The stock status of the pelagic fish in Banyuasin Coastal Waters, Indonesia

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The stock status of the pelagic fish 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. The study aimed to estimate the stock status for *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 Water, South Sumatra Province, Indonesia. All seven surplus production models (SPMs), model performance, and fish stocks status were estimated by the excel program. 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 Fox model. The optimum effort (E_{msy}) value for *S. commerson*, *Rastrelliger* spp., *Auxis* spp., and *S. leptolepis* were 68,677 trip, 18,226 trip, 23,402 trip, and 22,403 trips respectively. The maximum sustainable catch (C_{msy}) value for *S. commerson*, *Rastrelliger* spp., *Auxis* spp., and *S. leptolepis* were 1,845 ton, 515 ton, 286 ton, 667 ton. The stock of *S.commerson* in 2016 was recovery stock and overfishing stock for *Auxis* spp. while for *S.leptolepis* and *Rastrelliger* spp. in the depleted stock condition.

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

1. INTRODUCTION

Banyuasin Coastal Waters is the center of capture fisheries in South Sumatra Province, Indonesia (Fauziyah *et al.* 2018a, 2019). Fishing units that develop in the area are included in 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 and information are very important for fisheries managers to determine the appropriate action plan so that fisheries resources remain sustainable. Researchers in the fisheries field have carried out various researches to study how fishing can reach equilibrium so that populations of aquatic species can develop in 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 in order to the fishing can be sustainable are the exploitation level and the fishing effort level (Fauziyah *et al.* 2020). Other factors that also influence 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 centers of fishing (Tinungki *et al.* 2004). These models can be used as an alternative analysis when virtual population analysis can't be done due to the age structure information of the catch is not available (Meraz-Sánchez *et al.* 2013).

In order to better assess for the dynamical fisheries resources, the approach and concept of SPM have developed by many authors such as 1) Schaefer's Model, 2) Fox Model, 3) Schnute Model, 4) Gulland Model, 5) Clark, Yoshimoto and Pooley (CYP) Model, 6) Pella & Tomlinson Model, 7) Walter-Hilborn Model, 8) Cushing model, etc (Tinungki *et al.* 2004; Kekenusa *et al.* 2018; Fauziyah *et al.* 2020). And 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 SPM were applied to assess the current stock status of the pelagic fish, such as *Auxis* spp., *Scomberomorus commerson, Selaroides leptolepis,* and *Rastrelliger* spp.

The status assessment of fish resource stocks in the Banyuasin coastal waters is still rarely studied. The fish stock status in these waters has been only analyzed for snapper in 2018 (Fauziyah *et al.* 2020), meanwhile, the status of pelagic fish stocks is unknown. The information on fish stock status was essential as basic data for determining the fisheries management and action plan in these waters. On this basis, 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 (Fig. 1) of the South Sumatra Province, Indonesia. This location has the most significant contribution to capture fisheries production in South Sumatra Province.

