



# Population Dynamics of *Ammodytes personatus* (Girard, 1856) in Shandong, China: Does this Resource Needs Management?

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## ABSTRACT

China is the biggest fish producing country in the world. Its marine waters are frequently declared as over-harvested. Therefore, accessing the exploitation status of commercial fishery resources becomes very important for their proper management. This study uses catch statistics, 2007-2018, of a vital fishery resource, viz., *Ammodytes personatus* (Girard, 1856) to know its stock status and ongoing economic implications. For this purpose, Surplus Production Models (SPMs) were applied to the data through two world famous fishery routines, viz., Catch and Effort Data Analysis (CEDA) and A Stock Production Model Incorporating Covariates (ASPIC). In CEDA, we applied two SPMs, viz., Fox, Schaefer and Pella Tomlinson Models abbreviated as FM, SM and PTM, in that order. On the other hand, in ASPIC, we used two SPMs, viz., FM and Logistic Model (LM). For principle IP 0.9, CEDA calculated MSY in a range between 13500 t and 30500 t whereas the estimates of ASPIC remained between 71500 t and 85000 t. Maximum sustainable yield (MSY) estimates are considerably lower than recent catch statistics which evidently indicates overexploitation. It is suggested that the target catch of this fishery resource should be between 14000 t and 20000 t. Moreover, it is highly recommended to conduct further more comprehensive and detailed studies on *A. personatus* fishery resource as this study is just a first step.

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## Authors' Contribution

MM and ZL initiated the project, performed statistical analysis and wrote the manuscript. ZT and YH revised many parts and gathered review of literature. QC constructed tables and figures and gave suggestions on the manuscript.

## Key words

*Ammodytes personatus*, Overexploitation, Management, SPMs, China

## INTRODUCTION

The use of surplus production models (SPMs) is very common for managing fishery resources. These models estimate exclusive fishery parameters such as maximum sustainable yield (MSY), fishing mortality (F), fish stock biomass (B) etc. and are easy to employ. The word surplus represents that B will propagate in the absence of fishing. It means fishing can be continued without affecting the fish stock. In other words, fishing can be sustainably continued as overall fishery stock will not decrease. These models use the concept of depletion. It refers to the fishery stock reduction reflected through a decrease in abundance index. These models require a comprehensive and continuous record of catch statistics. Catch statistics means reported catch which is usually in tons (t) and effort which is mostly represented by either number of fishermen or number of boats. Commonly, without gap statistics are preferred (Hoggarth *et al.*, 2006). These models are usually given

priority over the other fishery models, such as age-structured, because of their ease of use. These models use a simple catch index or catch per unit effort (CPUE) to estimate fishery management parameters, i.e., MSY. In view of MSY estimates, management advice can be given (Jensen, 2002). A considerable amount of published literature uses SPMs to assess fishery status (Ricker, 1975; Hilborn and Walters, 1992; Maunder *et al.*, 2006; Mohsin *et al.*, 2019). This is the reason for using SPMs in this study.

There are different versions of SPMs. Generally, SPMs selection depends upon the type of data to be analyzed and its purpose. Mostly, several SPMs are applied to the data. It is done to ensure the reliability of results and find a suitable good fit model. Once the good fit model is found certain reference points can be determined for making management advice. One very important aspect of SPMs is that sometimes they compute the same parameter estimates. Although different models have different assumptions, but same output means that model application is independent of some biological assumptions. Hence, obtained results are valid, but the key point is to find the best fit model (Hoggarth *et al.*, 2006).

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Model evaluation is a very important step. At this stage, one important parameter is good of fit ( $R^2$ ). Its higher value indicates a better fitting of model. However, along with this parameters, other parameters like MSY, coefficient of variation CV, etc., should also be considered (Hoggarth *et al.*, 2006).

