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Original Article

The stock status of the pelagic fishes in Banyuasin coastal waters, Indonesia

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Abstract
Information on the condition of pelagic fish stocks in Banyuasin coastal waters is currently very limited. This study aimed to estimate the stock status of *Auxis* spp., *Scomberomorus commerson*, *Selaroides leptolepis* and *Rastrelliger* spp. based on the time series catch and effort data from 2008 to 2016 in the Banyuasin coastal waters, South Sumatra Province, Indonesia. All seven surplus production models, model performance, and fish stocks status were estimated. In order to determine the best-fitted model, several indicators of model performance were required. The Pella and Tomlinson model was the best-fitted model for *S. commerson* while the best-fitted model for *Rastrelliger* spp., *Auxis* spp. and *S. leptolepis* was the Fox model. The optimum effort (E_{MSY}) value for *S. commerson*, *Rastrelliger* spp., *Auxis* spp. and *S. leptolepis* were 68677, 18226, 23402 and 22403 trips respectively. The maximum sustainable catch (C_{MSY}) value for *S. commerson*, *Rastrelliger* spp., *Auxis* spp. and *S. leptolepis* were 1845, 515, 286, 667 tons respectively. In 2016 the stock of *S. commerson* was in recovery condition whereas it was subjected to overfishing for *Auxis* spp. and depleted for *S. leptolepis* and *Rastrelliger* spp.

Keywords: Banyuasin; pelagic fish; stock status; surplus production model

1 | INTRODUCTION

Banyuasin coastal waters are the centre of capture fisheries in South Sumatra Province, Indonesia (Fauziyah *et al.* 2018a, 2019). Fishing units that develop in the area are included to the small-scale fisheries category (Fauziyah *et al.* 2018a). The local government has not applied regulatory methods to manage fisheries resources such as controlling fishing gear and technology, fishing time and area, as well as limiting fishing units. The regulations methods can be used to protect fisheries resources (Chae and Pascoe 2005).

Currently, fisheries statistics in Indonesia (including in Banyuasin) only record catch and effort data by each gear type, while data and information on effort level, exploitation level, and fish stock status is not yet available. The data are very important for sustainable management of fisheries resources. Various researches are being carried out to reach the equilibrium between the populations of aquatic species and dynamically fluctuating and changing environments. Therefore, sustainable harvests are needed for determining how much fish stock can be sustainably taken from the fishery (Holmes *et al.* 2014). Two key factors that need to be balanced for sustainable fishing are the exploitation and the fishing effort levels (Fauziyah *et al.* 2020). Other influencing factors are predator abundance, food availability, environmental variables, climate change, and so on. The exploitation and fishing effort level can be estimated using a surplus production model (SPMs). When the data is limited, SPM can be used to estimate the maximum sustainable yield (MSY) and can assess fish stock (Chaloupka and Balazs 2007; Bordet and Rivest 2014).

The SPMs are the simplest stock-assessment models commonly used in fisheries (Walters and Hilborn 1976; Kurian 1989; Chen and Andrew 1998). These models only need a time-series data of catch and catch per unit of effort (CPUE) for running the models (Yoshimoto and Clarke 1993; Chen and Andrew 1998; Chen 2003) and relatively more available in most centres of fishing (Tinungki *et al.* 2004). These models can be used as an alternative analysis when virtual population analysis cannot be done due to the age structure information of the catch is not available (Meraz-Sánchez *et al.* 2013).

In order to better assess the dynamic fisheries resources, the approach and concept of SPM have developed by many authors; common SPMs are Schaefer's Model; Fox Model; Schnute Model; Gulland Model; Clark, Yoshimoto and Pooley (CYP) Model; Pella & Tomlinson Model; Walter-Hilborn Model; Cushing Model etc. (Tinungki *et al.* 2004; Kekenusa *et al.* 2018; Fauziyah *et al.* 2020). However, some researchers used several models to get the best-fitted models (Colvin *et al.* 2012; Mayalibit *et al.* 2014; Kekenusa *et al.* 2015, 2018; Singh 2015; Sin and Yew 2016). In the present analysis, seven different SPMs were applied to assess the current stock status of the common pelagic fishes including *Auxis* spp., *Scomberomorus commerson*, *Selaroides leptolepis* and *Rastrelliger* spp.

The status assessment of fish resource stocks in the Banyuasin coastal waters is poorly studied. The fish stock status in these waters has been only analysed for snapper in 2018 (Fauziyah *et al.* 2020) and the status of pelagic fish stocks remain unknown. The information on fish stock status are essential as basic data are important for determining the appropriate fisheries management and action plans. Therefore, the purpose of this study was to assess the status of pelagic fish stocks in the Banyuasin coastal waters using the best-fitted SPM based on the time series catch and effort data from 2008 to 2016.

