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Population Dynamics and Stock Assessment of Stripped Murrel *Channa striata* from River Sutlej, Punjab

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Abstract: Present study is conducted to assess population dynamics and stock assessment of *C. striata* first time from Sutlej River stretches in Punjab, India to evaluate its present status and outlining the future policies. Length frequency data of *C. striata* around 500 fish samples was collected at monthly intervals from selected three sites (November 2020 to October 2021) and analyzed using the FiSAT II (FAO-ICLARM). Asymptotic length (L_∞), growth coefficient (K) and age at zero length (t_o) to be calculated as 63 cm, 0.77 yr^{-1} and 0.02 yr, respectively. The growth performance indices (Ø) and longevity (t_{max}) value was 3.488 and 3.92 yr. Total mortality (Z), fishing mortality (F) and natural mortality (M) were 2.51, 1.27 and 1.24 yr^{-1}, respectively. The exploitation ratio was 0.51 and the exploitation rate (U) to be 0.39 yr^{-1} indicating overexploited condition. The $E_{cur} < E_{0.1}$ denotes there is little scope to increase further fishing efforts for this species to reach the target reference point (TRP). Existing fishing pressure should be reduced substantially for sustainable development of *C. striata* species in River Sutlej.

Keywords: Sutlej River, *Channa striata*, Growth parameters, Exploitation ratio, Overexploitation

Fisheries are a key source of employment and revenue for the country development and if they are used in a planned manner, fish populations are subjected to natural management process and are a renewable resource (Rizvi et al 2010). Knowledge of population dynamics is an important fundamental part of fish biology for establishing the status of fish stocks and management of targeted fisheries (Dwivedi and Nautiyal 2012). *Channa striata* commonly known as stripped Murrel/snakehead (locally known as Shol fish) is an important member of Channidae family that can be found in a variety of habitats including rivers, marshes, pond, canals, lakes and rice fields. It is a freshwater fish that is native to Asia and tropical Africa. It can withstand harsh environmental condition in water with low dissolved oxygen content and can even survive for long time in land with the help of its accessory respiratory organ. Dua and Kumar (2006), Khan and Khan (2009) and Khan et al (2012) worked on population dynamics of *Channa* species such as *C. marulius* and *C. punctata* but the literature with respect to population dynamics and stock assessment of *C. striata* from India is in scanty. Fahmi et al (2013) and Sofarini et al (2018) studied population dynamics and stock assessment of *C. striata* from Indonesian waters. *C. striata* also has a very good demand as a potential candidate species in ornamental fish markets. The species is mostly harvested from natural water bodies, road side's ditches, derelict water bodies, and is placed under least concerned category in IUCN Red list.

This is the first study to look into population dynamics and stock assessment of C. *striata* from Sutlej River, India. The latest modelling approach is employed in this study to compute growth, recruitment, mortality, yield/ recruit and virtual population analysis (VPA) using FAO's fishery software FiSAT II and developing management plans for the conservation of this valuable aquatic resource.

MATERIAL AND METHODS

Study sites and experimental design: Length-frequency data of a *C. striata* has been collected on weekly interval basis from the three different sampling sites of Sutlej river i.e. Rupnagar (30°59′ 52.9404″N, 76°32′ 00.636″E), Rail/road Bridge at Phillaur, Ludhiana (30°59′ 35.2608″N, 75°47′ 28.2516″E) and Harike (31°08′ 32.334″N, 74°56′ 55.0032″E). The basin shapefile was obtained from the NRSC/INDIA-Water Resource Information System, and the sampling map was created using the ArcMap 10.8.1 platform (Fig. 1). Population dynamics and stock assessment of one of the commercially important *C. striata* has been evaluated from November, 2020-October, 2021 using FiSAT II (FAO-ICLARM Stock Assessment Tools) computer software package. A total of 500 numbers of *C. striata* was considered for population dynamics study. Total length was measured to a nearest 0.1 cm from tip of snout to the posterior end of caudal fin in measuring board and fish weight was noted to nearest gram with the help of a precision balance (Mettler

Toledo, Switzerland). Multistage stratified random sampling method described by Srinath et al (2005) of CMFRI, Cochin was followed during sampling.