China is a world leader in fish production. In 2018, more than thirty percent in the global fish supply was contributed by China (FAO, 2020). Diverse fishery resources are found in Chinese marine waters and thousands of coastal fishermen families thrive on them. Capture fisheries constitutes a significant portion of total fish catch (Zhang *et al.*, 2020). Thus, study of Chinese capture fisheries has immense importance to understand the future of fish stocks and food security issues (Szuwalski *et al.*, 2020). *Ammodytes personatus* fishery is among significant commercial resources in China. This fish is a native fish in many countries, such as Japan, Korea, the USA, and China (Hong *et al.*, 2000). It is a shallow water dwelling cold-water fish species. During night it swims at the sea surface and buries into sand when temperature rises (Tomiyama and Yanagibashi, 2004). It prefers to spawn in bay waters (Kitagawa and Yamashita, 1986). Long distance migration is not evident in this fish species (Hashimoto and Kawasaki, 1981). This feature increases the reliability of this study as statistical methods would assume no migration of fish stock. However, various morphological, genetic and ecological differences exist between populations of this species (Okamoto *et al.*, 1988). This fish has various local names. It is known as Tobis, Pacific sandeel, Sandaal, Ikanago, Salton, and Mian tiao yu in Danish, English, German, Japanese, Spanish and Chinese languages (FAO, 2021; Fish Base, 2021). Its body shape is cylinder type (FAO, 2021). Unfortunately, reported statistics indicate that the catch of this commercially important fish is declining gradually (CFY, 2019). Several other fishery resources in China have already been declared overexploited (CFY, 2019). Thus evaluating stock status for fishery management becomes crucial.

Online available scientific literature mostly documents diverse aspects of research on *A. personatus* in China. Some studies evaluated the genome sequence of mitochondria of *A. personatus* (Gao *et al.*, 2013). There is also available literature regarding the segregation and classification of diverse shapes of micro-satellites in *A. personatus* (Ren *et al.*, 2009). Some researchers have worked on feeding habits and the ecological performance of *A. personatus* (Sun *et al.*, 2010). Thus, published literature focuses on various aspects of *A. personatus*, excluding its fishery status. We could find the only study which evaluated the stock status of this fishery resource.

But, this study is very old, conducted almost two decades before in 2003 (Chen, 2004). However, there is no updated study in this regard. Thus, this study is the first recent attempt to access the fishery status of *A. personatus* because knowing stock status is a very essential and basic step for fishery management (Panhwar and Liu, 2013). The main objective of this study is to calculate fishery harvest levels of *A. personatus* in Shandong marine water of China by using SPMs. Outcomes of this study can be used to identify some basic information about the ongoing stock status of *A. personatus* on which further research can be planned.

## MATERIALS AND METHODS

### Data acquisition

Catch statistics, 2007-2018, of *A. personatus* fish from Shandong, China were statistically evaluated by using non-equilibrium SPMs (surplus production models). Data was fetched through various volumes of the published China Fisheries Yearbooks (CFY, 2019). Catch and effort statistics are given in t and fishermen count or number, respectively.

### Data analysis

Collectively we used non-equilibrium versions of three famous fishery SPMs, viz., Fox, Schaefer and Pella-Tomlinson Model hereafter abbreviated as FM, SM and PTM, in that order. SM is very frequently employed to access reliable fishery status of important resources around the globe. It uses a special assumption regarding fish population increase which is logistic increase. It is simply presented through the following equation:

$$\frac{dB}{dt} = rB(B_{\infty} - B) \text{ (Schaefer, 1954)}$$

In the above equality,  $r$ ,  $B$ ,  $B_{\infty}$  and  $t$  denote growth rate, the biomass of fish population, carrying capacity of the environment, and time, respectively. On the other hand, the remaining two models, i.e., PTM and FM use the idea of generalized fishery population increase and peculiar growth formula presented by Gompertz. These models are represented as follows:

$$\frac{dB}{dt} = rB(\ln B_{\infty} - \ln B) \text{ (Fox, 1970)}$$

$$\frac{dB}{dt} = rB(B_{\infty}^{n-1} - B^{n-1}) \text{ (Pella and Tomlinson, 1969)}$$

Here,  $n$  represents the parameter for shape. The rest of the parameters have already been explained. In addition, it is mandatory to clarify that SPMs as mentioned earlier were used with the help of specialized fishery routines. We used two software CEDA (catch and data analysis) (Hoggarth *et al.*, 2006) and ASPIC (a stock production

model incorporating covariates). Both the software were obtained by using online web resources. Former software was taken by requesting MRAG, UK whereas later one was obtained through NOAA fisheries, USA. Moreover, we used particular assumptions in CEDA, known as error assumptions (EA). These EA were called normal, log-normal and gamma EA and were abbreviated as NEA, LNEA and GEA, in that order. We did not use any EA in ASPIC. Only two models, i.e., FM and LM (Logistic Model) were used in ASPIC. More than one SPMs were used in this study to ensure increased reliability of results. To compare different models, we used some specific criteria, i.e., values of MSY, CV and  $R^2$ . These parameter values were considered collectively to consider output parameter result or reject it. MSY estimates beyond reasonable range, either too high or low, were not considered. Similarly, only results with reasonable CV values were taken into consideration. Likewise, estimates having  $R^2$  higher than 0.5 were used to draw scientific results.