2 | METHODOLOGY

2.1 Study area

This study was carried out in Banyuasin coastal waters (Figure 1) of the South Sumatra Province, Indonesia. This location has the most significant contribution to capture fisheries production in South Sumatra Province.

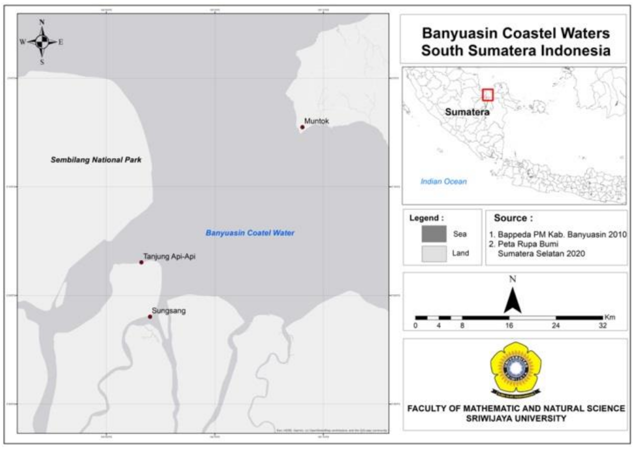

FIGURE 1 The study location of Banyuasin coastal water, Province of South Sumatra, Indonesia.

2.2 Data

As the simplest stock-assessment models, the SPMs only use annual fish catch and fishing effort data. In this study, all data were retrieved from the Annual Fishery Statistics of Banyuasin Regency (DKP 2009 – 2017). However, four species of pelagic fish (*Auxis* spp., *Scomberomorus commerson*, *Selaroides leptolepis* and *Rastrelliger* spp.) were considered in this study. Data of 2008 – 2016 were considered in this study and they were classified based on fish catch in fishing gears per fishing trip for each species. The fishing effort considered here is the number of operational fishing boats (*i.e.* trips) whereas the total catch represents the total amount of fish landed (Baset *et al.* 2017).

In Banyuasin coastal waters, the local fishermen captured *S. commerson* by using drift gillnet, set gillnet, trammel net, hook and lines, stationary lift net, and traps. *Auxis* spp. were captured using drift gillnet, trammel net, hook and lines, and traps. *Rastrelliger* spp. were captured using Danish seines, trammel net, stationary lift net, and traps. Whereas *S. leptolepis* were captured using Danish seines, drift gillnet, set gillnet, trammel net, and stationary lift net.

2.3 Catch per unit effort (CPUE) and effort standardization

As fishing gears used for sampling had different catchabilities they were standardised using the following equations (after Sparre and Venema 1998; King 2007; Fauziyah *et al.* 2018b):

$$E_{jt} = \varphi_{jt} D_{jt}$$
$$\varphi_{jt} = \frac{U_{jt}}{U_{st}}$$
$$U_{jt} = \frac{C_{jt}}{D_{jt}}$$

Where,

E_{jt} = Effort from gear *j* at *t* standardised; D_{jt} = Effort from gear *j* at *t* period (trip); φ_{jt} = Fishing power of gear *j* at *t* period; U_{jt} = CPUE of gear *j* at *t* period; U_{st} = CPUE of gear based for standardised; U_{jt} = CPUE of gear *j* at *t* period (ton / trip); C_{jt} = the catch of gear *j* at *t* period (ton).

2.4 Surplus Production Models

In this study, the SPMs have used the catch data of each pelagic species and fishing effort used in term of the fishing trip number. The functions for seven SPMs equations are presented in Table 1. The sustainable catch of each pelagic species can be estimated by the logistic growth function and Gompertz growth function (Sin and Yew 2016). Parameters estimated from Schaefer, Gulland, Pella & Tomlinson, Walter and Hilborn, and Schnute models were used in the logistic catch equation while those estimated from Fox and Clarke Yoshimoto Pooley (CYP) models were used in Gompertz catch equation.

TABLE 1 The equations for Surplus Production Models and reference points.