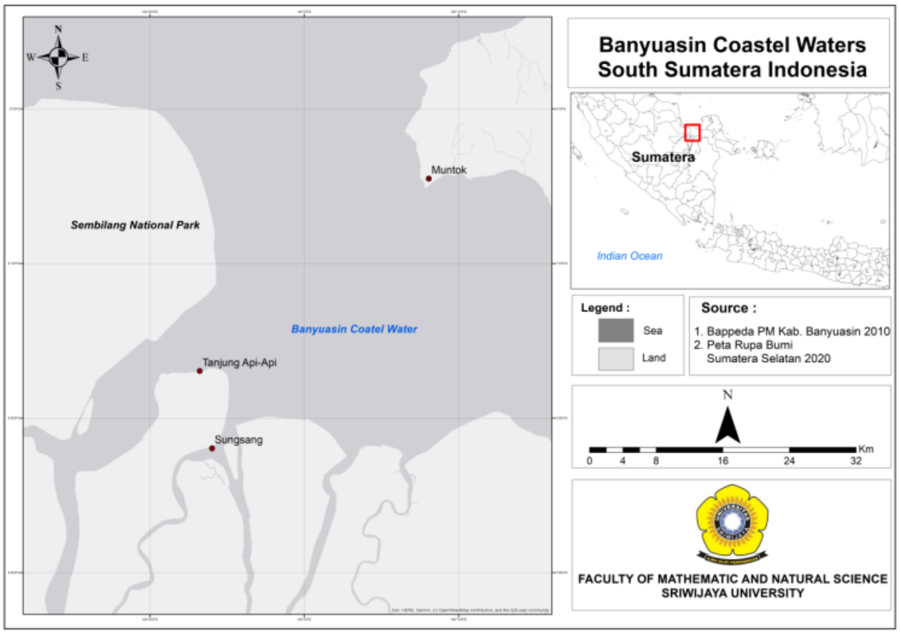

FIGURE 1. The study location of Banyuasin Coastal Water, Province of South Sumatra, Indonesia

2.2. Data

As the simplest stock-assessment models, the SPMs only used annual data of catch and fishing effort. All data were available in the Annual Fishery Statistics of Banyuasin Regency so this study only used secondary data (DKP 2009, 2010, 2012, 2013, 2014, 2015, 2016, 2017). This study only used four species of pelagic fish (*Auxis* spp., *Scomberomorus commerson*, *Selaroides leptolepis*, and *Rastrelliger* spp.) due to their available time-series data were limited. These data were classified based on catch data per trip by fishing gear type for each species during the years 2008-2016. The fishing effort was a number of the operational fishing boat (trip) whereas the total catch was the total weight of fish landed by fishermen (Baset *et al.* 2017).

In Banyuasin Coastal Waters, the local fishermen captured *Scomberomorus 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 *Selaroides leptolepis* were captured using Danish seines, drift gillnet, set gillnet, trammel net, and stationary lift net. All of these fishing gears were operated during one day for their every trip.

2.3. CPUE and effort standardization

Each fishing gear has a different catchability so it needs to be standardized a standardization technique (Sparre and Venema 1998; King 2007; Fauziyah *et al.* 2018b), such as following:

$$E_{jt} = \varphi_{jt} D_{jt}$$

$$\varphi_{jt} = \frac{U_{jt}}{U_{st}}$$

$$U_{jt} = \frac{C_{jt}}{D_{jt}}$$

Where,
E_{jt} = Effort from gear j at t standardized
D_{jt} = Effort from gear j at t period (trip)
φ_{jt} = Fishing power of gear j at t period
U_{jt} = Catch per unit effort (CPUE) of gear j at t period
U_{st} = Catch per unit effort (CPUE) of gear based for standardized
U_{jt} = Catch per unit effort (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 the term of the fishing trip number. The functions for 7 SPMs equations were 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 SPM and reference points

Model	Equation	MSY	References
1. Schaefer	$\frac{C_t}{\bar{E}_t} = \alpha - \beta E_t$; $C_t = aE_t - bE_t^{\,2}$	$E_{msy} = \frac{a}{2b}$ $C_{msy} = \frac{a^2}{4b}$	(Aristiantin *et al.* 2017; Kekenusa *et al.* 2018)
2. 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)
3. 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)
4. 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)
5. 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)
6. Schnute	$Y_t = a + bX_{it} + cX_{2t}$ $C_t = KqE_t - \frac{Kq^2}{r}E_t^{\,2}$	$E_{msy} = -\frac{a}{2c} = -\frac{r}{2q}$	(Sholahuddin *et al.* 2015; Kekenusa *et al.* 2018)

Model	Equation	MSY	References
	$Y_t=Ln(U_{t+1}/U_t)$; $X_{1t}=½(U_t+U_{t+1})$; $X_{2t}=½(E_t+E_{t+1})$; a=r; q=-b; K= a/(bc)	$C_{msy} = \frac{\alpha^2}{4b} = \frac{rK}{4}$	
7. 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)

Note:

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

2.5. Best-fitted Model

By using linear regression between CPUE and effort can be obtained regression coefficient values (a, b, and c) and biological parameters (r, q, and K). 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 will be carried out by the model performance test. Some researchers (Siyal *et al.* 2013; Seong *et al.* 2015; Singh 2015) used several 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. These values must be standardized 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) ware as follows:

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

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

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

Where:

V(X) = Value function of criteria X
X = Value of criteria X
Xa = The best value of criteria X
Xo = 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

There are different categories of fish stock status carried out by several researchers (Carruthers *et al.* 2012; Tsikliras *et al.* 2015; Froese *et al.* 2018). 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 of the Republic of Indonesia. Based on these references, this study created a modification of the fish stock status (Table 2) with considering 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 were presented in Table 3, Table 4, Table 5, and Table 6 respectively. The results showed that Walter-Hilborn (Table 3) and Schnute (Tabel 4) model do not adequately for *Rastrelliger* spp., and *S. commerson* because the biological parameters did not show the proper sign. While Gulland, Walter-Hilborn, Schnute, and CYP model (Table 5) were not adequately for *Auxis* spp. as well as Walter-Hilborn, Schnute and CYP model (Table 6) were not adequately for *S. leptolepis.*

TABLE 3. Summary statistics for various SPM of *Rastrelliger* spp. from Banyuasin Coastal Waters

Parameter	**The Surplus Production Models (SPMs) that used in the study**						
	SPM_1	**SPM_2**	**SPM_3**	**SPM_4**	**SPM_5**	**SPM_6**	**SPM_7**
1. 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					-1,129.783 ^{NA}	2,160.08689	122.0186
m	-	-	-	1.4			
2. 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

Parameter	The Surplus Production Models (SPMs) that used in the study						
	SPM_1	SPM_2	SPM_3	SPM_4	SPM_5	SPM_6	SPM_7
RSR	0.922	1.013	0.872	0.880		1.64917	0.893
3. MSY							
E_{msy}	20,324	19,652	18,226	18,872		20,913	16,935
C_{msy}	516	528	515	515		554.12	525
TAC	413	422	412	412		443	420
4. Best-fitted model							
V(A)	6.521	6	**7.000**	6.900		0	6.773

Note:
SPM_1: Schaefer
SPM_2: Gulland
SPM_3: Fox
SPM_4: Pella and Tomlinson
SPM_5: Walter-Hilborn
SPM_6 : Schnute
SPM_7: CYP
NA : Not Appropriate
V(A) : Scoring value

Table 3 showed 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, namely: 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 18,226 trips, 515 tons, and 412 tons respectively.

TABLE 4. Summary statistics for various SPM of *S. commerson* from Banyuasin Coastal Waters

Parameter	The Surplus Production Models (SPMs) that used in the study						
	SPM_1	SPM_2	SPM_3	SPM_4	SPM_5	SPM_6	SPM_7
1. 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					4,005.81323	-2,536.56 [NA]	95.5593
m	-	-	-	1.1			
2. 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	8,716.116	8,632.994	8,271.787	8,077.282	10,014		8,262.571
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
3. MSY							
E_{msy}	48,108	49,658	63,173	68,677	59,559		63,681
C_{msy}	1,704	1,712	1,800	1,845	1,867		1,809
TAC	1,363	1,369	1,440	1,476	1,493		1,448
4. Best model							
V(A)	5.266	5	6.505	**6.972**	0		6.577

Note:
SPM_1: Schaefer
SPM_2: Gulland
SPM_3: Fox
SPM_4: Pella and Tomlinson
SPM_5: Walter-Hilborn
SPM_6 : Schnute
SPM_7: CYP
NA : Not Appropriate
V(A) : Scoring value

Table 4 shown that Pella and Tomlinson's model was the best-fitted model for *S. commerson* based on scoring value (V(A)=6.972). The scoring value was the scoring results of the seven parameters which indicated model performance, namely: R^2, NSE, MAD, MSE, RMSE, MAPE, and RSR. The parameters values were 0.802, 0.771, 73.665, 8,077.282, 89.874, 0.050 and 0.478 respectively. The Pella and Tomlinson model had the six best values of the seven model performance parameters, namely: 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 68,677 trips, 1,845 tons, and 1,476 tons respectively.

