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ORIGINAL ARTICLE

Capture fisheries sustainable management in Aceh Province: potential analysis of Shortfin Scads (*Decapterus macrosoma*) in Aceh eastern coastal waters case study

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Abstract
The shortfin scads (*Decapterus macrosoma*) are Aceh's eastern waterways' most commonly exploited fish. Shortfin scads contribute significantly to the economic development of Aceh's fishery, making its survival rate an unavoidable condition. This study was carried out between November 2021 and January 2022. This qualitative description was designed to learn about the state of fish in Aceh's eastern seas and how they might be managed sustainably. The data was obtained through intensive interviews and literature studies. Aceh Province's Marine and Fisheries Office provides the statistics of Aceh's capture fisheries from 2006–2020, which is essential. Surplus production and dynamic system modelling were analyzed based on the STELLA 9.0.2 application. The results showed that the utilization status value (URy) of *D. macrosoma* was 80%. The sustainable management scenario of *D. macrosoma* fisheries for the following decade (2021-2030) predicts that biomass stocks 2030 will reach their maximum on an allocation of fishing efforts similar to the 2020 effort, which was 108 percent. Therefore, the *D. macrosoma* fishery resource is fully exploited. The implementation of fishing efforts, equivalent to the 2020 effort, implicates the sustainability of biomass stocks until 2030.

Keywords: Biomass, Fishing effort, Shortfin Scads, Sustainability, Utilization rate

INTRODUCTION

The Andaman Sea and FMA 572 (Indian Ocean), Malacca Strait is the eastern part of Aceh Province. Legislatively, the eastern waters of Aceh lie between Indonesia and Malaysia, which simultaneously manage the fisheries potential, including common fish stocks (straddling and shared stocks). The continental shelf of Malacca Strait is a highly productive and densely populated fishing ground. Both conventional and modern fishermen intensively pursue fisheries exploitation (Bintoro et al. 2021; Harun et al. 2023). Fish stocks are always renewable; thus, knowledge of their condition is necessary for the quick development of fisheries. This step is essential for developing fisheries to gather current scientific data to identify foolproof management and exploitation strategies for fishery resources that can guarantee the long-term viability of the fishing industry (Kemp et al. 2023).

As a pelagic fish, shortfin scads (*Decapterus macrosoma*) are the most important commercial pelagic fish found in the waters to the east of Aceh Province. In the eastern waters of Aceh Province, the utilization rate of small pelagic fisheries stocks has reached its maximum potential and is fully exploited (Sofyan et al. 2022). Therefore, it is crucial to study the shortfin scads (*D. macrosoma*) ecosystem and management system in Aceh's eastern waters to ensure the long-term viability of the fishery and the prosperity of the region's fishing community.

MATERIAL AND METHODS

Research methods: This descriptive study applies scientific concepts that are empirical, objective, quantifiable, logical, and methodical to provide a systematic, factual, and accurate description of facts, features, and correlations between phenomena based on the data (Shields 2019). This research was conducted in November 2021 - January 2022 at the Marine and Fisheries Office of Aceh Province. The primary data was gathered through the documentation of intensive interviews (primarily about data validation processes) with officers handling captured fisheries data. Secondary data collection resulted in the compilation of information regarding the fish taken from the waters to the east of Aceh Province between 2006 and 2020. The information comprised the number of shortfin scads caught (in tons), the amount of effort put into capturing them according to the type of fishing gear used (in trips), and the amount caught according to the type of fishing gear used (tons). Other secondary data sources for this investigation include pertinent stock assessment documents, books, scientific journals, and articles from scientific publications.

Data analysis

Standardization of fishing gears: Indonesian fishing gear is typically categorized as multi-gear and multi-species, meaning that a single piece of fishing equipment can be used to catch a variety of fish species, and on the other hand, a single species can be caught using a variety of highly productive pieces of gear. Standardization of the gears is essential. The following actions are mandatory in the standardization of the gears (Sparre and Venema 1998):

1) Count fishing effort and catches every year for 15 years.

2) Calculate the CPUE of each effort using the following formula:

3)

$$CPUE = \frac{Catch}{Effort} CPUE = \frac{Catch}{Effort} \qquad (1)$$

Notes: CPUE is the catch (in tons) by effort (in trip).

