cushing). However, the realistic value of M for *W. attu* in the 'Dhir beel' was found to be 1.55 (assumed value). The average instantaneous total mortality (Z) values calculated by various methods were 3.44 (Jackson), 3.50 (Jones and Van Zalinge) and 3.70 (Beverton and Holt). The annual *Z* for the period 1980-'90 ranged from 1.45 (1988-'89) to 5.14 (1986-'87) for M = 0.83; 1.69 (1988-'89) to 4.95 (1986-'87) for *M* = 1.15 and 2.0 (1988-'89) to 4.67 (1986-'87) for *M = 1.55.* The potential yield per recruit (Y^1) for W. *attu* in the 'Dhir beel' was estimated to be 440.0 g corresponding to a length (1) of 70.80 cm and age (t) of 1.16 year as per the analytical model of Beverton and Holt. However, it was 427.78 g for 1 = 73.55 cm and t =1.22 year as per the Kutty and Qasim model. The biomass per recruit attained a peak at 1 = 62.63 cm and t = 0.98 year as per Jones' length cohort analysis. The potential yield per recruit was estimated for three different values of natural mortality, M(=0.83, 1.15 and 1.55) as a function of exploitation ratio (E) for the observed age at first capture, t = 0.36 year corresponding to l_c = 30.0 cm and also for the age at first recruitment, t = 0.21 year corresponding to l_r = 17.5 cm. In view of the highly predatory habit, the length a; first capture, l_c = 30.0 cm can be considered to be the optimum size at first exploitation of *W. attu* in 'Dhir beel'. The maximum sustainable yield (MSY) for *W. attu* has been estimated to be 10,458 kg for the optimum effort at MSY (f_{mgy}) of 182 men/day as per Schaefer and the MSY of 8,646 kg at f_{ms} of 182 men/day as per Fox. The f_{ms} of 182 men/day could be more economical for the *W. attu* fishery in the 'Dhir beel'.

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Introduction

The banks of the river Brahmaputra and the Barak and its tributaries are covered with myriads of fish prone to derelict and semiderelict wetlands in the form of floodplain lakes or oxbow lakes locally known as 'Beels'. The 'Beels' in Assam contain a vast and varied fisheries resource in an area of 1.0 lakh hectares capable of producing an annual fish crop of 70,000 tonnes (Dixitulu, 1981). The 'Dhir beel' is one of the biggest live 'beels' (connected with river) of the Brahmaputra basin, Assam with an effective water area (LSL) of 530 ha. The 'beel' is situated in a region of sub-tropical climate characterised by a somewhat cool weather. The acidic soil and water pH of 4.70 to 6.92 (average 5.50) are the characteristic features of the 'Dhir beel'. Further, the optimal growth of macrophytes in the 'beel' is also a conspicuous feature (Yadava, 1987). However, the overall ecological and biological richness of the 'Dhir beel[1] is quite favourable for further increase in catches from the present average annual yield of 96 t per year (Goswami and Devaraj, 1995) by judicious harvesting and manipulation of the stocks.

The fishery of the 'Dhir beel' is comprised of all commercial species of the region. The dominance of *W. attu* (8.19%) among the catfishes is a striking feature of the 'beel'. The abundance of benthic organisms (average 41,539 m^{-2} in terms of number) as well as weedfishes like *Gudusia chapra* (33.2%) in the beel favour the dominance of *W. attu.* It occurs round the year in the catch of 'Dhir beel'. The catch is dominated by the 40.0 to 45.0 cm size group (16.8% in the fishery).