Model	Equation	MSY	References
Schaefer	$\frac{C_t}{E_t} = \alpha - \beta E_t$; $C_t = aE_t - bE_t^{\,2}$	$E_{msy} = \frac{a}{2b}$ $C_{msy} = \frac{a^2}{4b}$	Aristiantin *et al.* (2017); Kekenusa *et al.* (2018)
Gulland	$U_t = \frac{C_t}{\bar{E}_t} = a - b\bar{E}_t$ $C_t = a\bar{E}_t - b\bar{E}_t^{\,2}$	$E_{msy} = \frac{a}{2b}$ $C_{msy} = \frac{a^2}{4b}$	Ricker (1975); Widodo (1986); Singh (2015)
Pella & Tomlinson	$U_t = \frac{C_t}{E_t} = a - bE_t^{\,m-1}$ $C_t = aE_t - bE_t^{\,m}$	$E_{msy} = \left(\frac{a}{mb}\right)^{(1/(m-1))}$ $C_{msy} = aE_{msy} + bE_{msy}^{\,m}$	Widodo (1986); Singh (2015)
Fox	$Ln\left(\frac{C_t}{E_t}\right) = a - bE_t$ $C_t = E_t\, Exp(a - bE_t)$	$E_{msy} = \frac{1}{b}$ $C_{msy} = \frac{1}{b}\, exp(a-1)$	Mohsin *et al.* (2017); Kekenusa *et al.* (2018)
Walters-Hilborn	$\frac{U_{t+1}}{U_t} - 1 = a + bU_t + cE_t$ $C_t = KqE_t - \frac{Kq^2}{r}E_t^{\,2}$ a=r; q=-c; K= a/(bc)	$E_{msy} = -\frac{a}{2c} = -\frac{r}{2q}$ $C_{msy} = \frac{a^2}{4b} = \frac{rK}{4}$	Kekenusa *et al.* (2018)
Schnute	$Y_t = a + bX_{it} + cX_{2t}$ $C_t = KqE_t - \frac{Kq^2}{r}E_t^{\,2}$ Y_t=Ln(U_{t+1}/U_t); X_{1t}=½(U_t+U_{t+1}); X_{2t}=½(E_t+E_{t+1}); a=r; q=-b; K= a/(bc)	$E_{msy} = -\frac{a}{2c} = -\frac{r}{2q}$ $C_{msy} = \frac{\alpha^2}{4b} = \frac{rK}{4}$	Sholahuddin *et al.* (2015); Kekenusa *et al.* (2018)
CYP	$Y_t = a + bX_{it} + cX_{2t}$ $C_t = KqE_t exp\left(\frac{-q}{r}E_t\right)$ Y_t=ln(U_{t+1}); X_{1t}=ln(U_t); X_{2t}=(E_t+E_{t+1}); a=âln(qK); r=2(1- b)/(1+ b) q=-c(2+r); $K = e^Q/q$ Q= a(2+r)/(2r)	$E_{msy} = \frac{r}{q}$ $C_{msy} = \frac{a^2}{4bc} = \frac{rK}{e}$	Supriatna *et al.* (2016); Kekenusa *et al.* (2018)

E_t , effort standardised at *t* period; $\bar{E}_t$, moving average of effort standardise at *t* period; E_{t+1}, effort standardised at *t+1* period; C_t, catch at *t* period; U_t , CPUE standardised at *t* period; U_{t+1}, CPUE standardised at *t+1* period; *r*, intrinsic growth rate; *q*, catchability coefficient; *K*, carrying capacity; *a*, *b* and *c* are regression coefficients.

2.5 Best-fitted model

By using linear regression between CPUE and effort regression coefficient values (*a*, *b* and *c*) and biological parameters (*r*, *q* and *K*) can be obtained. The best-fitted of SPM is a model that has a sign suitability of biological parameter (positive value) and the best model performance among the other SPM applied.

For the equation of the Schaefer, Pella & Tomlinson, Fox, and Gulland models, only the intercept and slope values are obtained while the biological parameter can not be directly identified. For the Schaefer Model, Gulland Model, Pella & Tomlinson Models, the biological parameters are considered appropriate if the value of the intercepts (*a*) is positive and the slope (*b*) is negative. While for the Fox model, the value of slope (*b*) must be negative (Sparre and Venema 1998; Kekenusa *et al.* 2018). Only models that have the sign suitability can be carried out by the model performance test. Several researchers (*e.g.* Siyal *et al.* 2013; Seong *et al.* 2015; Singh 2015) used different models performance tests such as determination coefficient (R^2), root means square error (RMSE), mean absolute deviation (MAD), mean square error (MSE), mean absolute percentage error (MAPE), RMSE-observations standard deviation ratio (RSR) and Nash-Sutcliffe efficiency (NSE). The best model is the model that has the highest R^2 and NSE values, and the contrary has the lowest MAD, MSE, RMSE, MAPE and RSR (Singh 2015; Fauziyah *et al.* 2020). These values must be standardised with the scoring method to obtain the same standard values so that it is easier to determine the best model. The standardization formulas (Iskandar and Guntur 2014; Fauziyah *et al.* 2018a) are as follows:

$$V(X) = \frac{X - X_0}{X_a - X_0}$$

$$V(A) = \sum_{i=a}^{n} Vi(Xi)$$

$$i = a, b, c, d \dots \dots n$$

Where: *V(X)*, value function of criteria *X*; *X*, value of criteria *X*; X_a, the best value of criteria *X*; X_o, the worst value of criteria *X*; *V(A)*, value function of alternatives *A*; *Vi(Xi)*, value function of alternatives in criteria *i*.