4) Calculate the Fishing Power Index (FPI), which is the ability of fishing gear to catch fish at each time and in a specific fishing ground where the maximum effort is required.

5) If the value of FPI / RFP (Fishing Power Index / Relative Fishing Power) of the standard fishing gears is equal to 1 (one), the next step is to calculate the value of FPI / RFP of other fishing gears with lower FPI / RFP value. The formula for calculating FPI is as follows:

$$\mathrm{FPI}i = \frac{\mathrm{CPUE}i}{\mathrm{CPUE}s} \mathrm{FPI}i = \frac{\mathrm{CPUE}i}{\mathrm{CPUE}s} \qquad (2)$$

Notes: FPI*i* is the fishing power index of gear *i*, CPUE*i* is the catch divided by the catch of gear *i*, and CPUEs is the catch divided by the effort-to-catch of a standardized gear.

6) Calculate the value of a standardized fishing effort (standard effort) of each fishing gear using the following equation:

$$\mathrm{Fs} = \mathrm{FPI}i \times \mathrm{F}i\mathrm{Fs} = \mathrm{FPI}i \times \mathrm{F}i \qquad (3)$$

Notes: Fs is a standard capture effort, FPI is the fishing power index of the fishing gear *i*, and Fi is the number of effort-to-catch fishing gear *i*.

Sustainability potential analysis of Schaefer's 1954 Model: The catch volume for which the stock will be examined was determined using the surplus production method and the Schaefer 1954 equilibrium model. With the following formula, the form of this equation model has been reduced linearly (Sparre and Venema 1998).

$$\mathrm{U} = \mathrm{a} + \mathrm{b} \times \mathrm{fU} = \mathrm{a} + \mathrm{b} \times \mathrm{f} \qquad (4)$$

Notes: U is catch per unit effort (CPUE), a and b are the coefficients of the Schaefer model, and f is the value of the effort (capture effort).

The effort of maximum sustainable yield (EMSY) was calculated using the following formula:

$$\mathrm{Emsy} = -\frac{\mathrm{a}}{2\mathrm{b}}\mathrm{Emsy} = -\frac{\mathrm{a}}{2\mathrm{b}} \qquad (5)$$

The maximum sustainable yield value (YMSY) was calculated using the following formula:

$$\mathrm{Ymsy} = -\frac{a^2}{4\mathrm{b}}\mathrm{Ymsy} = -\frac{a^2}{4\mathrm{b}} \qquad (6)$$

The value of a is the intercept, and the value of b is the slope of the linear equation. Thus, the CPUE in the maximum sustainable fishing effort (MSY) can be calculated using the formula as follows:

$$\mathrm{Ut} = \frac{Ymsy}{\mathrm{Emsy}}\mathrm{Ut} = \frac{Ymsy}{\mathrm{Emsy}} \qquad (7)$$

Notes: Ut is catch by effort (tons/trips), Y_{msy} is catch by year (tons), and E_{msy} was a catch effort by year (trips).

Estimated Total Allowable Catch (TAC): TAC is set at 80% of the maximum sustainable yield (MSY). The fishing effort will not exceed the maximum sustainable stock level if the TAC MSY is true. The MSY limit calculation necessitates an increase in fishing effort for optimal outcomes. The TAC calculation uses the Schaefer 1954 model with the following equation (Bintoro et al. 2021).

$$\mathrm{TAC} = 0.8 \times \mathrm{Ymsy}\mathrm{TAC} = 0.8 \times \mathrm{Ymsy} \quad (8)$$

The TAE value using the Schaefer 1954 model is estimated according to the following formula.

$$\mathrm{TAE} = \frac{-b \pm \sqrt{b^2-4ac}}{2a}\mathrm{TAE} = \frac{-b \pm \sqrt{b^2-4ac}}{2a} \quad (9)$$

Notes: TAE is the number of trips with the permitted fishing gear and is an intercept in the regression equation, b is a slope in the regression equation, and c is TAC.

Estimation of utilization rate and status: Managing fish stocks is critical for determining the utilization rate and status of fish stocks in bodies of water. This utilization rate can be calculated by comparing actual production to the potential value of the TAC. The utilization rate of fishery resources is equated as follows (Bintoro et al. 2021)

$$\mathrm{URy} = \frac{Ci}{\mathrm{TAC}} \times 100\%\mathrm{URy} = \frac{Ci}{\mathrm{TAC}} \times 100\% \quad (10)$$

Notes: URy represents utilization rate (%), Ci is the average of the total catch (tons), and TAC is the total allowable catch (tons).