Materials and methods

The von Bertalanffy (1938) length and weight growth parameters, namely, the asymptotic length, L_M (136.16 cm), the annual length growth coefficient, K (0.654), the arbitrary origin of the length growth curve, t_0 (0.036) and also the asymptotic weight, W_M (7,636.92 g), the annual weight growth coefficient, K (0.89) and the arbitrary origin of the weight growth curve, t_o (0.036) were earlier calculated by Goswami and Devaraj (1992) for *W. attu* in the 'Dhir beel' for the years 1982, 1983 and 1984 by using the age-length key developed from the length-frequency data and by applying the Bagenal's (1955) method. In the present study, the same length-frequency data and von Bertalanffy growth parameters were used for the estimation of mortality rates and the potential yield of *W. attu* in the 'Dhir beel'. The total mortality (Z) and its constituents natural mortality (M) and fishing mortality (F) were estimated by different methods. The annual instantaneous natural mortality (M) was determined following the method of Cushing (1968; Z = M = (1/Tmax — 1) (In Nt/ N_{Tmax}) ; where the maximum age of the fish, i.e., Tmax was calculated following Taylor (1958) and the empirical formula of Pauly (1978; Log M = 0.1226 - 0.1912 log L_M + 0.7845 log K + 0.2391 log T ; where T = ambient temperature). Besides the above estimate of M, certain assumed values of M were also used to arrive at a realistic value of M. Z was estimated as per Jackson (1939; $Z^{1,2}$ = —

In S = $N_t + N_2 + N_3 + N_4$ ..../ N + $N_t + N_2 + N_3 + N_4$ .....; where S ° = survival rate) ; Beyertqn and Holt (1956) $Z = K(L_M — L)/(L - l_c)$; where L = mean length and l_c = length at first capture) and from the cumulative catch curve method of Jones and Van Zalinge (1979 ; log L N - Z/K In (L. — L) + log C ; where L N = cumulative numbers of size L and C = a term independent of L). As there were no length - frequency data for years other than 1982, 1983 and 1984, Z (F + M) for the 1980-'90 period was estimated from the values of the catchabilny coefficient a (= F/f) estimated for the years 1982, 1983 and 1984 for which the values of both F (=Z - M) and annual fishing effort (f) were available.

The yield per recruit (Y/R) model of Beverton and Holt (1957) was applied for *W. attu* in the 'Dhir beel[1] taking yield as a function of annual instantaneous fishing mortality coefficient, (F) as well as exploitation ratio, E (=F/Z) for the age at first capture, t, in years for constant values of von Bertalanffy's (1938) growth parameters (W_, K and t_o) and the instantaneous natural mortality coefficient, M. In view of considerable uncertainity with M estimates obtained by different methods, Y/R was estimated for the three different values of M as a function of E following Smita and Devaraj (1989) and also Goswami and Devaraj (1993). An yield isopleth diagram was drawn by tracing the isolines of yield by choosing a convenient interval between the yield contours. Further, the graphic method of Corten (1974) was employed for the conversion of Y/R curve into absolute yield in kg and plotting the mean annual yield (Y) for the period of 1980-'90 against the corresponding values of fishing morality (F) or exploitation ratio (E). The optimum age of exploitation (t) and the potential yield per recruit were estimated independently according to the method of Kutty and Qasim (1968). Jones (1984) length cohort analysis was also applied for the sexes together to find out the yield and the biomass at each length group. The maximum sustainable yield (MSY) which is considered to be the biologically optimum yield, and the biologically optimum fishing- effort (f_{ms}) were estimated by means of the surplus production models of Schaefer (1954) and Fox (1970). Time series data for the annual catch (Y) and annual fishing effort (f) for 1980 - '90 period (excluding 1985-'86) were used for the study.

Results

The estimated annual M values for *W. attu* by using three different methods were : 1.15 (for the Tmax of 5.0 year following Taylor, 1958) by employing the method of Cushing (1968) ; 0.83 (for the temperature of 27°C) by the method of Pauly (1978) and 1.55 (assumed value) by the method of Smita and Devaraj (1989) and Goswami and Devaraj (1993).