2.6 | Fish stock status

Different categories of fish stock status were considered by several researchers (see Carruthers *et al.* 2012; Tsikliras *et al.* 2015; Froese *et al.* 2018 for details). The Indonesian government also makes an exploitation level classification that is referring to the estimation of potential, total allowable catches and exploitation level of fish resources in the Fisheries Management Areas within the country. Based on these, this study created a modification of the fish stock status (Table 2) with consideration of C_{MSY} and E_{MSY} as reference points (Fauziyah *et al.* 2020).

TABLE 2 The classification of fish stock status.

The status of fisheries and criterion applied		The fish stock status
Exploitation level	**Fishing effort Level**	
Over-exploited ($C/C_{MSY} \geq 1$)	Underfishing ($E/E_{MSY} < 1$)	Healthy stock
Over-exploited ($C/C_{MSY} \geq 1$)	Overfishing ($E/E_{MSY} \geq 1$)	Depleting stock
Fully-exploited ($0.5 \leq C/C_{MSY} < 1$)	Underfishing ($E/E_{MSY} < 1$)	Recovery stock
Fully-exploited ($0.5 \leq C/C_{MSY} < 1$)	Overfishing ($E/E_{MSY} \geq 1$)	Overfishing stock
Moderate exploited ($0.2 < C/C_{MSY} < 0.5$)	Overfishing ($E/E_{MSY} \geq 1$)	Overfishing stock
Moderate exploited ($C/C_{MSY} < 0.5$)	Underfishing ($E/E_{MSY} < 1$)	Transitional recovery stock
Moderate exploited ($C/C_{MSY} \leq 0.2$)	Overfishing ($E/E_{MSY} \geq 1$)	Collapsed stock

3 | RESULTS

3.1. Best fitted model

The best-fitted model for *Rastrelliger* spp., *S. commerson*, *Auxis* spp. and *S. leptolepis* using various SPM are presented in Tables 3–6 respectively. The results showed that Walter-Hilborn (Table 3) and Schnute (Tabel 4) model do not adequately fit for *Rastrelliger* spp. and *S. commerson* because the biological parameters did not show the proper sign. While Gulland, Walter-Hilborn, Schnute and CYP models were not adequately fit for *Auxis* spp (Table 5). Whereas Walter-Hilborn, Schnute and CYP models were not adequately fit for *S. leptolepis* (Table 6).

Table 3 shows that the Fox model was the best-fitted model for *Rastrelliger* spp. based on scoring value (*V(A)* = 7). The scoring method was carried out on seven parameters which indicated model performance, *viz.* R^2, NSE, MAD, MSE, RMSE, MAPE, and RSR. The parameters values were 0.905, 0.24, 19.678, 630.831, 25.116, 0.039 and 0.872 respectively. The parameter values were the best value when compared to other types of SPM used in the analysis. The value of E_{MSY}, C_{MSY} and Total Allowable Catch (TAC) were 18226 trips, 515 tons and 412 tons respectively.

For *S. commerson*, Pella and Tomlinson's model was the best-fitted model based on scoring value (*V(A)* = 6.972). The scoring values of seven model performance parameters were as follows: R^2, 0.802; NSE, 0.771; MAD, 73.665; MSE 8077.282; RMSE 89.874; MAPE 0.050; and RSR 0.478. The Pella and Tomlinson model had the six best values of the seven model performance parameters (R^2, NSE, MSE, RMSE, MAPE and RSR). While the best value for MAPE was owned by the CYP model. The values of E_{MSY}, C_{MSY}, and TAC for the Pella and Tomlinson model were 68677 trips, 1845 tons and 1476 tons respectively.

TABLE 3 Summary statistics for various SPMs for *Rastrelliger* spp. (SPM_1, Schaefer; SPM_2, Gulland; SPM_3, Fox; SPM_4, Pella and Tomlinson; SPM_5, Walter-Hilborn; SPM_6, Schnute; SPM_7, CYP; *V(A)*, scoring value; NA, not appropriate).

