EVALUATION OF *LABEO CALBASU* FISHERY STATUS USING SURPLUS PRODUCTION MODELS IN KAPTAI RESERVOIR, BANGLADESH

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Abstract. Surplus-production models were used for estimating the sustainable exploitation of *Labeo calbasu* fish stock in Kaptai reservoir, Bangladesh. The annual catch and effort data of 14 years (2001-2014) were analyzed to estimate the Maximum Sustainable Yield (MSY) using software packages CEDA and ASPIC. The average production was found 156 mt while the topmost and undermost catch was 263 mt (in 2009) and 108 mt (in 2003) respectively MSY and CV of Fox model for normal, log normal and gamma assumption were 87 mt (0.339), 65 mt (0.464) and 67 mt (0.551) respectively whereas values from Schaefer model were 139 mt (0.055), 130 mt (0.055) and 137 mt (0.064) and 139 mt (0.059), 130 mt (0.056) and 137 mt (0.064) in Pella-Tomlinson models. As regards, ASPIC estimated MSY and CV values for Fox and Logistic models were 127 mt (0.054) and 133 mt (0.057) respectively. Higher R2 values (above 0.879) in ASPIC in contrast with CEDA (0.71-0.818) represent its better fitting to data. To be conservative, we choose the MSY of 80-100 mt which indicates overexploited condition of *L. calbasu* in Kaptai reservoir and actions should be taken for sustainable management.
Keywords: *population dynamics, CEDA, ASPIC, maximum sustainable yield, exploitation, management*

Abbreviations: ASPIC - A Stock Production Model Incorporating Covariates; B - biomass; B/B_{MSY} - ratio of biomass to B_{MSY}; BDM - Biomass Production Model; B_{MSY} - biomass at giving MSY; CEDA - Catch and Effort Data Analysis; CPUE - Catch Per Unit Effort; *CV* - Coefficient of Variation; DoF - Department of Fisheries; F - fishing mortality; F/F_{MSY} - ratio of fishing mortality to F_{MSY}; F_{MSY} - fishing mortality rate at MSY; FAD - Fish Aggregating Device; FRSS - Fisheries Resource Survey System; IP - Initial Proportion; K - carrying capacity; MF - Minimization Failure; MSY - Maximum Sustainable Yield; q - catchability coefficient; r - intrinsic population growth rate; R^2 - coefficient of determination; SD - Standard Deviation; SE - Standard Error; SPM - Surplus Production Model

Introduction

Fishery is one of the lion's share consequential sources of revenue and socio-economic industry in Bangladesh as the country is glorified with hundreds of rivers and ditches, large coastal waterbody, a huge portion of wetlands, oxbow lakes, Bay of Bengal etc. Kaptai reservoir locally known as Kaptai Lake (latitude 22°22'-23°18' N; longitude 92°00'-92°26' E, *Fig. 1*) is the largest artificial freshwater resource of South-East Asia (Fernando, 1980; Haldar et al., 1991). It was constructed for hydro-electrical power generation damming the river Karnafuli situated in the Chittagong hill tracts in 1961. However fisheries, flood control, drainage and irrigation are considered as secondary option. The total outer area and average deepness of water is about 68,800 ha

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and 9 m respectively containing the highest depth of 32 m (Alamgir and Ahmed, 1986; Haldar et al., 2003). The significant role of Kaptai reservoir in fishery production and socio-economic sectors has made this reservoir one of the most potential fisheries support of Bangladesh.

Kaptai reservoir constitutes a major portion of inland water resources. According to the report of Ahmed (1999) it comprises about 46.8% of the entire pond area of Bangladesh offering a huge potential for fish production. The major fish landing sites of the reservoir are shown in *Figure 1*. Ahmed et al. (2001) stated that during their study in this lake, fishery has been found to contribute around 6000 mt annually and the number of engaged fishers were estimated as 5560. Mesbahuddin (1966) documented that a small scale fishers group first started fishing here in 1963 using gill nets, seine nets, hooks and lines. About 74 freshwater species produce around 6000 mt of fish every year (Ahmed et al., 2001; Chakma, 2007). But according to the recent production records, a declining trend has been found in the productivity of high-value fish with the courses of time.