The estimated Z values were 4.47, 1.82 and 4.02 (corresponding survival rates : 0.11, 0.40 and 0.13) for 1982, 1983 and 1984 respectively by following the method of Jackson (1939). The average annual Z was 3.44. By using the Beverton and Holt method (1956), the annual Z was calculated as 3.22, 2.23 and 5.56 (average : 3.70) for L values of 47.9, 54.1 and 41.0 cm for 1982,1983 and 1984 respectively (length at first capture, l_c = 30.0 cm). The annual Z as per the cumulative catch curve method of Jones and Van Zalinge (1979) was estimated to be 4.30, 2.45 and 3.74 for 1982, 1983 and 1984 respectively ; the mean Z = 3.50 (Fig. 1).

For the known values of Z (cumulative catch curve method) and fishing effort f (men/day) for the years 1982, 1983 and 1984, the annual average

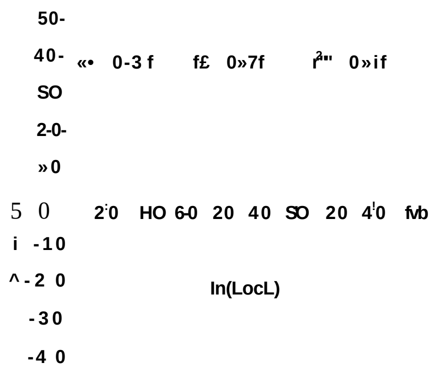

Fig. 1. Cumulative catch curve of *W. attu* for 1982, 1983 and 1984 also showing respective a, b, r^2 and Z values.

catchability coefficient q for *W. attu* in the 'Dhir beel' was estimated to be q = 0.0123 for M = 0.83; q = 0.0108 for M = 1.15 and q = 0.0089 for M = 1.55 (Table 1). Assuming these average values of q to be equally true for the years 1980-'90, Z was calculated to range from 1.45 in 1988-'89 to 5.14 in 1986-'87 for M = 0.83; 1.69 in 1988-'89 to 4.95 in 1986-'87 for M = 1.15 and from 2.0 in 1988-'89 to 4.67 in 1986-'87 for M = 1.55 (Table 2).

The yield per recruit (Y/R) curve for *W. attu* was fitted for the age at first capture t_c = 0.36 year (l_c = 30.0 cm) and t_r = 0.21 year (l_r = 17.5 cm) for 1981-'84 for three different estimated values of M : 0.83, 1.15 and 1.55 as a function of exploitation ratio, E. For M = 0.83, Y/R increases rapidly to attain MSY/R of 640.0 g at E = 0.50 and decreases thereafter to 245.0 g at E = 0.90 (Fig. 2). At M = 1.15, Y/R increases steadily upto 435.0 g at E = 0.50 and declines with further increase of E = 0.90 to 185.0 g (Fig. 3). For M = 1.55, Y/R continues to increase steadily to 390.0 g at E = 0.50 and declines gradually to 175.0 g at E = 0.90 (Fig. 4).

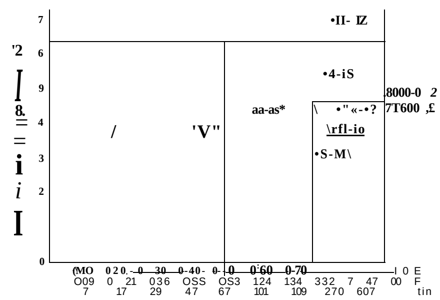

Fig. 2. Yield per recruit curve as a function of E for M = 0.83, t_c = 0.36 years and conversion of Y/R into absolute yield for *W. attu.*

The Y/R curves were converted into absolute yield curves by plotting the annual yield for 1980-'90 during which the mean E values were 0.75, 0.66 and 0.55 for M = 0.83, 1.15 and 1.55 respectively. The observed annual yield values for the known E values were

TABLE 1. *Catchability coefficient, q for the three different values of annual instantaneous natural mortality, M in respect* o/"W. attu *for 1981-'84*