There are three baseline categories in determining the utilization status of fish stocks used in this study (Napitupulu et al. 2022):

1. Moderately exploited, when the annual fish catch is less than 80% of the estimated fixed potential.
2. Fully exploited, when the annual fish catch amounts to between 80-100% of the estimated potential.
3. Over-exploited, when the quantity of annual fish catch exceeds the estimated fixed potential (> 100%).

Estimation of sustainable stocks: The potential of sustainable stocks (Be) in an area can be calculated using Walter Hilborn (1976) first and second models. The first model uses a simple differential equation (Bintoro et al. 2021) as follows:

$$\frac{Ut+1}{Ut} - 1 = r - \frac{r}{Kq}\,Ut - qEt$$
$$\frac{Ut+1}{Ut} - 1 = r - \frac{r}{Kq}\,Ut - qEt \quad (11)$$

where a = r, b = $\frac{r\ r}{KqKq}$, and c = q are the estimators of the parameters of the multiple regression coefficient.

A frequent error in the estimation of r and q parameters, which are negative, encouraged Walter Hilborn 1 to modify the first equation into the second equation (Hidayat et al. 2024) as follows:

$$U(t+1) - Ut = r\ x\ Ut - \left[\frac{r}{Kq}\right]Ut^2 - q\ x\ Ut\ x\ Ft$$
$$U(t+1) - Ut = r\ x\ Ut - \left[\frac{r}{Kq}\right]Ut^2 - q\ x\ Ut\ x\ Ft$$

(12) The Walter Hilborn 1976 model can estimate individual parameters of the overproduction function, such as the intrinsic growth rate (r) of fish, which includes length, weight, and gonad maturity, the catch coefficient (q), which is the number of efforts required to catch a resource, and natural environmental impact (k), which is the ability of fish resources to renew themselves (Jauhari 2018). The following is the Walter Hilborn second equation:

$$\mathrm{Bt}+1 = \mathrm{Bt} + r \times \mathrm{Bt}\left(\frac{\mathrm{Bt}}{\mathrm{K}}\right) \times \left(1 - \left(\frac{\mathrm{Bt}}{\mathrm{K}}\right) - \mathrm{Yt}\right.$$
$$\mathrm{Bt}+1 = \mathrm{Bt} + r \times \mathrm{Bt}\left(\frac{\mathrm{Bt}}{\mathrm{K}}\right) \times \left(1 - \left(\frac{\mathrm{Bt}}{\mathrm{K}}\right) - \mathrm{Yt}\right.$$

(13)

The method of the Walter Hilborn 1976 model is as follows:

$$\mathrm{Yt} = q \times \mathrm{X}t \times \mathrm{FtYt} = q \times \mathrm{X}t \times \mathrm{Ft}$$

If $\mathrm{Bt} = \frac{CpUEt}{q}\mathrm{Bt} = \frac{CpUEt}{q}$

This equation yields the value CpUEt = Yt/Ft, the Catch by Unit Effort (CpUE). The production surplus model's basic equation is as follows:

$$\frac{\mathrm{CpUE}+1}{1} = \left(\frac{\mathrm{CpUE}t}{\mathrm{q}}\right) + \left(\frac{\mathrm{rCpUE}t}{\mathrm{q}}\right) \times \left(1 - \frac{\mathrm{CpUE}t}{kq}\right) - \mathrm{CpUE}t \times \mathrm{Ft}$$
$$\frac{\mathrm{CpUE}+1}{1} = \left(\frac{\mathrm{CpUE}t}{\mathrm{q}}\right) + \left(\frac{\mathrm{rCpUE}t}{\mathrm{q}}\right) \times \left(1 - \frac{\mathrm{CpUE}t}{kq}\right) - \mathrm{CpUE}t \times \mathrm{Ft}$$

(14)

Information:

Bt+1: Stocks of biomass in year t + 1

Bt: Stocks of biomass in year t

Yt: Catch in year t

q: Capability of fishing gears

r: Intrinsic growth rate

K: Carrying capacity of the environment

Dynamic System Modeling Based on STELLA 9.0.2: STELLA is software that increases the efficiency of several procedures used to present, simulate, examine, and communicate a desired model. STELLA aims to speed up and improve the model-building process to be more accurate and useful (Malone et al. 2018). The intrinsic growth rate (r), storage capacity (K), and