Growth parameter: The growth pattern of fish has been expressed using Von Bertalanffy growth equation (Von Bertalanffy 1938):

$L_t = L_\infty(1-e^{-K(t-to)})$

Where: L_t is the mean length at age t, L_∞ is the asymptotic length, K is the growth coefficient and t_o is the age at zero length (initial condition parameter). During the present study estimation of growth parameter was performed by employing computer based FiSAT program developed by Gayanilo et al (1996).

Age at Zero Length (t_o): Pauly's empirical equation (Pauly 1979) was used to determine the age at zero length (t_o)

$\log(-t_0) = -0.392 - 0.275 \log L_\infty - 1.0381\ K$

Where, t_0 = age at zero length, L_∞ = asymptotic length, K = growth coefficient

Growth Performance Index (Ø): The final estimations of asymptotic length (L_∞) and growth coefficient (K) (Pauly and Munro 1984) were used to calculate the growth performance index:

Phi (Ø) = $\log K + 2 \log L_\infty$

Where, Phi (Ø) = growth performance index, L_∞ = asymptotic length, K= growth coefficient.

Longevity (t_{max}): The equation presented by Pauly (1983) was used to calculate the longevity.

$t_{max} = 3/K + t_o$

Mortality parameters: The mortality parameters are those key parameters which are used to describe the rate of death. A cohort is the batch of fish with approximately the same age and belonging to the same stock. The total mortality rate of the cohort Z is the sum of the instantaneous rate of fishing mortality F, which is caused by the fishing operation and the instantaneous rate of natural mortality M, which includes deaths caused by all other factors other than fishing like predation, starvation, disease, competition and senility. Length converted catch curve was used to calculate total mortality (Z). Pauly's empirical formula was used to determine natural mortality (M) by taking the mean water surface temperature of River Sutlej as 28.7°C (Pauly 1980).

$\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.463 \ln(T)$

Where, L_∞= Asymptotic length, K= Growth coefficient, T= Surface water temperature

Total mortality (Z) was calculated from the length converted catch curve using FiSAT software (Pauly 1983). Fishing mortality (F) was estimated by Pauly (1980).

$F = Z - M$

Where, F= Fishing mortality, Z= Total mortality, M= Natural mortality

Length structured virtual population analysis (VPA) of FiSAT was used to calculate fishing mortality of each length class. Exploitation ratio (E) and exploitation rate (U) were estimated from the equations given below (Narasimham 1994):

$E = F/Z$

$U = (F/Z)^*(1-e^{-z})$

Where, F= Fishing mortality, Z = Total mortality, E = Exploitation ratio

Relative yield and Biomass per recruit: The original yield per recruit model of Beverton and Holt (1957) has modified by Beverton and Holt (1966) to estimate relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R). The L_c can be taken from knife-edge selection method suggested by Beverton and Holt (1957).

Relative yield per recruit (Y'/R):

$Y/R' = E^*U\ M/K^*[1-\{3U/(1+m)\}+\{3U^2/(1+2m)\}-\{U^3/1+3m\}]$

Where,

$U = 1-(L_C/L_\infty)$

$m = (1-E)/(M/K) = (K/Z)$

$E = F/Z$

Relative biomass per recruit (B'/R) was estimated from the following relationship

B'/R = (Y'/R)/F, while E_{max}, $E_{0.1}$ and $E_{0.5}$ were assessed by using the first derivative of this function. In FiSAT package 'E_{max}' represents the exploitation rate which produces maximum yield. The Y'/R and B'/R were calculated at different exploitation ratios by keeping the L_{c50} as constant. The yield isopleth diagram is a three dimensional figure giving exploitation ratio (E) on the X-axis and different sizes at first capture by using L_c/L_∞ ratios on Y-axis the iso-values of Y'/R were plotted to generate the yield isopleth diagram. The output of this process are plots of Y'/R vs. E = (F/Z) and of B'/R vs. E, from which E_{max} (is the exploitation rate which produces maximum yield), $E_{0.1}$ (is the exploitation rate at which the marginal increase in relative yield per recruitment is $1/10^{th}$ of its value at E=0) and $E_{0.5}$ (value of E which denote 50% deduction of its unexploited biomass) are also estimated. Data was analysed using the FiSAT II (FAO-ICLARM) computer software package.