TABLE 5. Summary statistics for various SPM of *Auxis* spp. from Banyuasin Coastal Waters

Parameter	The Surplus Production Models (SPMs) that used in the study						
	SPM_1	SPM_2	SPM_3	SPM_4	SPM_5	SPM_6	SPM_7
1. 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					$1,693.058^{NA}$	-691.586^{NA}	-30.604^{NA}
m	-	-	-	1.2			
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	1,335.751	-	1,278.131	1,297.837	-	-	-
RMSE	36.548	-	35.751	36.026	-	-	-
MAPE	0.129	-	0.125	0.127	-	-	-
RSR	0.362	-	0.354	0.357	-	-	-
3. MSY							
E_{msy}	23,693	-	23,402	1,916	-	-	-
C_{msy}	292	-	286	83	-	-	-
TAC	233	-	229	67	-	-	-
4. Best model							
V(A)	0.688	-	**6.000**	4.825	-	-	-

Note:
SPM_1: Schaefer
SPM_2: Gulland
SPM_3: Fox
SPM_4: Pella and Tomlinson
SPM_5: Walter-Hilborn
SPM_6 : Schnute
SPM_7: CYP
NA : Not Appropriate
V(A) : Scoring value

Table 6. Summary statistics for various SPM of *S. leptolepis* from Banyuasin Coastal Waters

Parameter	The Surplus Production Models (SPMs) that used in the study						
	SPM_1	SPM_2	SPM_3	SPM_4	SPM_5	SPM_6	SPM_7
1. 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					2,975.958	1,433.1421	$-3,330.1^{NA}$
m	-	-	-	1.1			
2. 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	20,716.965	30,046.535	15,520.150	17,137.178	-	-	-
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	-	-	-
3. MSY							
E_{msy}	21,172	54,783	22,403	19,337	-	-	-
C_{msy}	726	873	667	707	-	-	-
TAC	581	698	533	565	-	-	-
4. Best model							
V(A)	3.349	1.76	**6.763**	5.323	-	-	-

Note:
SPM_1: Schaefer
SPM_2: Gulland
SPM_3: Fox
SPM_4: Pella and Tomlinson
SPM_5: Walter-Hilborn
SPM_6 : Schnute
SPM_7: CYP
NA : Not Appropriate
V(A) : Scoring value

In Table 5, the highest-scoring value was 6.00 which the Fox model was the best-fitted model for *Auxis* spp. The scoring values have shown that the Fox model had the 6 best parameter values for the model performance, namely: NSE, MAD, MSE, RMSE, MAPE, and RSR. While the best R^2 value was the Schaefer model. The values of R^2, NSE, MAD, MSE, RMSE, MAPE and RSR for Fox model were 0.267, 0.875, 34.963, 1,278.131, 35.751, 0.125 and 0.354 respectively. And the values of E_{msy}, C_{msy}, and TAC were 68,677 trips, 1,845 tons, and 1,476 tons respectively.

For *S. leptolepis* (Table 6), the Fox model was the best-fitted model with the highest scoring value (V (A) = 6.763) compared to other models. The scoring values have shown that the Fox model had the 6 best parameter values for the model performance, namely: R^2, NSE, MAD, MSE, RMSE, and RSR. While the best value of MAPE was the Gulland model. The values of R^2, NSE, MAD, MSE, RMSE, MAPE and RSR for Fox model were 0.650, -0.212, 89.082, 15,520.150, 124.580, 0.142 and 1.157 respectively. While the value of E_{msy}, C_{msy}, and TAC were 22,403 trips, 667 tons, and 533 tons respectively.

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. in the 2008-2016 period fluctuated (Figure 3). The *Rastrelliger* spp. catch in the 2008-2012 period are not exceeded the sustainable catches (C_{msy}) but over the optimum efforts (E_{msy}) so that the stock status was in an overfishing condition. Furthermore, in 2013 there was a decrease in an effort below E_{msy} value, but the catch was just higher than C_{msy} value so that the stock status was in a healthy condition. In 2014-2016 there was an increase in the effort to exceed E_{msy} value and the catch also exceeded the C_{msy} value so that the stock status was in a depleting condition.