Parameter	Surplus Production Models (SPMs)						
	SPM_1	SPM_2	SPM_3	SPM_4	SPM_5	SPM_6	SPM_7
Sign suitability							
a	0.050760	0.053710	–2.566806	0.300097	–2.23425	1.02611	–4.2251
b	–0.000001	–0.000001	–0.000055	–0.101927	25.06502	–19.36268	–0.7079
c					0.00008	–0.00002	–0.0001
r					–2.23425^{NA}	1.02611	11.6942
K					–0.00008^{NA}	0.00002	0.0007
q					–1129.783^{NA}	2160.08689	122.0186
m	-	-	-	1.4			
Performance test							
R^2	0.886	0.614	0.905	0.893		0.009012	0.805
NSE	0.149	–0.025	0.240	0.225		–1.719757	0.202
MAD	21.938	22.287	19.678	20.142		39.25051845	19.807
MSE	706.100	850.713	630.831	642.837		2,257	661.984
RMSE	26.573	29.167	25.116	25.354		47.51	25.729
MAPE	0.044	0.046	0.039	0.041		0.0806	0.040
RSR	0.922	1.013	0.872	0.880		1.64917	0.893
MSY							
E_{MSY}	20324	19652	18226	18872		20913	16935
C_{MSY}	516	528	515	515		554.12	525
TAC	413	422	412	412		443	420
Best-fitted model							
V(A)	6.521	6	7.000	6.900		0	6.773

TABLE 4 Summary statistics for various SPM of *Scomberomorus commerson* (SPM_1, Schaefer; SPM_2, Gulland; SPM_3, Fox; SPM_4, Pella and Tomlinson; SPM_5, Walter-Hilborn; SPM_6, Schnute; SPM_7, CYP; *V(A)*, scoring value; NA, not appropriate).

Parameter	Surplus Production Models (SPMs)						
	SPM_1	SPM_2	SPM_3	SPM_4	SPM_5	SPM_6	SPM_7
Sign suitability							
a	0.070833	0.068935	–2.558363	0.295441	1.86391	–2.69039	–4.9302
b	–0.000001	–0.000001	–0.000016	–0.088185	–29.73651	36.02756	–0.9252
c					–0.00002	0.00003	–0.0000
r					1.86391	–2.69039^{NA}	51.4714
K					0.00002	–0.00003^{NA}	0.0008
q					4005.81323	–2536.56^{NA}	95.5593
m	-	-	-	1.1			
Performance test							
R^2	0.776	0.513	0.798	0.802	0.442446		0.796
NSE	0.753	0.755	0.766	0.771	0.716233		0.766
MAD	74.028	73.595	73.665	73.591	80.483112		73.395
MSE	8716.116	8632.994	8271.787	8077.282	10014		8262.571
RMSE	93.360	92.914	90.949	89.874	100.07		90.899
MAPE	0.05085	0.05011	0.05013	0.05000	0.05370		0.05006
RSR	0.4970	0.4946	0.4842	0.4784	0.5327		0.4839
MSY							
E_{MSY}	48108	49658	63173	68677	59559		63681
C_{MSY}	1704	1712	1800	1845	1867		1809
TAC	1363	1369	1440	1476	1493		1448
Best model							
V(A)	5.266	5	6.505	6.972	0		6.577

TABLE 5 Summary statistics for various SPMs of *Auxis* spp. (SPM_1, Schaefer; SPM_2, Gulland; SPM_3, Fox; SPM_4, Pella and Tomlinson; SPM_5, Walter-Hilborn; SPM_6, Schnute; SPM_7, CYP; *V(A)*, scoring value; NA, not appropriate).

Parameter	Surplus Production Models (SPMs)						
	SPM_1	SPM_2	SPM_3	SPM_4	SPM_5	SPM_6	SPM_7
Sign suitability							
a	0.024629	0.008586	–3.405611	0.152247	–2.03121	–3.38829	–3.9218
b	–0.000001	0.00000[NA]	–0.000043	–0.051071	–14.84577	45.81594	0.3805
c					0.00008	0.00011	0.0000
r					–2.03121[NA]	–3.38829[NA]	0.8975
K					–0.00008[NA]	–0.00011[NA]	–0.0001[NA]
q					1693.058[NA]	–691.586[NA]	–30.604[NA]
m	-	-	-	1.2			
Performance test							
R^2	0.318	-	0.267	0.341	-	-	-
NSE	0.869	-	0.875	0.873	-	-	-
MAD	35.789	-	34.963	35.215	-	-	-
MSE	1335.751	-	1278.131	1297.837	-	-	-
RMSE	36.548	-	35.751	36.026	-	-	-
MAPE	0.129	-	0.125	0.127	-	-	-
RSR	0.362	-	0.354	0.357	-	-	-
MSY							
E_{MSY}	23,693	-	23,402	1,916	-	-	-
C_{MSY}	292	-	286	83	-	-	-
TAC	233	-	229	67	-	-	-
Best model							
V(A)	0.688	-	6.000	4.825	-	-	-

Table 6 Summary statistics for various SPMs of *Selaroides leptolepis* (SPM_1, Schaefer; SPM_2, Gulland; SPM_3, Fox; SPM_4, Pella and Tomlinson; SPM_5, Walter-Hilborn; SPM_6, Schnute; SPM_7, CYP; *V(A)*, scoring value; NA, not appropriate).