#### CEDA software

This software is a reliable tool for accessing fishery status. It helped us to compute very important fishery parameters. Various parameters estimated by using this statistical routine were model fit goodness ( $R^2$ ), rate of fishery growth ( $r$ ), MSY, loading capacity of the aquatic system ( $K$ ),  $B$  and coefficient of catchability ( $q$ ). This statistical tool uses a special estimation method for fishery parameters which is scientifically called as bootstrapping technique. Moreover, it used a confidence interval of 95% while calculating parameters. We applied this software to data in two steps. First, various parameters by using principle initial proportion (IP) value were estimated. This value was obtained by diving the highest catch by initial catch in the used catch and effort data series. The principle IP values in our study remained as 0.9. Second, we also applied CEDA to compute various parameters by using assumed other IP values from 0.1 to 0.8 which is usually called sensitivity analysis. The rationale for using other IP values is that IP value demonstrates fishery status. A higher value like 0.9 indicates that fishery is about fully exploited whereas its lower values like 0.1, 0.2 etc. represent that fishery stock is almost virgin or not fully exploited.

#### ASPIC software

In addition to CEDA, this software was also applied to data. It computed important fishery parameters like  $K$ ,  $R^2$  and MSY. Besides, it also estimated  $F$  and  $B$  and their ratios at MSY, i.e.  $F/F_{MSY}$  and  $B/B_{MSY}$ . Two different types of files, viz., BOT and FIT were prepared to analyze data. Each of them represents the dissimilar mode of computation program. Only BOT used bootstrapping

methods like CEDA and estimated general means of parameters among these two modes or files. On the other hand, FIT estimated specifically those parameters which are for management purposes. 500 trials for each of these files were set into ASPIC. In addition to using principle IP value, sensitivity analysis was also performed by using IP values from 0.1 to 0.8.

## RESULTS

Computed results indicate significant variation in catch and effort statistics during the course of the study period. The maximum catch is reported during 2009 (94289 t), while the minimum is observed during 2018 (30741 t). On the other hand, the average catch was estimated at 62272 t / year. Statistics indicate that effort increased swiftly between 2007 (498141 no. of fishermen) and 2012 (1009228 no. of fishermen). However, effort steadied between 2012 (1009228 no. of fishermen) and 2018 (1019108 no. of fishermen). Another important point regarding data pattern is that although effort remained stabilized as aforementioned during the last six reported years, quite interestingly, the catch showed declining trend during this time period (Fig. 1). CPUE has shown decreasing trend from 2007 (0.162) to 2018 (0.03) (Fig. 2). CEDA graphs are graphically presented in Figure 3. There are very minute differences in these graphs.

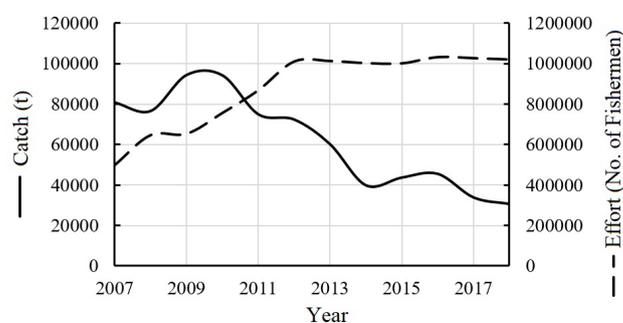


Fig. 1. Catch and effort statistics of *A. personatus* in Shandong, China.

#### CEDA result

MSY estimates along with their CV values were calculated by using CEDA for all IP values. It was found that CEDA estimated higher values of MSY against lower IP values and vice versa. For instance, for IP 0.1 and 0.9, MSY estimates remained 1.88E+11 t and 14291 t by using FM (NEA), respectively. A similar data pattern was observed for other models and their EA (Table I). Various parameters estimated for principal IP value are given in Table II. For FM, MSY along CV value was computed as

14291 t (0.771) and 24239 t (0.265) by employing NEA and LNEA, in that order. In this model, GEA produced minimization failure. In SM and PTM, EA produced the same MSY estimates, i.e., 13933 t, 30354 t and 23628 t for NEA, LNEA and GEA, respectively. However, their

CV values differed from each other. For SM, CV values remained 1.202, 0.274 and 0.530 and for PTM, CV values were estimated as 1.085, 0.255 and 0.599, in that order. The highest  $R^2$  value, 0.890, was observed in FM (LNEA).