The fisheries development of *S. commerson* as shown in Figure 4 indicated that an increase in the catch in the 2008-2016 period did not exceed the C_{msy} value (fully exploited) and the effort also did not exceed the E_{msy} value (underfished). This condition indicated that the status of fish stocks is in recovery condition. Figure 5 shown that the catch of *Auxis* spp. exceeded the C_{msy} value (over-exploited) and the effort also exceeded the E_{msy} value (overfished) in the 2011-2013 period so that the stock status was in a depleting condition. Furthermore, in the 2014-2016 period the effort carried out exceeded the E_{msy} value (overfished) but there was a decrease in catch to below the C_{msy} value (fully exploited) so that the stock status was in an overfishing condition.

In Figure 6, the catch of *S. leptolepis* in 2008 exceeded the C_{msy} value (overexploited) but the effort did not exceed the E_{msy} value (underfished) so that the stock status was in a healthy condition. In 2009 there was an increase in efforts that still did not exceed the E_{msy} value (underfished) but the catch actually decreased dramatically below the C_{msy} value (fully exploited). This phenomenon indicated that the stock status for the *S. leptolepis* in 2009 was recovery stock. Furthermore, in 2010-2013 the trend of efforts have increased more than the E_{msy} value while the catch obtained still did not exceed the C_{msy} value which indicated that fish stock status was overfishing stock. In 2014-2016 the effort still exceeded E_{msy} and the catch also exceeded the C_{msy} value which indicated that the fish stock status was depleting.

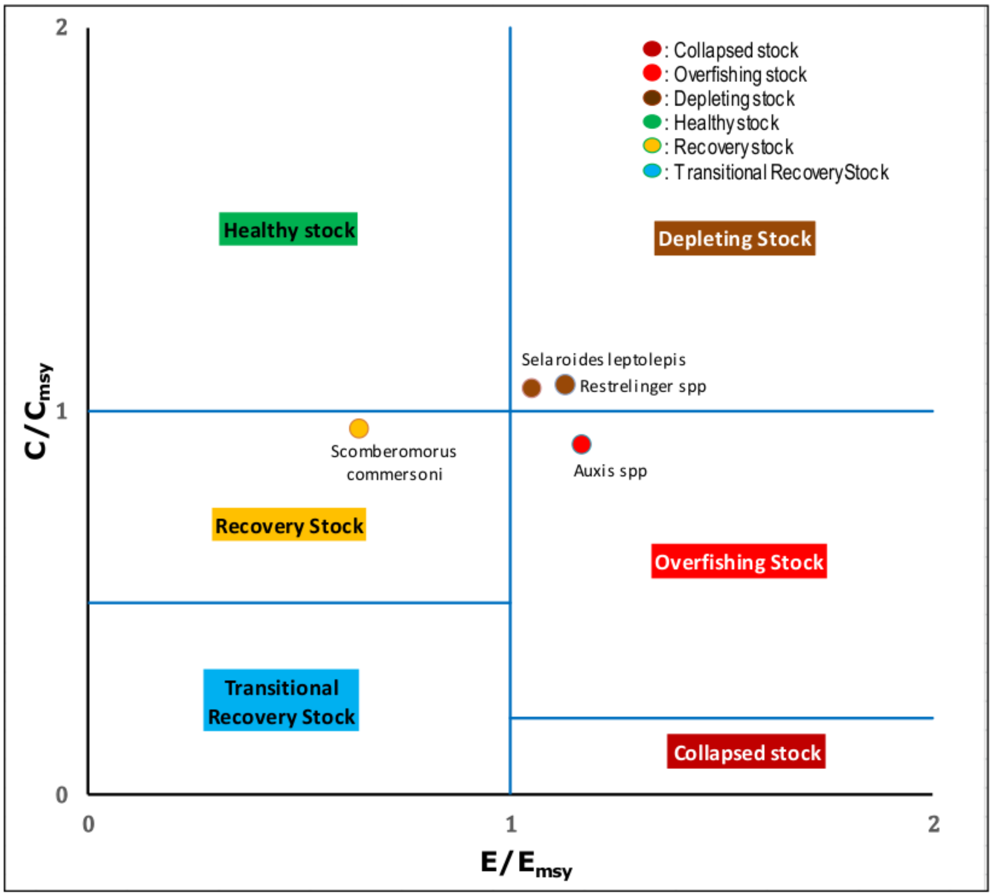

FIGURE 2. The stock status of 4 pelagic fish in Banyuasin Coastal Waters for the 2016 year based on available data (2008–2016).