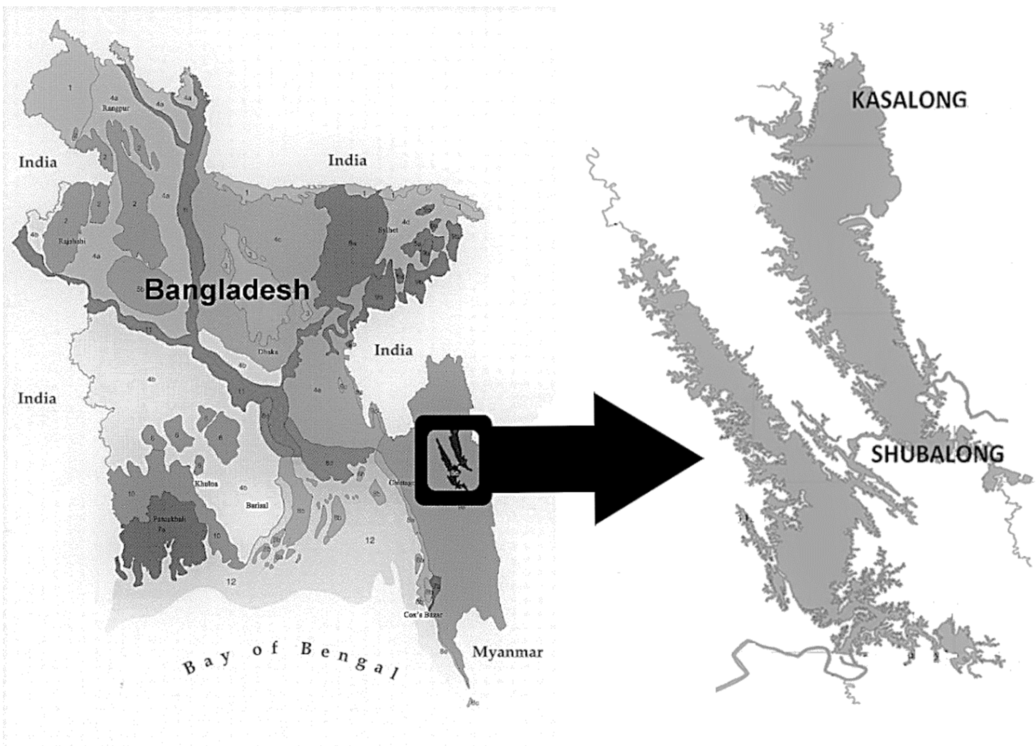

Figure 1. *Map showing the major landing sites of Kaptai reservoir*

Borre et al. (2001) stated that it could happen because the world’s lakes suffer from some crucial threats for example quick eutrophication, invasive species, noxious pollution, excess fishing, alteration in water direction, acidic water and altered climate. Remarkably, Kaptai reservoir is also troubled by invasive species, overfishing of certain species and water diversion issue due to regulating electricity. Thus the performance of Kaptai reservoir has been suffering from a host of environmental, socioeconomic and management constraints as well affecting its potential.

Productivity record says that highly commercial important carps such as *Labeo rohita*, *Catla catla*, *Cirrhinus cirrhosis*, *L. calbasu* and *Tor tor* were found to show a

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dramatic decrease and it has been noted that the carp production was about 81% of the total production in 1965/66 while now it is only 5% (Alamgir and Ahmed, 1986). *L. calbasu* is an important profit-making omnivorous fish found in slow running rivers, ponds and lakes and normally attains a length of about 90 cm and weight of 5.5 kg. It is available throughout India except in Kerala (Jayaram, 1999), Bangladesh, Pakistan, Nepal, Myanmar, Burma, Thailand, Yunnan and also South China. Moreover, being a profitable species it is often cultured in South Western China (Jhingran, 1982). The productivity record of 2001-2014 reveals that the annual average yield of carp was about 415 mt while the average production of *L. calbasu* per annum comprises 156 mt (37.6% of total carp production) in this reservoir.

Hitherto, the orange fin *Labeo* along with other species have suffered from blind commercial fishing, dreadful conditions of ecosystem, destruction of habitat, lack of policy implementation, reduction of water level, toxic waste, using of unconstitutional fishing gears, deterioration of breeding ground, catching of juveniles etc. In this regard, the understanding of population dynamics of aquatic resources is essential for getting the maximum benefit and protecting water resources. Undoubtedly, the principal management approaches of a species are to assess its stock. The aim of this assessment includes the understanding of fish population dynamics (Jennings et al., 2001) predicting the fish population for alternative management approaches if needed (Hilborn and Walters, 1992).