Parameter	Surplus Production Models (SPMs)						
	SPM_1	SPM_2	SPM_3	SPM_4	SPM_5	SPM_6	SPM_7
Sign suitability							
a	0.068603	0.031874	–2.51469	0.401944	–0.47293	–0.58155	–2.9094
b	–0.000002	–0.0000003	–0.000045	–0.136186	–6.46752	–12.50757	0.2501
c					0.00002	0.00003	0.0000
r					–0.47293[NA]	–0.58155[NA]	1.1996
K					–0.00002[NA]	–0.00003[NA]	–0.00001[NA]
q					2975.958	1433.1421	–3330.1[NA]
m	-	-	-	1.1			
Performance test							
R^2	0.583	0.179	0.650	0.641	-	-	-
NSE	–0.617	–1.346	–0.212	–0.338	-	-	-
MAD	110.898	94.414	89.082	99.716	-	-	-
MSE	20716.965	30046.535	15520.150	17137.178	-	-	-
RMSE	143.934	173.339	124.580	130.909	-	-	-
MAPE	0.182	0.129	0.142	0.166	-	-	-
RSR	1.272	1.532	1.101	1.157	-	-	-
MSY							
E_{MSY}	21172	54783	22403	19337	-	-	-
C_{MSY}	726	873	667	707	-	-	-
TAC	581	698	533	565	-	-	-
Best model							
V(A)	3.349	1.76	6.763	5.323	-	-	-

In Table 5, the Fox model was the best-fitted model with the highest scoring value (6) for *Auxis* spp. Whereas for *S. leptolepis*, it was also the Fox model, obtained as the best-fitted model with the highest scoring value (6.763) (Table 6).

3.2 Fish stock status

Based on available data, the stock status of *S. leptolepis*, *Auxis* spp., *S. commerson* and *Rastrelliger* spp. in 2016 were depleting, overfishing, recovery and depleting stock respectively (Figure 2). The fisheries development of *Rastrelliger* spp. between 2008 and 2016 fluctuated (Figure 3). *Rastrelliger* catch in the 2008 – 2012 period did not exceed the sustainable catches (C_{MSY}) but it was over the optimum efforts (E_{MSY}) that results in an overfishing condition of the stock. Furthermore, in 2013 there was a decreasing effort below E_{MSY} value, but the catch was just higher than C_{MSY} value that indicates a healthy condition of the stock. In 2014 – 2016, increased fishing efforts beyond E_{MSY} value also results in more catches than C_{MSY} value put the stock in depleting condition.

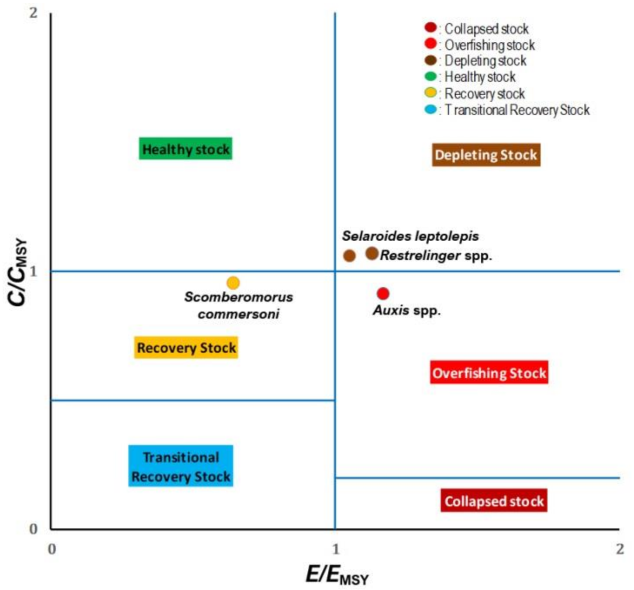

FIGURE 2 The stock status of four pelagic fishes in Banyuasin coastal waters for the 2016 year based on data from 2008 – 2016).

The fisheries development of *S. commerson* as shown in Figure 4 which indicates an increase in the catch in 2008 – 2016 period but it did not exceed C_{MSY} value (fully exploited) and E_{MSY} value (*i.e.* underfished). These conditions indicated that the status of fish stocks was in recovery condition. The catch of *Auxis* spp. exceeded both the C_{MSY} value (over-exploited) and E_{MSY} value (*i.e.* overfished) in 2011 – 2013 period that put the stock status in a depleting condition (Figure 5). Furthermore, in the 2014 – 2016, the efforts carried out exceeded the E_{MSY} value (*i.e.* overfished) but the catch was below C_{MSY} (*i.e.* fully exploited) that results in an overfishing condition.