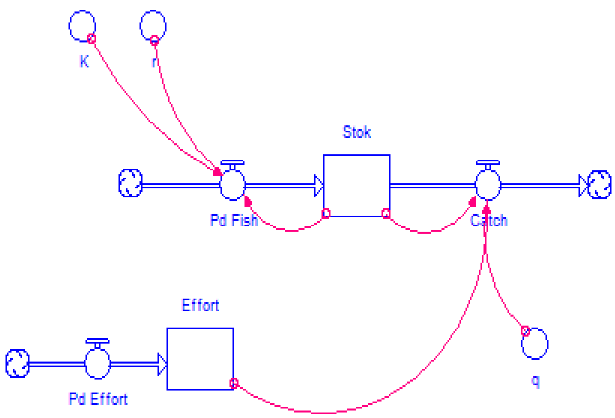

Fig.1. Modeling biomass stocks with STELLA 9.0.2 application.

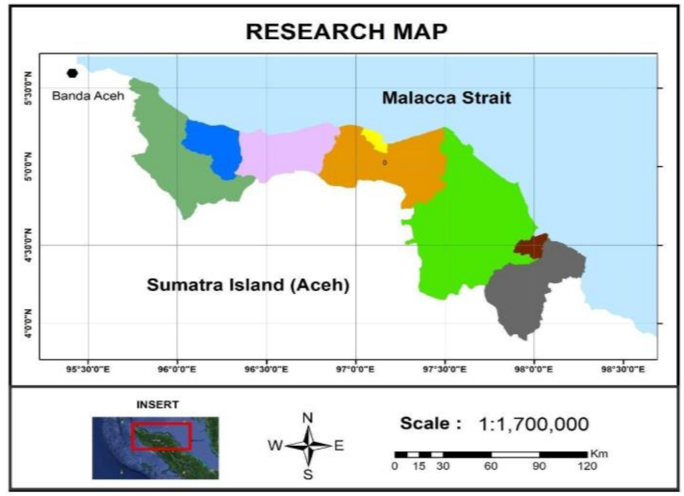

Fig.2. Research map (the eastern waters of Aceh).

biomass uptake's maximum environmental carrying capacity influence the production volume in the STELLA 9.0.2 modeling. The q-value, on the other hand, directly impacts the amount of catch. The level of production value (Pd fish), the number of catches, and the value of the biomass (stock) the previous year all have an impact on the value of the biomass (stock) (Patonai and Fábián 2022) (Fig. 1).

RESULTS

Geographical condition of research location: Aceh province is a special region in Indonesia located in the westernmost province of Indonesia. It is located on Sumatera Island between 2^{0}00'00"–6^{0}04'30" N and 94^{0}58'34"–98^{0}15'03" E. Marine catches are mostly landed and marketed among eight districts/ cities which are North Aceh Regency, East Aceh Regency, Bireun Regency, Aceh Tamiang Regency, Pidie Regency, Pidie Jaya Regency, Langsa City and Lhokseumawe City (Fig. 2).

Catch of shortfin scads (*D. macrosoma*): The most abundant total catch of shortfin scads occurred in the eastern waters of Aceh in 2010 (9401 tons), and the lowest total production occurred in 2016 (126 tons). These findings are derived from statistical data on marine catches between 2006 and 2020. A purse seine is the most effective fishing gear for catching shortfin scads, with the highest catch record of 5222.5 tons in 2010. In contrast, the raft net has failed to catch any fish for a total of 8 years, making it the most ineffective fishing gear (Table 1).

Fishing gear productivity of shortfin scads (*D. macrosoma*): In the eastern waters of Aceh Province, many different types of fishing gear are typically utilized to catch shortfin scads. According to Table 2, seven distinct types of fishing gear are successful. The purse seine is the most used by fishers to establish itself at the top of the list of the most productive fishing gear (Table 2).

Fishing gear production (Table 1) was divided by fishing effort to estimate shortfin scads productivity (Table 2). The data show that in 2014, with a total productivity of 0.246 tons/trip, shortfin scads were caught at a record rate. In contrast, 2016 recorded the lowest productivity recorded at just 0.004 tons per trip (Table 3).