Year	Annual effort f (men/day)	Z	M = 0.83 F	q	M==1.15 F	q	M= 1.55 F	q
1981-'82	244	4.30	3.47	0.0142	3.15	0.013	2.75	0.0113
1982-'83	201	2.45	1.62	0.0081	1.30	0.0065	0.90	0.0044
1983-'84	200	3.74	2.91	0.0150	2.59	0.013	2.19	0.0110
		Average *q*	=	0.0123	=	0.0108		0.0089

TABLE 2. *Annual yield, Y, fishing effort, f, total mortality, Z and fishing mortality, F for* W. attu *in the 'Dhir beel', Assam during 1980 - '90 period (excepting 1985 - '86 for which annual catch and effort data were not available*

Year	Annual yield	Annual effort	M = 0.83		M=1.15		M=1.55	
	Y(kg)	f (men/day)	Z	F	Z	F	Z	F
1979-'80	6,164.0	281	4.29	3.64	4.18	3.03	4.05	2.50
1980-'81	8,587.0	251	3.92	3.09	3.85	2.70	3.78	2.23
1981-'82	11,664.0	244	4.30	3.47	4.30	3.15	4.30	2.75
1982-'83	9,523.0	201	2.45	1.62	2.45	1.30	2.45	0.90
1983-'84	5,588.0	200	3.74	2.91	3.74	2.59	3.74	2.19
1984-'85	8,870.0	245	3.84	3.01	3.75	2.60	3.73	2.18
1985-'86	NA	NA	-	-	-	-	-	-
1986-'87	7,738.0	350	5.14	4.31	4.95	3.80	4.67	3.12
1987-'88	7,652.0	311	4.66	3.83	4.51	3.36	4.32	2.77
1988-'89	6,090.0	50	1.45	0.62	1.69	0.54	2.00	0.45
1989-'90	7,774.0	203	3.33	2.50	3.34	2.19	3.36	1.81

NA = Not available

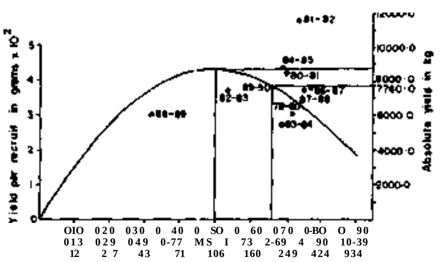

Fig. 3. Yield per recruit curve as a function of E for M = 1.15, t_c = 0.36 years and conversion of Y/R into absolute yield for *W. attu.*

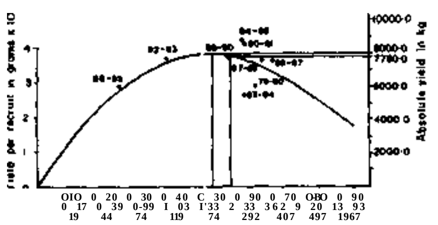

Fig. 4. Yield per reo-uit curve as a function of E for M = 1.55, t_c = 0.36 years and conversion of Y/R into absolute yield for M7 ntti,

superimposed on the respective yield curves. On the Y/R curve for M = 0.83, the observed annual yield values congregate between E = 0.43 in 1988 - '89 and E = 0.84 in 1986-'87 suggesting overexploitation of the stock (Fig. 2). On the Y/R curve for M = 1.15, the observed annual yield values form a cluster between E = 0.32 in 1988-'89 and E = 0.77 in 1986-'87 (Fig. 3). However, the annual yield values follow the Y/R curve for M = 1.55 with the Y values distributing themselves between E = 0.23 in 1988-'89 and E = 0.67 in 1986-'87 (Fig. 4). Thus, the assumed value of M = 1.55 appears to be the true or realistic value of M for *W. attu* in the 'Dhir beel'.