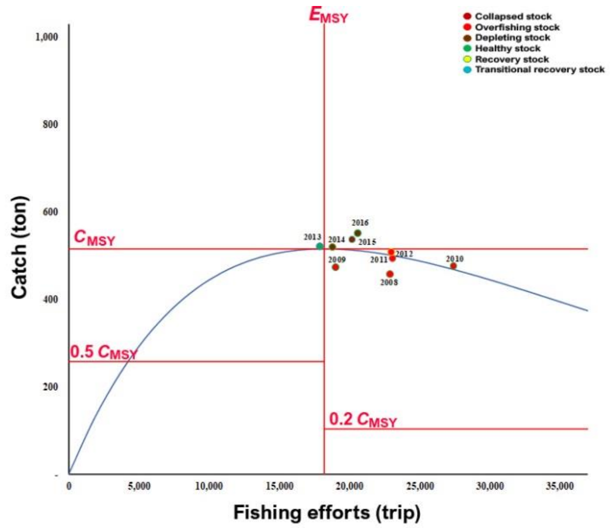

FIGURE 3 Fitted equilibrium Fox model and fish stock status for *Rastrelliger* spp. in Banyuasin coastal waters.

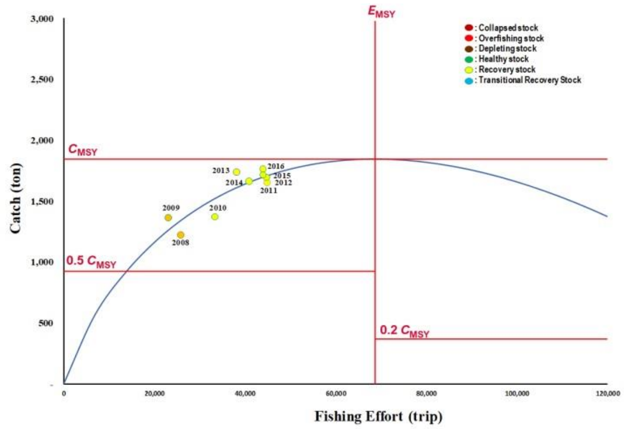

FIGURE 4 Fitted equilibrium Pella & Tomlinson model and fish stock status for *Scomberomorus commerson* in Banyuasin coastal waters.

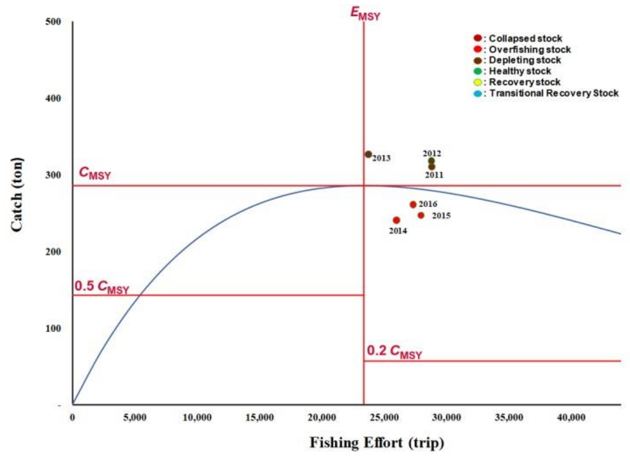

FIGURE 5 Fitted equilibrium Fox model and fish stock status for *Auxis* spp. in Banyuasin coastal waters.

The catch of *S. leptolepis* in 2008 exceeded the C_{MSY} (*i.e.* overexploited) but the effort did not exceed the E_{MSY} (*i.e.* underfished) reflecting a healthy condition of the stock

(Figure 6). In 2009 increased efforts were recorded but they did not exceed the E_{MSY} (*i.e* underfished) but the catch decreased dramatically below the C_{MSY} value (*i.e.* fully exploited). This phenomenon indicated that the stock status for the *S. leptolepis* in 2009 was recovering phase (recovery stock). Furthermore, in 2010 – 2013, the trend of efforts have increased and exceeded E_{MSY} value but the catch obtained did not exceed C_{MSY} value indicating an overfishing status of the stock. In 2014 – 2016, the efforts and catch exceeded both E_{MSY} and C_{MSY} values which indicated that the fish stock status was in depleting state.