**Table I. Predicted values of MSY for *A. personatus* in Shandong marine waters, China by using CEDA (IP = 0.1-0.9).**

IP	Model								
	FM			SM			PTM		
	NEA	LNEA	GEA	NEA	LNEA	GEA	NEA	LNEA	GEA
0.1	1.88E+11 (0.561)	130562 (0.001)	MF (MF)	MF (MF)	226999 (0.001)	568487 (95.7)	MF (MF)	222699 (0.01)	568487 (556.06)
0.2	88541 (0.011)	89541 (0.001)	85287 (0.017)	126442 (0.004)	126448 (0.001)	126448 (0.001)	126442 (0.005)	126449 (0.001)	126448 (0.001)
0.3	56310 (0.149)	41215 (0.141)	74532 (0.001)	MF (MF)	94341 (0.001)	94338 (0.001)	MF (MF)	94342 (0.001)	94338 (0.003)
0.4	40519 (0.268)	38126 (0.149)	66699 (0.038)	MF (MF)	79268 (0.001)	MF (MF)	MF (MF)	79268 (0.001)	MF (MF)
0.5	30918 (0.346)	36619 (0.161)	35965 (0.237)	MF (MF)	71998 (0.001)	MF (MF)	MF (MF)	71499 (0.004)	MF (MF)
0.6	24526 (0.444)	33042 (0.157)	2971 (7.497)	52496 (0.144)	66590 (0.002)	MF (MF)	52496 (0.161)	66590 (0.002)	MF (MF)
0.7	20054 (0.509)	31223 (0.174)	MF (MF)	32267 (0.482)	42905 (0.081)	MF (MF)	32267 (0.473)	42905 (0.101)	MF (MF)
0.8	16765 (0.638)	16765 (0.223)	26489 (MF)	MF (1.562)	9942 (0.421)	22704 (MF)	MF (0.781)	20604 (0.135)	38913 (0.462)
0.9	14291 (0.719)	24239 (0.244)	MF (MF)	13933 (1.118)	30354 (0.290)	23628 (0.629)	13933 (1.182)	30354 (0.252)	23628 (0.584)

CV, coefficient of variation (written in parenthesis); MF, minimization failure.

**Table II. Different parameters calculated by using CEDA for *A. personatus* in Shandong marine waters, China (IP = 0.9).**

Model	$K$	$q$	$r$	MSY	CV	$R^2$	B
FM (NEA)	718969	2.35E-07	0.054	14291	0.771	0.840	108270
FM (LNEA)	607737	2.90E-07	0.108	24239	0.265	0.890	99340
FM (GEA)	MF	MF	MF	MF	MF	MF	MF
SM (NEA)	722803	2.31E-07	0.077	13933	1.202	0.834	102999
SM (LNEA)	547835	3.19E-07	0.222	30354	0.274	0.883	85037
SM (GEA)	623308	2.73E-07	0.152	23628	0.530	0.861	97309
PTM (NEA)	722803	2.31E-07	0.077	13933	1.085	0.834	102999
PTM (LNEA)	547835	3.19E-07	0.222	30354	0.255	0.883	85037
PTM (GEA)	623308	2.74E-07	0.152	23628	0.599	0.861	97309

$K$ , carrying capacity;  $q$ , Catchability coefficient;  $r$ , intrinsic population growth rate; MSY, Maximum sustainable yield; CV, coefficient of variation;  $R^2$ , coefficient of determination; B, final biomass; MF, Minimization failure.