For M = 1.55, Y/R increases steadily upto E = 0.50 (F= 1.55; f = 174 men/ day) when the absolute yield is about 8,000 kg (the yield in weight per recruit, Yw/R = 385.0 g). The average annual yield of 7,965 kg for 1980-'90 is very close to the computed optimum of 8,000 kg at E = 0.50 on the Y/R curve for M = 1.55. However, the optimum f of 174 men/day computed as above is less than the mean annual f of 234 men/day for 1980-'90.

On the basis of the above findings, the value of the catchability coefficient q = 0.0089 for M = 1.55 (Table 1) was used for the estimation of F for the years for which the age composition data were not available. Thus, F for 1980-'90 was estimated to range from 0.45 (f= 50 men/day) in 1988-'89 to 3.12 (f = 350 men/day) in 1986-'87 (Table 2).

The yield isopleth diagram of Beverton and Holt (1957) indicates that the potential yield per recruit (Y'/R) to be 440.0 g at E = 0.95 (Fig. 5). The value of t corresponding to Y^1 is 1.16 year (1 = 70.80 cm). The value of t_y = was estimated to be 1.22 year (1 = 73.53 cm) as per Kutty and Qasim (1968). Following Jones (1984), W. *attu* was found to attain the maximum biomass in the 'Dhir beel' at t_y = 0.98 year (l_y= 62.63 cm) which was very close to the values estimated by the other methods.

The results of the linear (Schaefer, 1954) and exponential (Fox, 1970) regressions when fitted to the catch and effort data in respect of *W. attu* for 1980-'90 (excepting 1985-'86) are expressed as follows:

Y/f = 114.79 - 0.315 f................(1)

Y/f = exp (4.86 - 0.00549 f..........(2)