In accordance with fish population ecology and economics, MSY (maximum sustainable yield MSY) is the largest harvested sustainable catch from a species' stock under the privileges of current ecological conditions where non-equilibrium biomass production models (BDMs) (also known as surplus production models, SPMs) could be used to assess the MSY value for a fish stock. The stereotyped SPMs which has been used to assess fishery resources have got universality as it is easier to run. MSY parameters can be determined directly from catch and effort (CPUE) data (Polacheck et al., 1993). In spite of being questioned the MSY, estimated from surplus production models has kept increasing its popularity as fishery management target biological reference points (Ricker, 1975; Pitcher and Hart, 1982; Hilborn and Walters, 1992; Prager, 1994; Quinn and Deriso, 1999; Maunder et al., 2006). Nevertheless, the MSY reference points B_{MSY} (biomass at giving MSY, B_{MSY}) and F_{MSY} (fishing mortality rate at MSY, F_{MSY}) are frequently considered as management benchmark (Jacobson et al., 2002).

However, past works have been done focusing on the biological and limnological aspects of Lake Fishery (Chowdhury and Mazumder, 1981; Azadi, 1985; Mahmood, 1986; Hye and Alamgir, 1992; Ahmed et al., 1994) and on its socioeconomic aspects (Ahmed, 1999; Hye, 1988). Although some studies have been done on conservation *L. calbasu* of Kaptai lake (Alam et al., 2000; Haroon et al., 2002; Nahiduzzaman et al., 2012; Hasan et al., 2013; Kabir and Quddus, 2015) but no work has been done yet neither to estimate the sustainable yields nor to assess the stock size of *L. calbasu* in Kaptai reservoir using surplus production models. Studies on population dynamics and assessment of any fishery are of great importance in management. Therefore, it is crucial that fisheries experts deliver a dependable diagram of stock dynamics and stock status to the authorities (Lynch et al., 2012). Thus, different production models have been used in this study aiming at the estimation of the size of mentioned fish production. The study has been performed to draw the required management accesses for its sustainable exploitation which may help fishery administrators and fishery

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biologists to achieve the target. Therefore, the aim and scope of the article was to provide new perspective of surplus production models for the sustainable exploitation of the high value *L. calbasu* stock in Kaptai lake estimating its MSY.

Materials and methods

Data assemblage

The catch and effort data of Orange fin *Labeo* from 2001 to 2014 were obtained from the data documented by Fisheries Statistical Report of Bangladesh compiled by FRSS (Fisheries Resource Survey System, FRSS), DoF (Department of Fisheries, DoF). The catch data has been presented in weight (mt) while the CPUE in the form of catch captured per boat. The non-equilibrium models have been used to analyze the data. The reservoir is dominated by multi-species fishery and one gear can be used to catch different fishes at a time. Professional, seasonal professional and subsistence fishers use traditional fishing methods and artisanal gears such as seine net, cast net, gill net, lift net, hooks and lines and one type of fish aggregating device (FAD). Mostly Gill net and Sein Net are used with mechanized and non-mechanized vessels engaging for fishing. The mechanized crafts spend 8 to 12 h a day in each voyages, while non-mechanized are operated on daily basis where duration of operation is not fixed. The number of fishing boat fluctuated from 634 to 1702 in the study period. Use of fishing gears and its operating time vary depending on water depth, weather condition, fish abundance, type of fishing grounds, fisherman and vessels as well. Thus, the efforts were taken as fish captured by mechanize and non-mechanized boats per day. However, generally the fishing duration of seine net, gill net, cast net, lift net and FAD are 12 h, 13 h, 4 h, 12 h and 8 h per day, respectively (Roy et al., 2018).

Biomass production models

The available fishery census of *L. calbasu* were analyzed by CEDA (catch and effort data analysis) and ASPIC (a stock production model incorporating covariates) (Hoggarth et al., 2006; Prager, 2005). The Biomass Dynamics Models (BDMs) consist of Schaefer, Fox, and Pella-Tomlinson models.