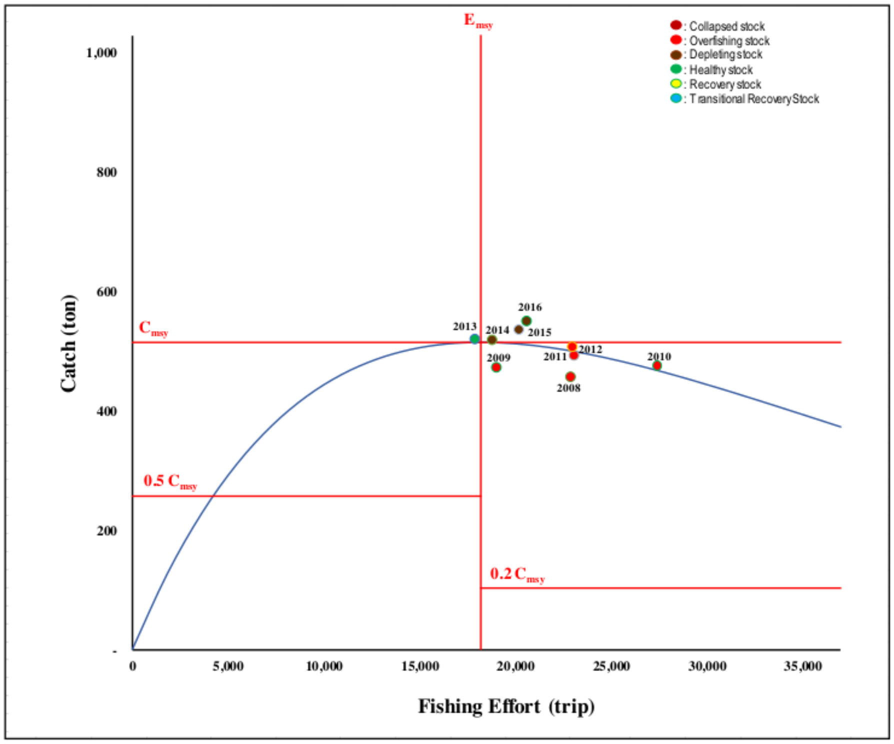

FIGURE 3. Fitted equilibrium Fox model and fish stock status for *Rastrelliger* spp. in Banyuasin Coastal Waters