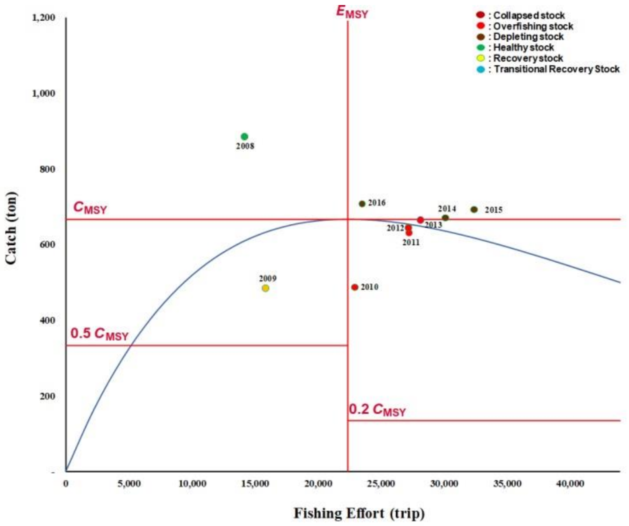

FIGURE 6 Fitted equilibrium Fox model and fish stock status for *Selaroides leptolepis* in Banyuasin coastal waters.

4 | DISCUSSION

This study has analysed seven SPMs and determined the best-fitted model based on R^2, NSE, MAD, MSE, RMSE, MAPE and RSR values using a scoring approach. Fox model was the best-fitted model for *Rastrelliger* spp. but the performance rating of the model was unsatisfactory (NSE = 0.24 ≤ 0.50 and RSR = 0.872 > 0.70; Moriasi *et al.* 2007). Nonetheless, based on R^2 value (0.905 > 0.85) this indicated excellent performances (Makungo and Odiyo 2017). Fox's model was also the best-fitted model for *Auxis* spp. and *S. leptolepis*. Referring to NSE and RSR values, the model performance rating for *Auxis* spp. was very good (0.75 ≤ NSE = 0.875 ≤ 1; and 0 ≤ RSR = 0.354 ≤ 0.5; (Moriasi *et al.* 2007) but R^2 value (0.267 < 0.5) indicated unsatisfactory performances (Makungo and Odiyo 2017). However, the model performance rating for *S. leptolepis* was unsatisfactory (NSE = –0.212 ≤ 0.5; RSR = 1.157 > 0.7; and R^2 = 0.267 < 0.5; Moriasi *et al.* 2007, Makungo and Odiyo 2017). On the contrary, the best-fitted model for *S. commerson* was Pella and Tomlinson model where the model performance rating was very good (0.75 ≤ NSE = 0.771 ≤ 1); RSR (0 ≤ RSR = 0.478 ≤ 0.5; and 0.75 ≤ R^2 = 0.802 ≤ 0.85) (Moriasi et al. 2007; Makungo and Odiyo 2017). The results showed that the performance rating, based on RSR and NSE, yielded similar result but different for R^2 values. In this study, R^2 described the degree of collinearity between CPUE and effort (linear regression model) and did not describe the degree of collinearity between the catch and effort (equilibrium model) while the other parameters (NSE, MAD, MSE, RMSE, MAPE and RSR) described the model performance evaluation in terms of the equilibrium model. However, there is no firm consensus on acceptable model performance parameters and no single statistic can be used to assess all aspects of model performance (Duda *et al.* 2012; Seong *et al.* 2015).

The stock status of *S. leptolepis*, *Auxis* spp., *S. commerson* and *Rastrelliger* spp. in 2016 were in depleting, overfishing, recovery, and depleting conditions respectively. This condition indicated that fishing efforts for *S. leptolepis*, *Auxis* spp. and *Rastrelliger* spp. were larger than their estimated E_{MSY}. However, overfishing stock status was recorded for *Auxis* spp. which is in line with the assessment of same species in Talaud waters (Kekenusa *et al.* 2015) and Bitung waters of North Sulawesi (Kekenusa *et al.* 2018) of Indonesia. While depleting stock for *S. leptolepis* and *Rastrelliger* spp. in this study were different from the assessment conducted in the Karangantu National fishing port of Banten and Sunda Strait waters, where the results showed that an overfishing stock of the species (Mayalibit *et al.* 2014; Sarasati *et al.* 2016). Recovery stock for *S. commerson* in this study was different from the assessment in the Meranti Islands waters where the results have shown a depleting status (Syaputra *et al.* 2016). Thus, fishing effort and catch should be kept limited in order to obtain a maximum sustainable yield. Variation in catch depends not only on efforts but also on the environmental factors (Meraz-Sánchez *et al.* 2013). Thus, in addition to promoting the development of sustainable fishing grounds lowering the number of fishing vessels may yield an improvement of the overfished stocks (Chae and Pascoe 2005; Siyal *et al.* 2013). And it is important to monitor the fish stock status on regular basis (Meraz-Sánchez *et al.* 2013).

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CONFLICT OF INTEREST

The author declares no conflict of interest.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available within the article [and/or] its supplementary materials.

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WAEP data collection and research supervision;
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