Standardization of fishing ears: Inb2006-2020, purse seine was the most common fishing gear for catching shortfin scads, as measured by the fishing power index (FPI). This result is then used to calculate the standard effort value (Table 4). In 2010, 280172 journeys were made, while in 2017, a total of merely 40545. Shortfin scads sustainability is estimated using the combined effort of these conventional fishing methods (Table 5).

Sustainable potential analysis of Schaefer's 1954 Model: The Schaefer 1954 model was used to estimate the sustainable potential of shortfin scads based on standard catch and effort data. The CPUE was calculated next by dividing catch and effort.

Table 1. Catch of shortfin scads in fishing gears at the eastern waters of Aceh Province (2006–2020) (tons).

Years	Purse seine	Inc. Lampara	Beach seine	Raft net	Set gillnet	Drift gillnet	Encircling gillnet	Total
2006	1893.1	307.3	345.0	79.2	262.4	647.3	254.1	3788.41
2007	2345.3	184.4	112.8	58.0	247.1	836.9	76.7	3861.23
2008	4859.1	471.0	37.2	78.6	583.4	1565.4	452.7	8047.33
2009	4619.6	321.6	82.3	0.0	112.7	1851.2	879.3	7866.55
2010	5222.5	514.7	113.5	71.7	566.5	1988.0	923.7	9400.55
2011	5189.5	270.2	215.7	34.1	820.6	1679.1	780.8	8989.98
2012	5031.8	47.2	300.8	0.0	1025.1	1364.2	634.9	8403.95
2013	2980.0	16.6	114.8	0.0	651.9	617.9	395.8	4776.91
2014	3141.3	31.2	199.0	0.0	437.6	845.9	95.1	4750.15
2015	321.8	0.0	2.2	0.0	102.9	41.4	84.7	553.01
2016	78.7	0.4	3.0	0.0	17.2	16.3	10.4	126.09
2017	86.7	0.3	2.1	0.0	23.1	14.8	16.8	143.72
2018	2066.9	0.1	123.0	40.5	507.9	1030.1	154.6	3923.12
2019	4047.0	0.0	244.0	81.0	992.7	2045.4	292.4	7702.52
2020	3507.0	0.0	109.5	0.0	632.9	1373.3	137.4	5760.14

Table 2. Total fishing effort in the eastern waters of Aceh Province (2006–2020).

Years	Purse seine	Inc. Lampara	Beach seine	Raft net	Set gillnet	Drift gillnet	Encircling gillnet
2006	35280	24024	69720	16368	573744	937032	123876
2007	30336	14256	47664	13608	371616	743736	83268
2008	57012	14256	8856	13608	329376	714432	123588
2009	65808	31416	5832	0	54888	347640	196584
2010	92484	32472	14688	13608	336864	857952	251676
2011	74846	17402	9761	6804	195835	490723	133517
2012	57208	2332	4835	0	54805	123495	15358
2013	50018	1166	3799	0	54662	80381	14342
2014	46824	2332	2965	0	9668	120344	2032
2015	53212	0	4632	0	99656	40417	26652
2016	40146	0	3498	0	75036	30489	20002
2017	27079	0	2364	0	50415	20562	13351
2018	42320	0	2615	5326	59325	126538	20468
2019	57560	0	2865	10652	68235	232514	27584
2020	44265	0	2332	0	30251	155042	17961

Table 3. Productivity of shortfin scads fishing gear in the eastern waters of Aceh Province (2006–2020).

2006	0.054	0.013	0.005	0.005	0.000	0.001	0.002
2007	0.077	0.013	0.002	0.004	0.001	0.001	0.001
2008	0.085	0.033	0.004	0.006	0.002	0.002	0.004
2009	0.070	0.010	0.014	0.000	0.002	0.005	0.004
2010	0.056	0.016	0.008	0.005	0.002	0.002	0.004
2011	0.069	0.016	0.022	0.005	0.004	0.003	0.006
2012	0.088	0.020	0.062	0.000	0.019	0.011	0.041
2013	0.060	0.014	0.030	0.000	0.012	0.008	0.028
2014	0.067	0.013	0.067	0.000	0.045	0.007	0.047
2015	0.006	0.000	0.000	0.000	0.001	0.001	0.003
2016	0.002	0.000	0.001	0.000	0.000	0.001	0.001
2017	0.003	0.000	0.001	0.000	0.000	0.001	0.001
2018	0.049	0.000	0.047	0.008	0.009	0.008	0.008
2019	0.070	0.000	0.085	0.008	0.015	0.009	0.011
2020	0.079	0.000	0.047	0.000	0.021	0.009	0.008

Table 4. Outcomes of FPI calculations for fishing gear used to catch shortfin scads in the eastern waters of Aceh Province.