RESULTS AND DISCUSSION

Growth parameters: The mean length of *C. striata* was higher in April (46.45 cm) followed by October and March but lower in December to August (Table 1). Using the ELEFAN I algorithm, the asymptotic length (L_∞) and growth coefficient (K) was calculated as 63 cm and 0.77 year^{-1} in *C. striata*, respectively (Fig 2).The t_o was estimated 0.02 year in *C. striata*. The growth equation of von Bertalanffy was estimated as $Lt=63\ [1-e^{-0.77(t-0.02)}]$

Fahmi et al (2013) reported L_∞ and K of the *C. striata* as 72.98 cm and 0.36 year^{-1} and t_o be estimated -0.52 year at Lubuk Lampam flood plains, South Sumetra. Sofarini et al (2018) at Danau Panggang swamp (South Kalimantan) reported L_∞ and K value as 63.4 cm and 0.15 year^{-1}, respectively and calculated t_o value as -0.52 year. The t_o value is considered as an indicator of juvenile development. If t_o be positive, it implies that juvenile growth is slow, while a negative value suggests that juvenile growth is quick as compared to adult fish (King 2013). In present study, the estimated value was 0.02 year indicating slow initial growth of juvenile fish in River Sutlej. The growth performance indices (ø) and longevity (t_{max}) was recorded 3.488 and 3.92 year which is considered good. Length-weight relationship in *C. striata* established as Log W = -1.12 + 2.15 log L with co-efficient 'b' value 2.15 (Fig.3). The co-efficient of determination (r^2) values explains the proper fit of the model for growth. Value of r^2 in *C. striata* was calculated as 0.85 indicating more than 85% variability by the model and good fitness (Table 2). Negative allometric growth was observed in *C. striata*; thus species became slender as it increased in length. The fish normally does not retain the same shape or body outline throughout their lifespan and specific gravity of tissue may not remain constant, the actual relationship may depart significantly from the cube law (Datta et al 2013).

Table 1. Length range and mean length of *C. striata* at Sutlej River

Month	Length range (cm)	Mean length (cm)
December-2020	27-46	36.5
January-2021	24.5-51.9	38.2
February-2021	23-55.8	39.4
March-2021	27.5-55.4	41.45
April-2021	36.9-56	46.45
August-2021	26-49	37.5
September-2021	25.2-53	39.1
October-2021	32.6-53.6	43.1

Mortality rate and exploitation ratio: Natural mortality rate calculation is important to understand the rate of stock decay. Calculation of 'M' is difficult for exploited resources. Natural mortality (M), fishing mortality (F) and total mortality (Z) was 1.24 year^{-1}, 1.27 year^{-1} and 2.51 year^{-1} for *C. striata*, respectively. Fishing mortality rate was to be higher than the natural mortality which implies existing fishing pressure in River Sutlej is high. The natural mortality generally casused due to disease, environmantal transition, predation, hazards, pollution and senility(Guilin et at 2019). Estimation of Z from Length converted catch curve method with extrapolated data points in *C. striata* from River Sutlej are depicted in Figure 4. Exploitation ratio (E) and explotation rate were 0.51 and 0.39, respectively which clearly indicates that the stock is over