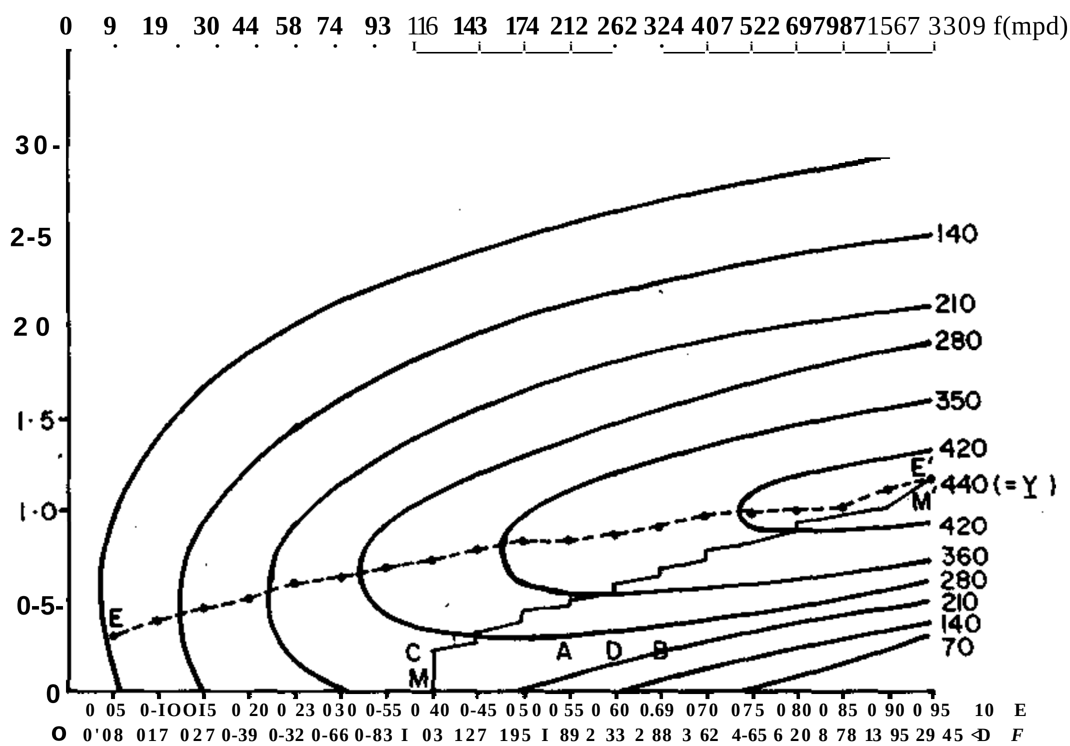

Fig. 5. Isopleth diagram for yield (g) per recruit as a function of f in men/day (also F and E) and t, for *W. attu* (EE' = curve tracing the eumetric yield; MM^1 = curve tracing the MSY ; A = average annual Y/R ; B = annual Y/R for 1982; C = annual Y/R for 1983 and D = annual Y/R for 1984.

The linear relation (Eqation 1) in which 75.0% of the variation (r^2 = 0.75) in Y/f is explained by f, gives MSY of 10,458 kg and f_{msy} estimate of 182 men/day (Fig. 6). In the exponential relation (Equation 2) where 79.0% of the variation (r^2 = 0.79) in Y/f is explained by f, the MSY estimate is 8,646 kg and f_{msy} 182 men/day (Fig. 6).

The highest annual yield of 11,664 kg during 1981-'82 was 1.12 and 1.35 times above the MSY of 10,458 kg (Schaefer, 1954) and 8,646 kg (Fox, 1970) respectively, while the annual effort of 244 men/day was 1.34 times above the f_{msy} of 182 men/day (Schaefer, 1954 and "fox, 1970). However, the annual catch of 8,587 kg and 8,870 kg during 1980-'81 and 1984-'85 for the annual effort of 251 men/day and 245 men/day respectively could reach the MSY level of 8,64(5 kg estimated by Fox model. At the same time much higher annual efforts of 350 men/day and 311 men/day during 1986-87 and 1987-'88 respectively failed to achieve the MSY levels of Schaefer (1954) and Fox (1970). The average annual yield of 7,965 kg for 1980-'90 was obtained with an average annual effort of 234 men/day which is 1.29 times the f_{msy} estimates of 182 men/day by Schaefer (1954) and Fox (1970) model. Thus, the f_{msy} of 182 men/day could be more economical with high catch per unit effort and for the realization of the optimal yield of *W. attu* in 'Dhir beel' (Goswami and Devaraj, 1994).

Discussion

There has been hardly any attempt to estimate mortalities by applying numerical methods for the freshwater fishes in India. Nothing was known about the instantaneous natural mortality and the total mortality estimates for *W. attu* in any other ecosystem. M

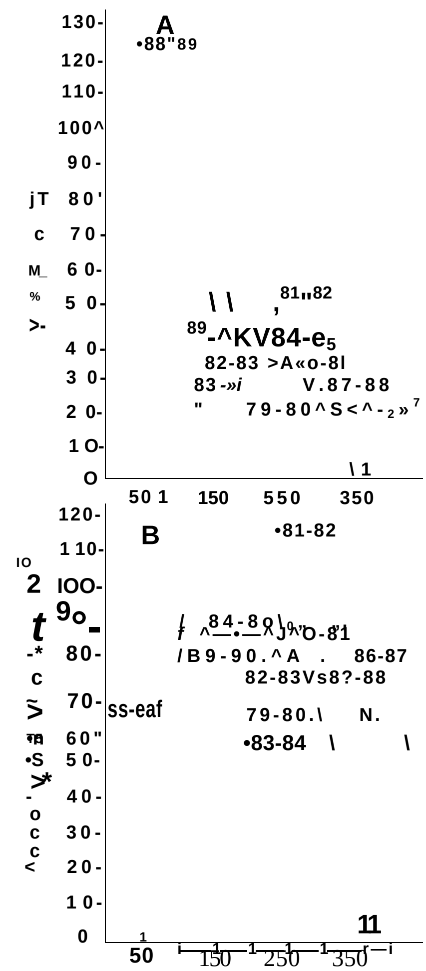

Fig. 6. Relative (A) and absolute (B) yields as a function of effort in men/day for 1980-'90 (1 = linear relation of Schaefer, 1954 and 2 = exponential relation of Fox, 1970) for *W. attu.*