Fishing Gears	Average (ton/trip)	FPI
Purse seine	0.056	1.00
Inc. Lampara	0.010	0.18
Beach seine	0.026	0.47
Raft net	0.003	0.05
Set gillnet	0.009	0.16
Drift gillnet	0.005	0.08
Encircling gillnet	0.011	0.20

The highest CPUE value of shortfin scads was in 2012 at 0.103 tons/trip, and the lowest was in 2016 at 0.002 tons/trip (Table 6). The results of the sustainable potential analysis using the Schaefer 1954 model resulted in an 80% utilization value of shortfin scads (Table 7). A parabolic curve resulted from the Schaefer 1954 model analysis obtained from the equation $y = af + bf^2$. The curve was obtained from the value of the fishing effort in 2006-2020, which was sorted from minimum to maximum with catches of shortfin scads. The relationship between catches and efforts using the Schaefer 1954 model was stated by the regression line or estimated catch value (Yest). Catches of shortfin scads shortfin scads in the eastern waters of Aceh Province have fluctuations that tend to incline (Fig. 3).

The value estimation of sustainable stock potential and biomass stock in 2017: According to the coefficient of determination (R^2), the value of sustainable biomass stocks of shortfin scads in the eastern waters of Aceh were estimated using the results of the second Walter-Hilborn 1976 model. In addition, r, k, and q values were used in the stock estimation scenario of shortfin scads (Table 8).

Management scenario of shortfin scads (*D. macrosoma*): Three alternatives provide management scenarios of shortfin scads resource in the eastern waters of Aceh. Those alternatives include the execution of an arrest effort, which corresponds to the effort in 2017 (66523 trips/year), the implementation of Emsy (269143 trips/year), and the implementation of total allowable catch (111483 trips/year).

Table 5. The standard effort of shortfin scads in the eastern waters of Aceh Province (2006-2020).

Years	Purse seine	Inc. Lampara	Beach seine	Raft net	Set gillnet	Drift gillnet	Encircling gillnet	Total
2006	35280	4258	33045	790	90865	77195	24751	266183
2007	30336	2527	22591	657	58853	61271	16637	192872
2008	57012	2527	4197	657	52164	58857	24693	200106
2009	65808	5568	2764	0	8693	28639	39278	150750
2010	92484	5755	6962	657	53350	70680	50285	280172
2011	74846	3084	4626	328	31015	40427	26677	181003
2012	57208	413	2291	0	8680	10174	3069	81835
2013	50018	207	1800	0	8657	6622	2866	70169
2014	46824	413	1405	0	1531	9914	406	60494
2015	53212	0	2195	0	15783	3330	5325	79845
2016	40146	0	1658	0	11883	2512	3996	60195
2017	27079	0	1120	0	7984	1694	2668	40545
2018	42320	0	1239	257	9395	10424	4089	67725
2019	57560	0	1358	514	10806	19155	5511	94905
2020	44265	0	1105	0	4791	12773	3589	66523

Table 6. Standard effort, catch, and CpUE of shortfin scads in the eastern waters of Aceh Province.

Years	Effort (trips)	Catch (tons)	CPUE
2006	266183	3788	0.014
2007	192872	3861	0.020
2008	200106	8047	0.040
2009	150750	7867	0.052
2010	280172	9401	0.034
2011	181003	8990	0.050
2012	81835	8404	0.103
2013	70169	4777	0.068
2014	60494	4750	0.079
2015	79845	553	0.007
2016	60195	126	0.002
2017	40545	144	0.004
2018	67725	3923	0.058
2019	94905	7703	0.081
2020	66523	5760	0.087
Average	126221	5206	0.046

According to these three alternatives, the best potential outcomes of biomass stocks are achieved by implementing a fishing effort that is equal to 2020 (Table 9). According to the biomass stocks modeling with an alternative total allowable effort (TAE) of 106247 trips/year, the remaining biomass stocks are projected to increase until 2025 (Fig. 4).