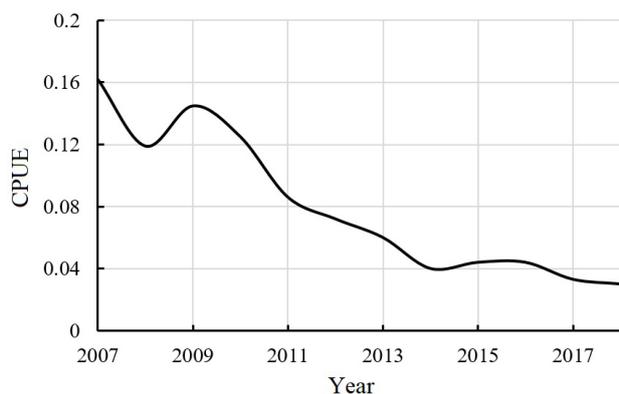


Fig. 2. Calculated CPUE for *A. personatus* in Shandong, China.

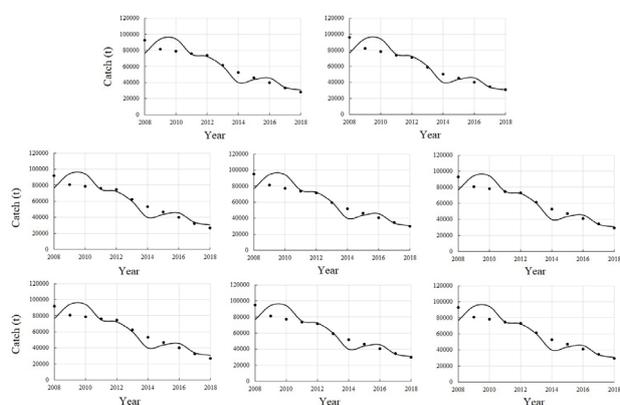


Fig. 3. CEDA graphs obtained for IP 0.9. Observed catch (t) is represented by dots whereas expected catch (t) is indicated by straight line.

#### ASPIC result

ASPIC estimated obtained by using principal IP value of 0.9 are given in Table III. For FM, MSY, CV and  $R^2$  estimates remained as 84540 t, 0.306 and 0.942 whereas for LM their values were calculated as 71840 t, 0.211 and 0.937, in that order. Various parameters were also estimated by using other IP values, i.e., from 0.1 to 0.8. Like CEDA, ASPIC also estimated higher MSY values when lower IP values were used. For example, for IP 0.1, this software calculated MSY as 89460 t whereas, for IP 0.9, MSY value was computed as 84540 t in FM. The same data estimation pattern was observed in LM (Table IV). Estimates regarding F and B are presented in Table V. It is clear for both the models, i.e., FM and LM, F is increasing and B is decreasing. For FM, in 2007, F was 0.462, which increased and became 0.864 in 2018. On the other hand, B has decreased from 178400 t (2007) to 36210 t (2018). The same pattern of change in F and B is observed in LM.

## DISCUSSION

Global published fishery management literature frequently documents the use of SPMs, which indicates worldwide recognition of these models as authentic scientific tools. A plethora of scientific work carried on population assessment of commercial fishery resources of Pakistan also employ the same SPMs used in this study (Memon *et al.*, 2015; Panhwar and Liu, 2013). The reason for the global trust and practice of these SPMs depends upon their ease of use. These models provide an opportunity to compute fishery status by employing simple statistics, i.e., catch and effort. Otherwise, complex statistics comprising age and length of fish data are generally needed to compute these parameters (Mohsin *et al.*, 2017). It is also worth mention that there are two main types of SPMs, viz., equilibrium and non-equilibrium SPMs. The former type of SPMs basically represents earlier or classical versions of SPMs. These SPMs assumed fishery in a constant or non-changing state. Hence, they were named equilibrium SPMs. Now, scientists find this assumption far beyond reality as fishery status is dynamic always. Therefore, modern SPMs transformed into the later type of SPMs, i.e., non-equilibrium SPMs. These SPMs are more accurate, realistic and dependable (Medley and Ninnis, 1997; Hoggarth *et al.*, 2006).

Models are commonly built on some specific suppositions. Non-equilibrium SPMs employed in this study are also based upon certain assumptions. Such as, there does not exist any kind of interaction in fishery stock, whether it is in the form of intra interaction or inter-interaction. Likewise, the coefficient of catch remains the same and does not change with the passage of time. No fish stock leave or enter into the local fish population, i.e., B remains unchanged. Similarly, there is no inter-dependence between the age of fish and its growth rate. Equally, obtained fishery statistics represent the actual fish stock position. Alike, both types of mortality, i.e., natural and artificial occur at the same time. Last but not the least, the efficiency of fishing boasts remains constant and does not change over time (Hoggarth *et al.*, 2006). Scientific knowledge signifies that may be some or many assumptions cannot be achieved practically. However, it does not mean that these models are useless rather, these are powerful fishery analysis tools widely used in the world to manage fishery resources. Therefore, they are of practical importance (Musick and Bonfil, 2005).