The most frequently used Schaefer model (Schaefer, 1954) is established on a logistic population growth model (*Eq. 1*):

$$\frac{\mathrm{d}B}{\mathrm{d}t} = rB(B_{\infty} - B) \qquad \text{(Eq.1)}$$

Later on, considering the Gompertz growth equation Fox suggested the following analysis (*Eq. 2;* Fox, 1970):

$$\frac{dB}{dt} = rB(1nB_{\infty} - 1nB) \qquad \text{(Eq.2)}$$

However, the final generalized equation (*Eq. 3*) was stated by Pella and Tomlinson (1969):

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$$\frac{dB}{dt} = rB(B_{\infty}^{n-1} - B^{n-1}) \quad \text{(Eq.3)}$$

where B = the biomass, t = time, B_{∞} = carrying capacity, r = intrinsic growth rate

CEDA (version 3.0.1)

The computer package CEDA version 3.0.1 has been built based on non-equilibrium surplus production models (Schaefer, 1954; Pella and Tomlinson, 1969; Fox, 1970). It follows the standard dynamics of the fish production models. Moreover, it also expresses three error assumptions named normal, log-normal and gamma. *CV* (coefficient of variation) of the estimated MSY could be calculated from the output confidence interval. CV of *Tables 2* and *3* were determined by bootstrapping method.

ASPIC (version 5.0)

The ASPIC package denotes the association of both Logistic (Schaefer) and Fox (a special case of GENFIT) production models. This package permits the bootstrap estimation of variability and is efficiently adaptable in case of handling different fishing patterns. Both the CEDA and ASPIC packages require an input value of initial proportion that is IP. Initial proportion defines the progressive fishery data series. IP equal to zero or near to zero implies that the fishery started from maiden state while the value of IP close to one refers to the fishery started from a heavily exploited population. The primary production was about 73% of the maximum catch so IP = 0.7 was used in this study for both CEDA and ASPIC computer packages. R^2 values determine the goodness-of-fit of the model to data.

Results

The observed highest and lowest catch were in 2009 (263 mt) and in 2003 (108 mt) respectively while the average yield was 156 mt in this period. The topmost and undermost values of CPUE were found as 0.255 mt/boat (in 2001) and 0.066 mt/boat (in 2014) respectively (*Table 1*) containing the average CPUE 0.148 mt/boat. It shows the increasing trend of effort causes decreasing rate of catch and CPUE with a slight fluctuation in courses of time.

CEDA result

CEDA has been found to be sensitive towards different IP values. Consequently, it has produced different outputs MSY estimations for different IP inputs (*Table 2*). In some cases, gamma error assumption has been found to exhibit minimization failure in different models (for IP = 0.1, 0.8 and 0.9). However, minimization failure was also observed in Fox model for IP = 0.8. *Table 3* shows the computed parameters for IP = 0.7. According to Fox model the R^2 values of normal, log normal and gamma assumption were 0.71, 0.75 and 0.734 respectively while IP = 0.7 (*Table 3*). On the other hand, the R^2 values calculated by Schaefer and Pella-Tomlinson for all error assumptions remained the same as 0.81, 0.818 and 0.815 orderly.

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Table 1. *Time series catch (mt) and CPUE (mt per boat) statistics (2001-2014) of Labeo calbasu of Kaptai reservoir, Bangladesh*

Year	Catch	Effort	CPUE
2001	192	754	0.255
2002	163	864	0.189
2003	108	670	0.161
2004	189	912	0.207
2005	121	634	0.191
2006	169	998	0.169
2007	149	956	0.156
2008	143	967	0.148
2009	263	1543	0.17
2010	173	1534	0.113
2011	148	1587	0.093
2012	125	1624	0.077
2013	123	1698	0.072
2014	113	1702	0.066
Sum	2179	16443	2.067
Max	263	1702	0.255
Min	108	634	0.066
Avg	156	1175	0.148
MEDIAN	148.5	982.5	0.158
SD	41.184	411.404	0.056
Variance	1696.093	169253.5	0.015
SE	11.007	109.952	0.015
CV	0.265	0.35	0.382

Note: Statistical analysis of base data sets are shown here

Table 2. *MSY (maximum sustainable yield) and CV (coefficient of variation) for Labeo calbasu in Kaptai reservoir, estimated by CEDA for IP = 0.1-0.9*