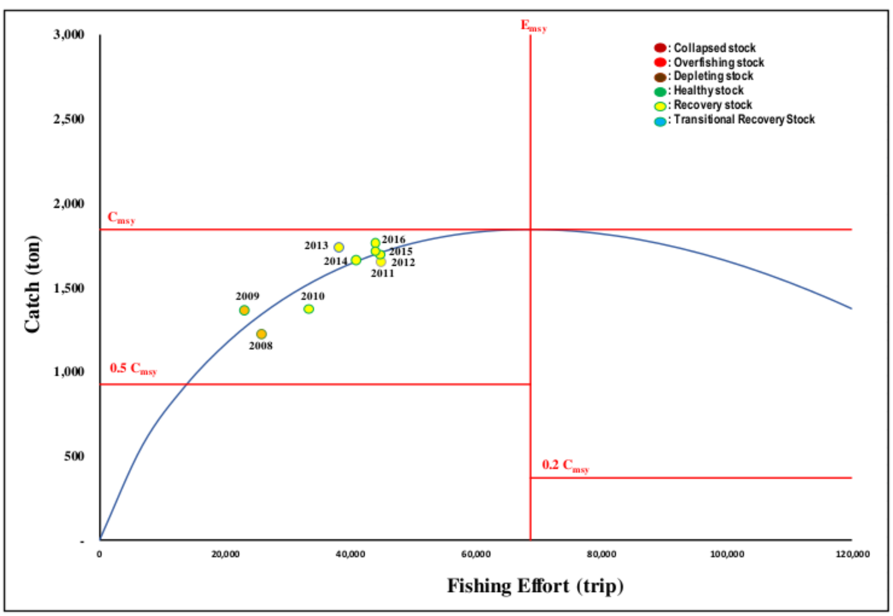

FIGURE 4. Fitted equilibrium Pella & Tomlinson model and fish stock status for *S. commerson* in Banyuasin Coastal Waters

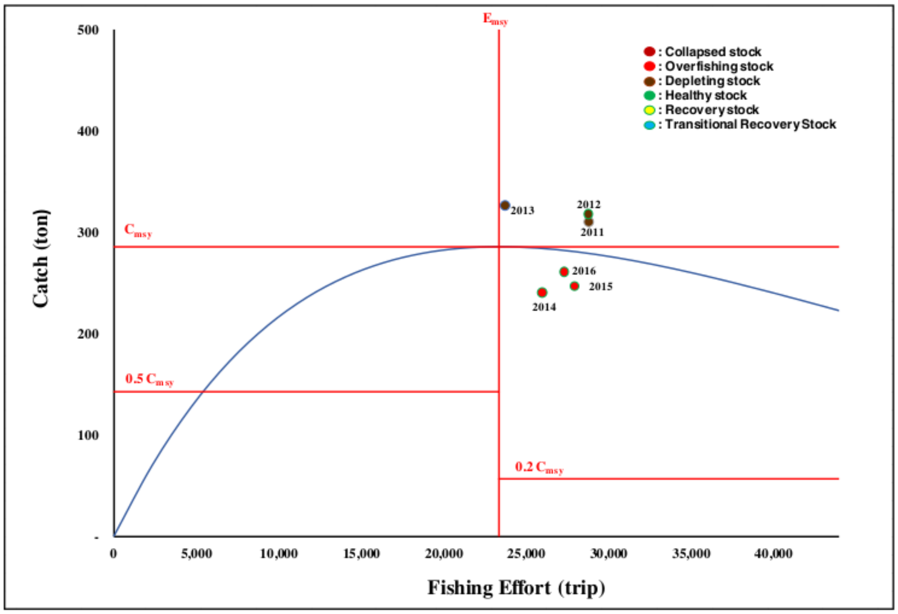

FIGURE 5. Fitted equilibrium Fox model and fish stock status for *Auxis* spp. in Banyuasin Coastal Waters