Estimated MSY range by using principle IP values through CEDA and ASPIC clearly fall into a distinct range. CEDA computes this parameter in a narrow range as compared to ASPIC (Tables II and III). As we have mentioned before, we used specific criteria to draw results

**Table III. Different parameters assessed by using ASPIC for *A. personatus* in Shandong marine waters, China.**

Model	IP	MSY	K	q	F <sub>MSY</sub>	B <sub>MSY</sub>	R <sup>2</sup>	CV
FM	0.9	84540	890100	8.68E-07	0.258	327400	0.942	0.306
LM	0.9	71840	273400	1.02E-07	0.526	136700	0.937	0.211

**Table IV. ASPIC outputs for *A. personatus* by using ASPIC in Shandong marine waters, China (IP = 0.5-1).**

Model	IP	MSY	K	q	F <sub>MSY</sub>	B <sub>MSY</sub>	R <sup>2</sup>	CV
FM	0.1	89460	886600	9.32E-07	0.274	326200	0.942	0.254
	0.2	86280	986100	8.28E-07	0.238	362800	0.942	0.302
	0.3	78510	456200	1.27E-06	0.468	167800	0.919	0.232
	0.4	84850	902000	8.65E-07	0.256	331800	0.942	0.329
	0.5	88250	875400	9.25E-07	0.274	322100	0.942	0.306
	0.6	90250	945500	9.00E-07	0.259	347800	0.942	0.269
	0.7	92290	935600	9.31E-07	0.268	344200	0.942	0.267
	0.8	86160	933400	8.59E-07	0.251	343400	0.942	0.295
	0.9	84540	890100	8.68E-07	0.258	327400	0.942	0.306
LM	0.1	74080	245200	1.15E-06	0.604	122600	0.937	0.166
	0.2	84900	2224000	3.26E-07	0.076	1112000	0.914	0.150
	0.3	75530	238700	1.20E-06	0.633	119400	0.938	0.203
	0.4	75150	242900	1.18E-06	0.619	121500	0.938	0.189
	0.5	76200	239700	1.21E-06	0.636	119800	0.938	0.208
	0.6	74720	247700	1.15E-06	0.603	123900	0.938	0.192
	0.7	76680	238500	1.23E-06	0.643	119300	0.938	0.222
	0.8	76930	233800	1.25E-06	0.658	116900	0.937	0.209
	0.9	71840	273400	1.02E-06	0.526	136700	0.937	0.211

**Table V. ASPIC estimates of fishing mortality (F) and biomass (B) (IP = 0.9).**

Year	Model							
	FM				LM			
	F	B	F/F <sub>MSY</sub>	B/B <sub>MSY</sub>	F	B	F/F <sub>MSY</sub>	B/B <sub>MSY</sub>
2007	0.462	178400	1.791	0.545	0.533	156700	1.015	1.147
2008	0.453	171100	1.756	0.522	0.531	147000	1.010	1.075
2009	0.613	167000	2.373	0.510	0.729	142000	1.387	1.039
2010	0.747	142500	2.895	0.435	0.900	119200	1.713	0.872
2011	0.731	112000	2.833	0.342	0.876	92730	1.666	0.678
2012	0.877	94270	3.396	0.288	1.036	79530	1.970	0.582
2013	0.948	72650	3.672	0.222	1.121	61750	2.134	0.452
2014	0.717	55800	2.776	0.170	0.841	46820	1.600	0.343
2015	0.826	55690	3.971	0.154	0.942	48120	1.793	0.352
2016	1.025	50520	3.487	0.120	1.156	44880	2.199	0.328
2017	0.900	39380	3.345	0.111	1.032	34730	1.964	0.254
2018	0.864	36210	3.345	0.111	1.036	31190	1.972	0.228