IP	Model								
	Fox			***Schaefer***			***Pella Tomlinson***		
	Normal	**Log normal**	**Gamma**	**Normal**	**Log normal**	**Gamma**	**Normal**	**Log normal**	**Gamma**
0.1	216	237	MF	357	312	MF	357	312	MF
	0.074	**0.033**	**MF**	**0.186**	**0.155**	**MF**	**0.1**	**0.165**	**MF**
0.2	157	142	142	202	186	189	202	186	189
	0.063	**0.097**	**0.099**	**0.089**	**0.133**	**0.122**	**0.097**	**0.134**	**0.125**
0.3	140	119	136	155	132	146	155	132	146
	0.059	**0.11**	**0.07**	**0.092**	**0.16**	**0.113**	**0.094**	**0.161**	**0.119**
0.4	135	136	132	137	114	130	137	114	130
	0.056	**0.035**	**0.064**	**0.078**	**0.154**	**0.104**	**0.084**	**0.149**	**0.107**
0.5	134	120	130	132	105	127	132	105	127
	0.061	**0.072**	**0.072**	**0.073**	**0.164**	**0.096**	**0.071**	**0.158**	**0.092**
0.6	133	128	126	134	135	130	134	135	130
	0.074	**0.044**	**0.082**	**0.063**	**0.043**	**0.075**	**0.068**	**0.045**	**0.074**
0.7	87	65	67	139	130	137	139	130	137
	0.34	**0.46**	**0.55**	**0.055**	**0.055**	**0.064**	**0.059**	**0.056**	**0.064**
0.8	MF	3	MF	144	131	142	144	131	142
	MF	**1.403**	**MF**	**0.052**	**0.044**	**0.053**	**0.051**	**0.05**	**0.046**
0.9	3.95E-04	3.50E-01	MF	148	145	147	148	145	147
	1.37E+05	**1.47E+02**	**MF**	**0.038**	**0.021**	**0.038**	**0.038**	**0.021**	**0.038**

CV is written below MSY values; MF represents minimization failure

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***Table 3.** Parameters computed by using CEDA computer package for Labeo calbasu in Kaptai lake (IP = 0.7) as the initial catch was about 73% of the maximum catch*

Model	R^2	*K*	*q*	*r*	MSY	*B*	R_{yield}	*CV*	B_{MSY}
Fox (Normal)	0.71	2087	1.74E-04	0.114	87	390	74.53	0.339	768
Fox (Log Normal)	0.75	2616	1.34E-04	0.067	65	471	54.45	0.464	962
Fox (Gamma)	0.734	2585	1.73E-04	0.07	67	474	56.332	0.551	951
Schaefer (Normal)	0.81	815	4.17E-04	0.684	139	143	80.734	0.055	407
Schaefer (Log Normal)	0.818	1048	3.19E-04	0.495	130	190	77.147	0.055	524
Schaefer (Gamma)	0.815	878	3.84E-04	0.623	137	158	80.844	0.064	439
Pella Tomlinson (Normal)	0.81	815	4.17E-04	0.684	139	143	80.734	0.059	407
Pella Tomlinson (Log Normal)	0.818	1048	3.19E-04	0.496	130	190	77.148	0.056	524

K: carrying capacity; *q*: catchability coefficient; *r*: intrinsic population growth rate; MSY: maximum sustainable yield; *CV*: coefficient of variation; R^2: coefficient of determination; *B*: current biomass; B_{MSY}: biomass at giving MSY

Fox model determined the values of MSY and CV for normal, log normal and gamma assumption as 87 mt (0.339), 65 mt (0.464) and 67 mt (0.551) respectively whereas values of these parameters were 139 mt (0.055), 130 mt (0.055) and 137 mt (0.064) in Schefer and 139 mt (0.059), 130 mt (0.056) and 137 mt (0.064) in Pella-Tomlinson models in that order. The estimated values of carrying capacity K were higher while the values of catchability coefficient q and intrinsic population growth rate r were lower in Fox model than Schaefer and Pella-Tomlinson models.

The graphical demonstration of observed and expected annual catch values has been shown in *Figure 2*. It illustrates an adjacent relationship between observed and estimated catch values for all the error assumptions used in every model.