Table 7. Sustainability potential analysis of shortfin scads (*D. macrosoma*) in the eastern waters of Aceh Province.

Variables	Shortfin Scads (*D. macrosoma*)
R square	0.10
Intercept	0.06
X Variable 1	-1.13E-07
Emsy	269143
Ymsy	8173
Umsy	0.03
TAC	6539
TAE	111483
Utilization rate	80%
Significance f	0.03
A	0.05

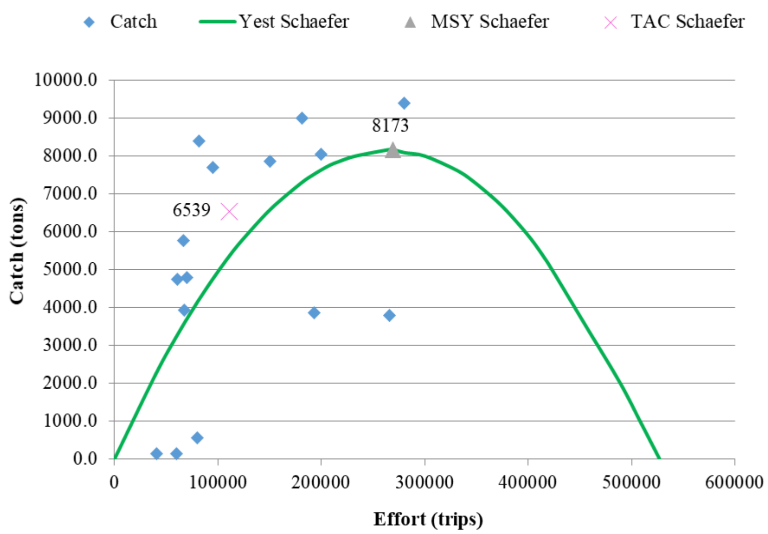

Fig.3. Relationship curve between effort and catch of shortfin scads (*D. macrosoma*) in the east waters of Aceh Province.

Table 8. The analysis results of shortfin scads by Walter-Hilborn 1976 model.

Variable	Walter-Hilborn 1	Walter-Hilborn 2
R square	31%	42%
r	3.41	0.58
K	76098	55194
q	-1.8E-06	3.8E-06
Be	38049	27597

Table 9. The estimation biomass stock of shortfin scads used allowable fishing effort.

Years	Biomass (tons)	Be (tons)	Biomass Stocks (Biomass/Be)
2020	11886	27597	43%
2030	29929	27597	108%

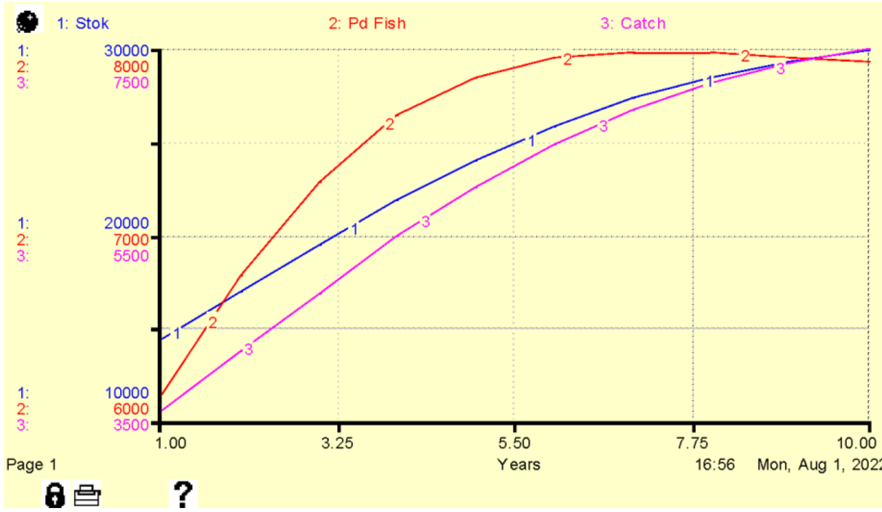

Fig.4. The modeling biomass stocks of shortfin scads (*D. macrosoma*) with fishing effort alternative equal 2020.