by considering obtained values of MSY, CV and  $R^2$ . Among these three parameters, MSY is the most important. The other two parameters just speak off about the model fitness and accuracy of results. MSY estimates when compared to catch data can tell fishery exploitation level. If the estimated value of this parameter is less than catch statistics it indicates that fishery resource is overexploited. If its value is higher, it means the fishery has a potential to increase the catch (Hoggarth *et al.*, 2006). Since MSY estimates of ASPIC are significantly high, we compare them with recent catches in the data series. Therefore, rationally, we consider CEDA results more accurate in this situation. In CEDA, not only computed MSY is under reasonable range but also CV, as well as  $R^2$ , values are in an appropriate range. CEDA estimates of MSY vividly affirm that *A. personatus* fishery resource has been consistently overexploited in the past. That's why this fishery resource is declining rapidly even effort is not increasing. The calculated CPUE pattern given in Figure 2 also indicates this is happening. CPUE is a very simple way to know about the fishery status. Decreasing CPUE is an alarming situation which indicates that fishery resource needs more effective management. *A. personatus* catch is decreasing even effort is more or less stable, indicates overexploitation. Moreover, declining B and increasing F also indicate degrading fish stock of *A. personatus*.

Various steps collectively form fishery management. The management process starts from data collection and ends at management advice implementation. At all stages of management, stakeholders are involved (FAO, 1997; Die, 2002). For giving management advice, fishery scientists use estimated parameters as a reference guide. Thus, reference points are the estimated fishery parameters which act as a signpost of fishery and help in making management advice (Hoggarth *et al.*, 2006). The trend of using reference points was started in 1992 (FAO, 1995). Most of the time, two types of reference points are recognized based on their purpose. These types include target points and limit points. According to the parameters, fishery scientists decide the limit of the suggested fishery population exploitation level, which is called are target point. Fishery officers try to manage the exploitation of fishery resources according to these levels. In addition to these, fishery officers also decide about those the harvest levels at which fishery stock will start to suffer scientifically. These points are termed as limit points, and fishery managers try to avoid these points (Caddy and Mahon, 1995; Cochrance, 2002). Thus, usually fishery resource exploitation range is defined because reference points do not represent a single fixed level rather, they symbolize threshold levels. The best fishery management strategy is that which manages fishery resources according

to the target and limit reference points. However, these points should be suggested with great care otherwise, management practice may deteriorate fishery stock status instead of improving it. For instance, if MSY is underestimated, this will result in economic loss as we shall harvest less B. On the other side, if MSY is overestimated, this situation will result in fishery degrading, thus the management will fail (Rosenberg *et al.*, 1993).

Models employed in this study do have certain advantages as well as disadvantages. These models estimate exclusive fishery parameters and indicate an ongoing fishery regime. In addition, these models use a non-equilibrium state of the fishery and are practically more reliable than other models (Hoggarth *et al.*, 2006; Medley and Ninnis, 1997). Moreover, these models use various assumptions regarding different fishery aspects and constitute a good framework of analysis (Musick and Bonfil, 2005). Nevertheless, it does not mean that these models only have advantages; instead, they also have disadvantages. For instance, changes in fishery input and  $q$  can result in wrong estimates obtained by these models. Furthermore, estimated parameters such as  $K$ ,  $r$  and  $q$  are interrelated with each other. This interconnection cannot be accurately estimated without accurate or dependable catch statistics. Data exhibiting good contrast of catch statistics is preferred to be used because low contrast data cannot differentiate between  $K$  and  $r$  (Hilborn and Walter, 1992).

The findings of this study suggest controlling overexploitation of *A. personatus* for its long term sustainable use. In this regard, fishery managers can play a vital role and implement existing strategies to observe catch. However, more in-depth studies are recommended to further and precisely investigate this issue before making any action plan. Moreover, stock assessment studies of other commercially important fish species should also be conducted to keep safe fishery resources of China.

## CONCLUSION

For principle IP 0.9, CEDA calculated MSY in a range between 13500 t and 30500 t. On the other hand, estimates of ASPIC remained between 71500 t and 85000 t. Hence, CEDA estimated MSY in a limited range and its lower values as compared to ASPIC. MSY estimates of CEDA are considerably lower than recent catch statistics, which indicates overexploitation. Furthermore, increasing F and decreasing B also exhibits the same results. Therefore, this study finds overexploitation of *A. personatus* fishery resource and considering CEDA results suggests that target catch of this fishery resource should be between 14000 t and 20000 t. Moreover, it is highly recommended to further conduct more comprehensive and detailed studies

on this fishery resource by using more long data series as this study is just a first step.

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### Statement of conflict of interest

The authors have declared no conflict of interest.

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