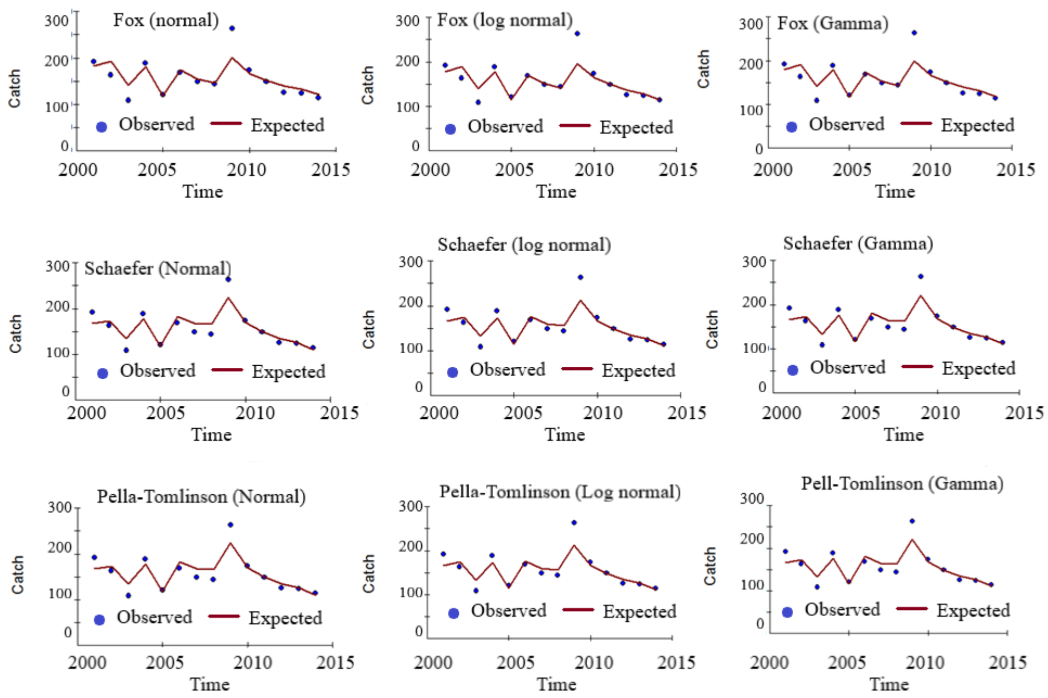

***Figure 2.** Annual expected (lines) and observed (dots) catches (mt) using IP = 0.7 from three production models (Fox, Schaefer and Pella-Tomlinson models) and three error assumptions (normal, log normal and gamma) from the CEDA computer package for Labeo calbasu fishery of Kaptai reservoir*

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ASPIC results

Table 4 shows the calculated parameters for IP = 0.7 where MSY and CV values for Fox and Logistic models were 127 mt (0.054) and 133 mt (0.057) respectively. The R^2 value for Logistic model (0.887) was higher than the Fox model (0.879). This result discloses its better fit to data than Fox model. According to Fox model the estimated values of F_{MSY} (fishing mortality rate at MSY, F_{MSY}), B_{MSY} (stock biomass at giving MSY, B_{MSY}) and K were 0.152, 832 mt and 2260 mt respectively while those values for Logistic model have been found as 0.281, 472.7 mt and 945 mt respectively.

Table 4. *Parameters estimated by using ASPIC software for Labeo calbasu in Kaptai reservoir (IP = 0.7)*

Model	*IP*	*R-squared*	*K*	*q*	*MSY*	B_{MSY}	F_{MSY}	*CV*
Fox	0.7	0.879	2.26E+03	2.70E-04	127	832	0.152	0.054
Logistic	0.7	0.887	9.45E+02	3.35E-04	133	472.7	0.281	0.057

MSY (maximum sustainable yield), q (catchability coefficient) K (carrying capacity), F_{MSY} (fishing mortality rate at MSY), B_{MSY} (stock biomass giving MSY), CV (coefficient of variation) and R^2 (coefficient of determination)

Different parameters computed for IP = 0.1 to 0.9 have been shown in *Table 5*. The estimation of different output parameters for different IP input indicates the sensitivity of ASPIC to IP values.

Table 5. *Comparison of ASPIC parameters for Fox and Logistic models by changing the starting initial proportion, (IP 0.1` 0.9) level*