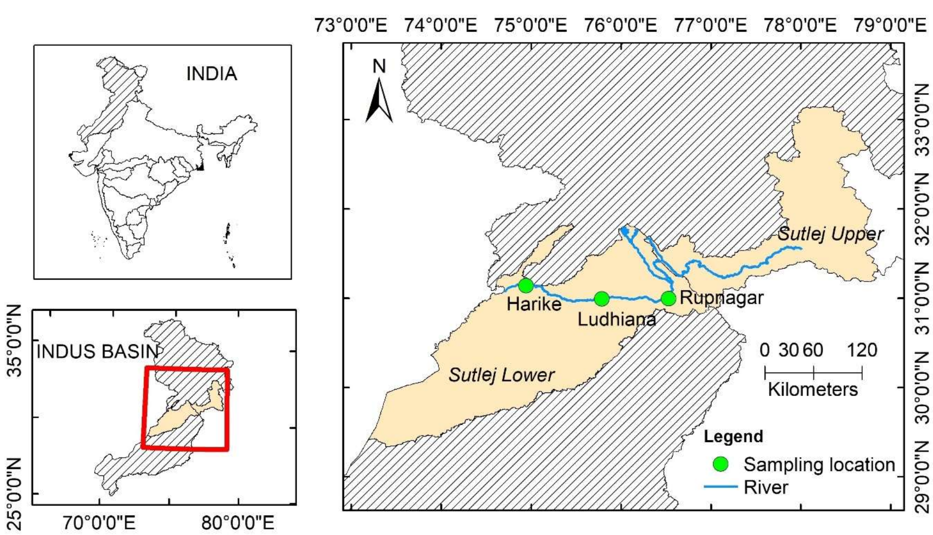

Fig. 1. Map view of the selected sampling site of Sutlej River

Table 2. Length-Weight relationships of *C. striata* collected from Sutlej River

Fish species	Logarithmic equation (Log W = Log a + b Log L)	Mean length (cm)	Mean weight (gm)	Growth coefficient 'b'	Correlation coefficient 'r'	Coefficient of determination 'r^2'	Growth type
Channa striata	Log W= -1.12+2.15 log L	41.00±1.64	570.58±53.72	2.15	0.92	0.85	Negatively allometric

exploted in River Sutlej. A stock is considered ideally exploted when F= M and or E= 0.50 when E value exceeds 0.5 the stock is considered over exploted (Guilin et at 2019). Fishing mortality should be reduced to be $E_{0.5}$ to achieve maximum sustainable yield for *C. striata*. Fahmi et al (2013) observed the average total, natural and fishing mortalities in *C. striata* in the Lubuk Lampam flood plains were 1.72, 0.73, and 0.58 per year, respectively. Fishing and total mortality were used to compute the exploitation rate (E), was 0.58, indicating overexploitation (E > 0.5). Sofarini et al (2018) observed average total, natural and fishing mortalities of *C. striata* at Danau Panggang swamp as 1.12, 0.43, and 0.69 per year, respectively. Natural mortality was predicted to be lower, which could be attributed to its extremely predatory nature.

Recruitment pattern: The recruitment pattern was investigated from recruitment curves using final estimated values of L_∞, K and t_o using FiSAT II program. In present study for the *C. striata*, recruitment was continuous throughout the year. However, higher recruitment peaks was detected during June (15.14%) and July (16.66%) (Fig. 5). The length at recruitment (L_r) of *C. striata* was 25 cm ry. Fahmi et al (2013) in *C. striata* at Lubuk Lampam flood plains, South Sumatera indicated average recruitment percentage as 8.3.

Virtual population analysis (VPA): Based on the VPA analysis it can be stated that the fish upto 25 cm are mainly subjected to natural mortality (Fig. 6). After this size, fish become more vulnerable to fishing gear, resulting in an increasing fishing related mortality. Total length ranging from 35 to 45 cm was vulnerable to fishing mortality.

Probability of capture: The probability of capture denoted the critical length of fish vulnerable to gear. In *C. striata* L_{25}, L_{50} and L_{75} were calculated 23.53 cm 27.28 cm and 31.08 cm, respectively. The L_C/L_∞ and M/K value was found to be 0.433 and 1.61, respectively (Fig. 6). The evaluated M/K score was 1.61, indicating good condition. M/K ratio determines the reliability within the range of 1.0-2.5 in most of the fishes.