and Z estimated in the present study exhibit less variations from one method to the other. The mortality rates of *W. attu* in the 'Dhir beel' are found to be much higher. Both biotic and abiotic factors govern mortality rates in the 'beel' ecosystem. Fishes in the 'beel' are more prone to diseases due to acidic soil and heavy infestation of aquatic macrophytes imposing hypoxic conditions. Abrupt changes in the hydrobiological parameters during floods create adverse situations to aquatic life in 'beels'. The inflow of allochthonous materials like pesticides and other chemicals add to natural mortality. Various human interferences such as distortion of the ecosystem, poaching and also predation by animals and birds contribute to Z in the 'beels'. The proposition of Rikhter and Efanov (1976) that fishes with high natural mortality mature early in their life seems to be quite true with fishes of the rivers and 'beels' in Assam where they attain maturity even in the first year of their life (Parameswaran *et al*,, 1970). Intensive fishing with multiple fishing gears especially the 'katal' type and 'banas' type in the 'beel' might cause greater fishing mortalities.

The biomass per recruit of *W. attu* attained a peak at a length (1) of 70.80 cm (t =1.16 year) as per the yield isopleth diagram of Beverton and Holt (1957), but at l_y = 73.53 cm (t = 1.22 year) according to Kutty and Qasim (1968) and l_y = 62.63 cm (t_y = 0.98 year) following Jones' (1984) length cohort analysis. The Y/R as a function of E for M = 1.55 increases steadily to a maximum (MSY) of E = 0.50 (f = 174 men/day) at which the absolute yield is 8,000 kg and then the Y/R curve abruptly declines to E = 0.90 (f=1567 men/day). As such the *W. attu* fishery in the 'Dhir beel' could be managed economically at E = 0.50 (f = 174 men/day). However, in view of its highly cannibalistic habit and predominance among the other catfishes, fishing of W. *attu* in 'Dhir beel' could be intensified to beyond E =0.50 (f = 182 men/day). Generally, the catfish are a cheaper source of protein for the lower middle class and poor people of Assam. The sizes above the length at first capture, l_c (= 30.0 cm) command higher commercial value than the sizes below 30.0 cm. Therefore, 1 = 30.0 cm can be considered to be the optimum size at first exploitation of *W. attu* in the 'Dhir beel'.

Among the catfishes, *W. attu* formed a substantial fishery in the 'Dhir beel'. During 1981-'82 the yield was the highest at 11,664 kg. Further, in the year 1980-'81 and 1984-'85 the annual catches of 8,587 kg and 8,870 kg respectively were equivalent to the MSY estimate of 8,646 kg (Fox model). In all the individual years during 1980-'90, higher annual effort was employed resulting in an average annual effort of 234 men/day (f_{msy} = 182 men/day) yielding an average annual catch of 7,965 kg which is 0.76 times and 0.97 times the MSY of 10,458 kg (Schaefer, 1954) and 8,646 kg (Fox, 1970) respectively.

The *W. attu* biomass is estimated to fix an annual radiant energy of 49,391 K Cal ha"^{1} in 'Dhir beel' ecosystem which is equivalent to 41.10 kg of fish ha^{-1} yr^{-1} (Jhingran and Pathak, 1987). At this rate, for LSL of 530 ha of the 'Dhir beel', the total annual stock (P_{msy}) of *W. attu* is estimated to be 21,783 kg. Following Devaraj (1983) and Goswami and Devaraj (1993), the maximum sustainable yield (MSY) is considered to be half of the P_{msy}. As such, the value of 10,892 kg is almost close to the average annual biomass of 10,036 kg as estimated by Jones' (1984) length cohort analysis and the MSY of 10,458 kg as calculated by the Schaefer (1954) model.

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