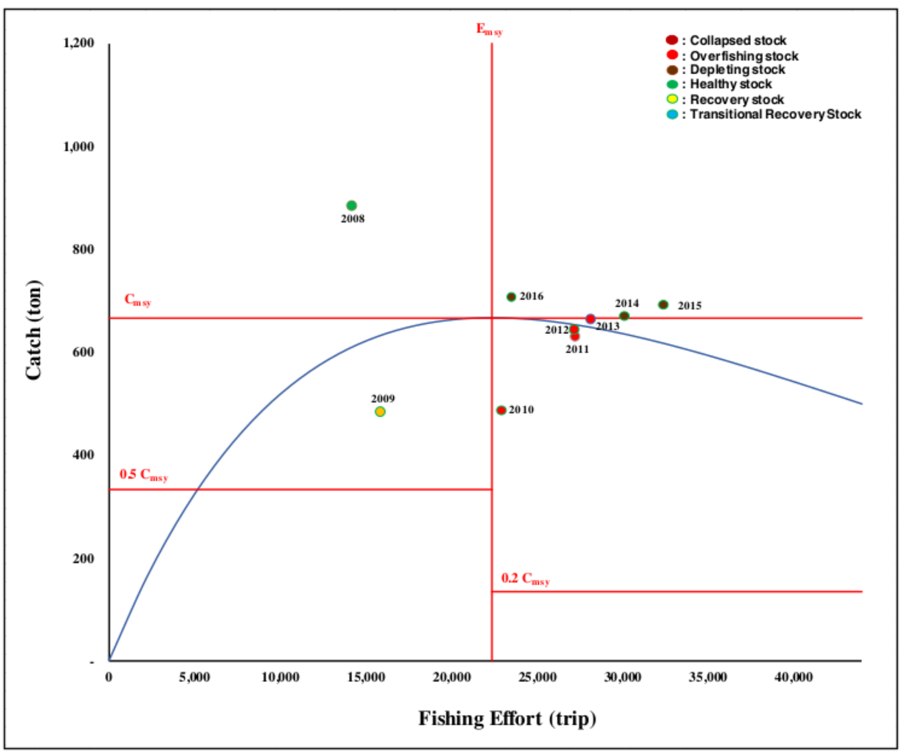

FIGURE 6. Fitted equilibrium Fox model and fish stock status for *S. leptolepis* in Banyuasin Coastal Waters

4. DISCUSSION

This study has analyzed seven surplus production models (SPMs) then determined the best-fitted model based on R^2, NSE, MAD, MSE, RMSE, MAPE and RSR value using a scoring approach. Fox model was the best-fitted model for *Rastrelliger* spp. where the performance rating of the model (Moriasi *et al.* 2007) was unsatisfactory ((NSE=0.24 ≤ 0.50 and RSR=0.872 > 0.70) but based on R^2 value (R^2=0.905 > 0.85) 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 value (Moriasi *et al.* 2007), the model performance rating for *Auxis* spp. was very good (0.75 ≤ NSE=0.875≤ 1; and 0 ≤ RSR=0.354 ≤ 0.5) but R^2 value (R^2=0.267< 0.5) indicated unsatisfactory performances (Makungo and Odiyo 2017). While the model performance rating (Moriasi *et al.* 2007; Makungo and Odiyo 2017) for *S. leptolepis* was unsatisfactory performances (NSE = -0.212 ≤ 0.5; RSR = 1.157 > 0.7; and R^2 = 0.267 < 0.5). On the contrary, the best-fitted model for *S. commerson* was Pella and Tomlinson model where has the model performance rating (Moriasi *et al.* 2007; Makungo and Odiyo 2017) which 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). The results showed that the performance rating results gave the same category in terms of RSR and NSE but did not always give the same category in terms of R^2. 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 the term of the equilibrium model. 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 depleting, overfishing, recovery, and depleting stock respectively. This condition indicated that fishing efforts *for S. leptolepis, Auxis* spp.*,* and *Rastrelliger* spp. were larger than their E_{msy} estimated. This condition of the most unhealthy stock was *Auxis* spp. Overfishing stock *for Auxis rochei* in this study was in line with the assessment of *Auxis rochei* in Talaud Waters (Kekenusa *et al.* 2015) and Bitung Waters North Sulawesi (Kekenusa *et al.* 2018). While depleting stock for *S. leptolepis* and *Rastrelliger* spp. in this study results were different from the assessment of the *S. leptolepis* in the Karangantu National Fishing Port of Banten where the results showed that overfishing stock has occurred (Mayalibit *et al.* 2014) as well as overfishing stock for *Rastrelliger* spp. in the Sunda Strait Waters (Sarasati *et al.* 2016). Recovery stock for *S.commerson* in this study result was different from the assessment of the *S. commerson* in the Meranti Islands Waters where the results have shown that depleting stock has occurred (Syaputra *et al.* 2016). Thus, ideally fishing effort and catch needs be limited so did not exceed their E_{msy} and C_{msy} values. Variation in catch depends not only on effort but the possibility is also influenced by environmental factors (Meraz-Sánchez *et al.* 2013). Thus, it is necessary to reduce the number of fishing vessels in addition to promoting the development of environmental-friendly fishing gear in order to reduce the efforts and rebuild overfishing stocks (Chae and Pascoe 2005; Siyal *et al.* 2013). And it is important to constantly update the fish stock status (Meraz-Sánchez *et al.* 2013).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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