Model	*IP*	*R-squared*	*K*	*q*	*MSY*	B_{MSY}	F_{MSY}	*CV*
Fox	0.1	0.879	2319	2.67E-04	126.5	853.1	0.148	0.06
	0.2	0.879	2324	2.67E-04	126.7	855.1	0.148	0.065
	0.3	0.879	2325	2.68E-04	126.7	855.2	0.148	0.054
	0.4	0.878	2246	2.73E-04	127.1	826.2	0.154	0.063
	0.5	0.879	2333	2.68E-04	126.9	858.2	0.148	0.063
	0.6	0.879	2326	2.68E-04	126.7	855.9	0.148	0.046
	0.7	0.879	2262	2.70E-04	126.7	832	0.152	0.054
	0.8	0.879	2325	2.68E-04	126.7	855.3	0.148	0.075
	0.9	0.879	2328	2.68E-04	126.8	856.4	0.148	0.065
Logistic	0.1	0.887	944	3.35E-04	133.1	472.1	0.282	0.06
	0.2	0.877	13250	1.47E-04	277.4	6624	0.042	0.866
	0.3	0.887	943	3.35E-04	133.1	471.6	0.282	0.06
	0.4	0.887	950	3.33E-04	132.9	475.2	0.28	0.064
	0.5	0.887	938	3.37E-04	133.3	469.1	0.284	0.06
	0.6	0.887	942	3.36E-04	133.2	471.1	0.283	0.067
	0.7	0.887	945	3.35E-04	133	472.7	0.281	0.057
	0.8	0.887	950	3.33E-04	132.9	474.9	0.28	0.064
	0.9	0.887	952	3.33E-04	132.9	475.8	0.279	0.059

q (Catchability coefficient), K (carrying capacity), F_{MSY} (fishing mortality rate at MSY), B_{MSY} (stock biomass giving MSY), CV (coefficient of variation) and R^2 (coefficient of determination)

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The ranges of MSY was 126 mt– 277 mt in ASPIC whereas it was 3 mt – 39500 mt for CEDA which depicts the lesser sensitivity of ASPIC to IP values. Again, the higher value of R^2 using ASPIC software provides its evidence to be better fit than CEDA. ASPIC estimated values of fishing mortality (*F*) and biomass (*B*) of *L. calbasu* for IP = 0.7 have been shown in *Table 6*. It shows an upward trend of fishing mortality rate and descending rate of biomass which has ultimately caused the increasing of F/F_{MSY} and decreasing of B/B_{MSY} in the long run of time. However, the changes in F/F_{MSY} and B/B_{MSY} defines that the overexploitation was being done consistently for the last years.

Table 6. *Fishing mortality (F) and biomass (B) from ASPIC (IP = 0.7) from 2001 to 2014*

Year	Model							
	Fox				Logistic			
	F	***B***	F/F_{MSY}	B/B_{MSY}	***F***	***B***	F/F_{MSY}	B/B_{MSY}
2001	0.242	826	1.59	0.993	0.3	701	1.04	1.48
2002	0.22	761	1.45	0.914	0.272	621	0.965	1.31
2003	0.147	723	0.97	0.869	0.183	582	0.65	1.23
2004	0.267	741	1.75	0.891	0.334	598	1.19	1.27
2005	0.178	677	1.17	0.814	0.223	537	0.79	1.14
2006	0.257	681	1.69	0.818	0.321	546	1.14	1.16
2007	0.24	635	1.58	0.763	0.298	509	1.06	1.08
2008	0.24	608	1.57	0.731	0.294	492	1.04	1.04
2009	0.519	586	3.41	0.705	0.643	482	2.28	1.02
2010	0.429	439	2.82	0.527	0.54	349	1.92	0.739
2011	0.428	372	2.81	0.447	0.537	295	1.91	0.625
2012	0.408	323	2.68	0.388	0.509	257	1.81	0.545
2013	0.451	291	2.96	0.35	0.558	235	1.98	0.497
2014	0.472	256	3.10	0.308	0.583	207	2.07	0.439

F= fishing mortality, *B*= biomass, F/F_{MSY}= ratio of fishing mortality to F_{MSY}, B/B_{MSY}= ratio of biomass to B_{MSY}

Discussion

Study on population dynamics is of great importance since the sustainable management policy of capture fisheries depends on the stock assessment outcomes. The main objective of this study was to estimate the MSY of *L. calbasu* in Kaptai reservoir, Bangladesh through non-equilibrium surplus production models using CEDA and ASPIC software packages. MSY from surplus production models is the reflector of a fishery stock in a certain area and thought as a biological reference point for attaining the sustainable production target (Hilborn and Walters, 1992; Prager, 2002; Musick and Bonfil, 2004). Greater MSY than the recent catch projects mushrooming fishery stock which permits more fishing till the estimated MSY while MSY lesser than current catch determines the resource as overexploited where conservation is must for feasible production. Equal figures for both parameters define the equilibrium status of the fishery. Based on the analysis in *Tables 2–6,* the estimated MSY for Fox model ranged 65-87 mt while Schaefer and Pella- Tomlinson determined ranging 130-139 mt which supports Fox model being more conservative than others.