Relative yield per recruit (Y/R) and biomass per Recruit (B/R): L_C/L_∞ = 0.433 and M/K = 1.61 was used as input data to calculate Y/R and B/R. *C. striata* was exploited by selective as well as semi selective gears; thus 'knife edge selection' is hardly met in real situation. The present study revealed maximum Y/R could be achieved at an exploitation ratio (E_{max}) of 0.647 in *C. striata*. However the exploitation level of a stock at E_{max} level can decrease the biomass in a drastic level thus it should not be used as a target reference point (TRP). As a part of precautionary measures the exploitation level should be reduced to a point where marginal increase in Y/R reaches 1/10th of the marginal increase calculated at a very low value of E ($E_{0.1}$) which was 0.55 in *C. striata* and this may be used as relatively safe reference TRP (Fig. 8). E_{cur} value (0.51) is less than $E_{0.1}$ (0.55) which indicates that there is little

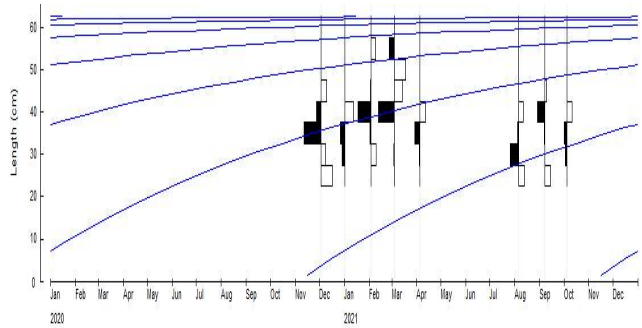

Fig. 2. von Bertalanffy growth curve of *C. striata* superimposed on the restricted length frequency histogram with normal length-frequency histograms (L_∞ = 63 cm, K = 0.77 yr^{-1}, t_o= 0.02 yr, C = 0 and WP = 0). Lines superimposed on the histograms link successive peaks of growing cohorts as extrapolated by the model

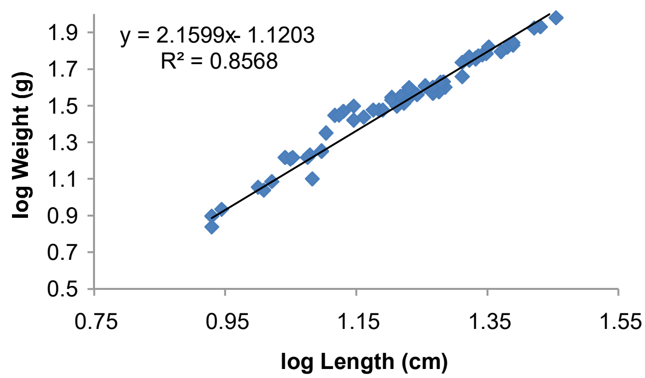

Fig 3. Length-weight relationship of *C. striata* collected from Sutlej River

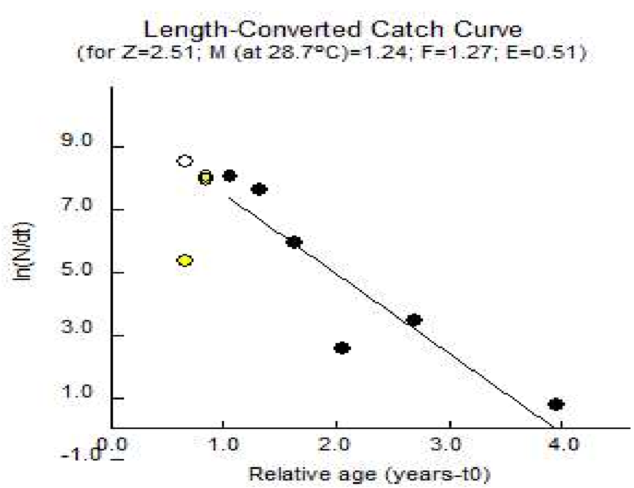

Fig. 4. Estimation of Z from length converted catch curve method with extrapolated data points in *C. striata* from River Sutlej