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On the other hand, the ASPIC estimated value of MSY (127-133 mt) is above than the recent catch (113 mt). Ewald and Wang (2010) has already reported about this uncertainty of MSY. Besides maximum sustainable yield, F_{MSY} and B_{MSY} also play role in sustainable fisheries management. The values of F/F_{MSY} had an upward trend meanwhile values of B/B_{MSY} decreased in the passage of time. Moreover, R^2 values from ASPIC (above 0.879) is higher than that of CEDA (0.71-0.818) which may pinpoint it is better fitting to the computed data. To be conservative we choose the MSY of 80-100 mt in this study, because the latest catch is higher than the MSY value, we found the overexploited condition of *L. calbasu* in Kaptai reservoir and managerial actions for its conservation are required.

Even though MSY is commonly used as biological reference point but when the unexplored CPUE data in indexing fish population abundance is used the interpretation, usage of derived population and management keys should be done carefully (Panhwar et al., 2012). The catch and effort data are required for surplus production models to appraise the status of stock (Mehanna and El-Gammal, 2007). In fact, in fish population and dynamics these models are the first conventional methodical tools of assessing an exploited fish stock when the data consists of year wise catches and some abundance index as well. Although these are not realistic as age-structured models but useful in representing yield policies (Jensen, 2002b). Not only that sometimes they could even produce better estimation of BRP (biological reference points) than age-structured models (Prager, 2002) and comparatively more suitable for management purposes at very practical cost (Haddon, 2011). Statistically the fluctuation in the data of catch, effort or CPUE indicates the changes of stock status. Contradictory relation between effort and catch suggest the swift downturn of fish stock. In some studies on marine fishery show the increasing rate of catch in spite of higher rate of effort (Balli et al., 2011; Kumar et al., 2012; Panhwar et al., 2012; Panhwar et al., 2013; Kalhoro et al., 2013; Mohsin et al., 2017; Karim et al., 2018). Remarkably, in our study greater rate of effort caused the catches to be reduced. The reason behind this consequence is the confined nature of reservoir. So, there is neither migration of fishes from other sources nor as a result lesser recruitment occurs there.

This study examined the current status of orange fin *Labeo* fishery stock of Kaptai reservoir using non-equilibrium SPMs which clearly projects that this fishery is in overexploited condition. In general, surplus production models comprise some unavoidable assumptions, many of which are not met in nature. These assumptions consist of interaction less species, independent *r* (intrinsic growth rate) over age composition, environmental factors free population, constant catchability coefficient, single stock unit, simultaneous fishing and natural mortality, accurate catch and effort statistics and consistent gear or vessel efficiency. In spite of having above mentioned assumptions its critical usage has made it as a powerful tool for fish stock assessment (Musick and Bonfil, 2005). Ahmed and Hambrey (1999) documented that the use of unlicensed fishing gears as well as non-permissible mesh size and brush shelters causes fingerlings reduction during the post-stocking period. Although every year, the authorities impose a ban on fishing from May 1 to July 31 considering the safety fish breeding and sound production in reservoir but subsistence fishermen and tribal people continue catching fish for home consumption and illegal marketing**.**

In light of the above, the following conservation schemes are suggested:

1. Addressing special legislative framework for Kaptai reservoir fisheries management as well as unbiased enforcement of this constitution

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2. Restricting illegal gears and mesh size
3. Boycotting undersized fish harvest
4. Improving the ecological condition for providing the fishes a healthy home
5. Introducing sanctuary for better and safe growth

In brief, considering the excessive fishing pressure the existing lake fishery should be investigated further wisely for appropriate management.

Conclusion

This is the first attempt to use non-equilibrium SPMs for stock assessment in the reservoir fishery of Bangladesh. The estimated outputs of both CEDA and ASPIC computer packages exhibit that the influential money earning *Labeo calbasu* fishery in Kaptai reservoir is overfished. Uncertainty in determining MSY could happen because of commercial data collection drawback as well as for the apprehensive reliability of CPUE data set. Moreover, there is not enough independent information to test its reliability. Therefore, during the time of interpretation and usage of derived population as well as management parameters obvious tentative steps should be considered. In the light of uncertainties of fisheries science further studies could be done to assess the fish stock accurately along with the studies of the improvement of artificial breeding techniques, modification in genes to increase its adaptability in adverse environmental condition, implementation of different culture techniques etc. This study is to provide an initial concept of stock assessment of *L. calbasu* fishery through surplus production models.

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