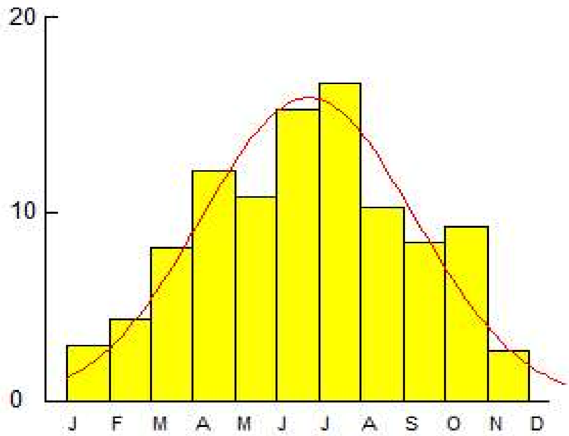

Fig. 5. Recruitment pattern of *C. striata* from River Sutlej during the study period

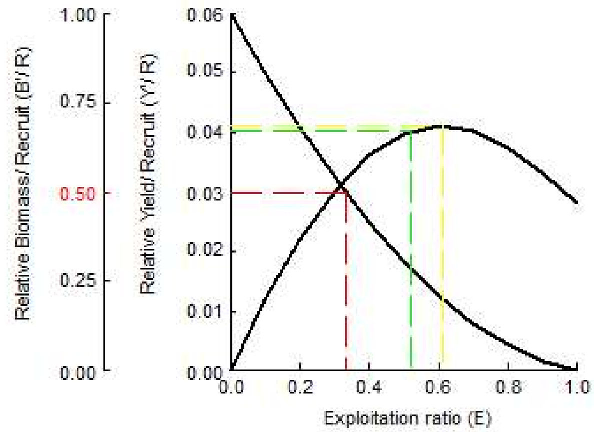

Fig. 8. *C. striata* stock structure with the use of Beverton and Holt's Relative yield per recruit and biomass per model from River Sutlej

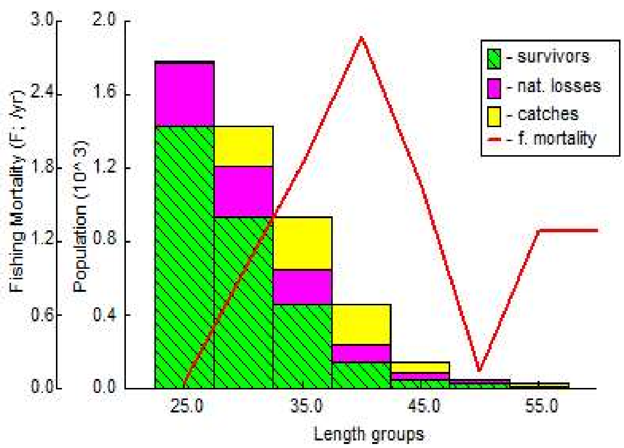

Fig. 6. Length structured virtual population analysis (VPA) of *C. striata* at River Sutlej

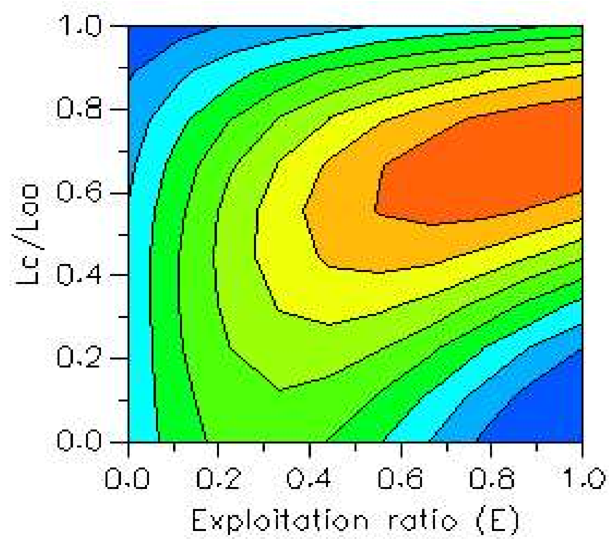

Fig. 9. Yield isopleth diagram of *C. striata* from River Sutlej

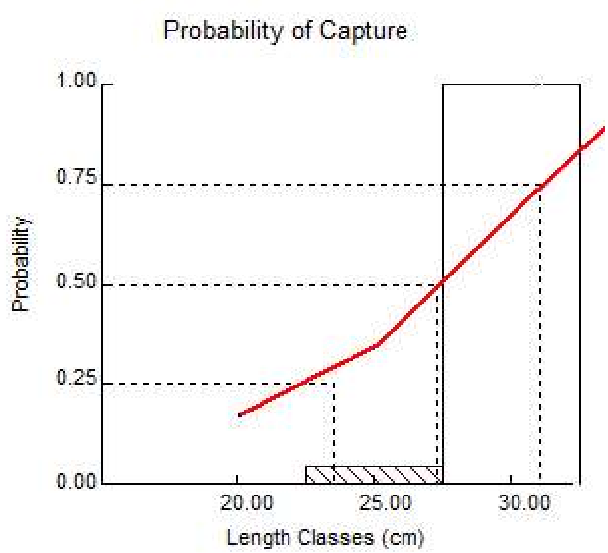

Fig. 7. Probability of capture of *C. striata* from River Sutlej during the study period ($L\infty$ = 63 cm, K= 0.77 $year^{-1}$ and t_o=0.02 year)

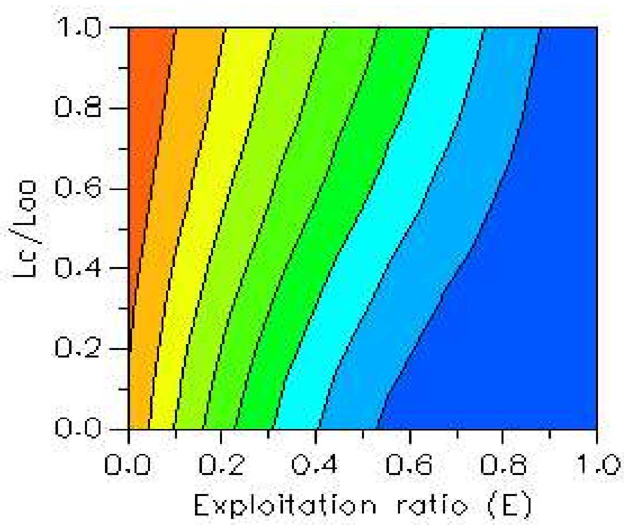

Fig. 10. Biomass isopleth diagram of *C. striata* from River Sutlej

scope to increase further fishing efforts for this species to reach the TRP. Fahmi et al. (2013) reported E_{max} (0.52) value less than exponential ratio (E= 0.58) in case of *C. striata* at Lubuk Lampam flood plains, South Sumatera. The yield isopleths diagram (Fig. 9 and 10) denoted that the relative yield per recruit may be obtained at L_C/L_∞ of 0.55 and an E of 0.5.

CONCLUSIONS

C. striata established negative allometric growth; thus species became slender as it increased in length. Length frequency distribution suggested that juvenile and adult stages of *C. striata* are equally vulnerable to fishing pressure. The highest recruitment peaks were detected during June and July in *C. striata* indicating monsoon is the breeding season for *Channa* species in Punjab waters. Fishing mortality was higher than natural mortality (thus the stock is subjected to heavy fishing pressure. E_{cur} value is less than $E_{0.1}$ which denotes there is little scope to increase further fishing efforts for this species to reach the target reference point The fishing pressure can be decreased until $E_{0.5}$ to get maximum sustainable yield for *C. striata* in river Sutlej. Population dynamics of *C. striata* revealed that existing fishing pressure should be reduced substantially for sustainable development of species in River Sutlej. Findings pertaining to present study may be useful as valuable time series data w.r.t. future study and policy making of fisheries in River Sutlej.

AUTHORS CONTRIBUTION

Shikha conducted sampling and analysed the data and wrote the manuscript. Surjya Narayan Datta conceptualized the theme, helped in sampling, interpreted the results and wrote the manuscript. Prabjeet Singh and Grishma Tewari helped in sampling.

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