DISCUSSION

Catch shortfin scads (*D. macrosoma*): According to statistics of marine catches in the eastern waters of Aceh, shortfin scads appear to be the dominant catch of small pelagic fish landed in all districts/cities. Henceforth, relevant and up-to-date information about its stock and management is vital to maintaining sustainable shortfin-scads fishery resources and improving the fishing community's economy in eastern and northern Aceh. Aceh province is located on the northern end of Sumatra Island, sandwiched between two distinct marine ecosystems - the Malacca Strait and the Indian Ocean. The province has eight districts/cities along the Malacca Strait and ten districts/cities along the Indian Ocean. This location provides a favorable situation for the province to enhance its fisheries industry, primarily around catch fishing. The province can also create backward linkages by establishing industries such as manufacturing fishing boats and equipment (Chaliluddin et al. 2021).

Productivity of the shortfin scads (*D. macrosoma*) fishing gears: Based on interviews with the marine and fisheries office staff of Aceh Province, seven types of fishing gear are employed to catch shortfin scads in the eastern waters of Aceh. Among these, purse seine is the most productive fishing gear due to its high effectiveness in capturing the largest quantity of fish. The outcome of the productivity calculation will be utilized to assess the efficacy of each fishing gear beforehand. Productivity refers to the total catch of each fishing gear within a specific time frame, either monthly or annually. Productivity calculation requires the availability of catch data and the number of units or trips made per gear (Aimon et al. 2018). To calculate productivity, the catch of each fishing gear is divided by the number of annual fishing gear trips (Ihsan et al. 2022)

Standardization of fishing gears: Based on the Fishing Power Index (FPI) calculation for fishing gear from 2006-2020, the standard fishing gear is the one with the highest productivity and an FPI value of 1. The purse seine is the most productive fishing gear with an FPI of 1, making it the standard gear that can yield more fish than other gears. The FPI value is utilized to determine the standard effort by multiplying the FPI value of each fishing gear with the number of trips for each gear. In areas where different fishing gear are used, one can be chosen as the standard gear, with another gear standardized against it. The standard fishing gear must have the FPI of 1 (Wiyono et al. 2018), and the standard effort can be calculated by multiplying the FPI values by the analyzed fishing gear's effort (Wujdi et al. 2021).

Sustainable potential analysis of Schaefer's 1954 Model: Shortfin scads in the eastern waters of Aceh Province are considered a fully exploited marine resource due to their high value and high utilization rate. Caught of shortfin scads has fluctuated over time due to the instability of the average annual fishing effort, which is not aligned with the optimal fishing effort. If the amount of effort put into fishing is close to its maximum, the total fish caught will drop. The estimated catch is negative, or there will be no catch even if the fishing effort exceeds the maximum level.

Estimating fish potential aims to provide information about the abundance of stocks in specific waters, recommendations on the best fishing effort, and the total allowable catch (TAC). Due to the lack of information regarding the utilization rate of shortfin scads, the fisheries laws are not fully applied in the Malacca Strait. Given its high economic potential, shortfin scads (*Decapterus spp.*), a small pelagic fishery resource, played a significant role in the fishery sector of the Malacca Strait (Feng et al. 2024).

The value estimation of sustainable stock potential and biomass stock in 2030: Biomass of shortfin scads tends to show declining fluctuations between 2006 and 2020. The shortfin scads catch rates are higher than fish growth and production rates. As a result, fish production at sea could not keep up with the rate of exploitation. Possible causes of the declining productivity include unsupervised fishing operations. High catch effort may result in overexploitation of fish stocks, which would be detrimental to the ecosystem. When efforts are intensified to reach the maximum level, the volume of sustainable production will also increase. Conversely, if the level of effort surpasses the maximum capacity, the number of efforts will rise while the sustainable production volume declines. Additionally, the lack of a suitable aquatic habitat and a lack of food contribute to the decline in production, which causes fish to migrate to other areas (Tamario et al. 2019).

Management scenario of shortfin scads (*D. macrosoma*): The state of the resources and the high production levels must be considered in alternative fisheries resource management. Because of this, there has been an increase in the biomass stocks, which can be attributed to the fact that the level of effort put into catching fish has not exceeded the maximum allowed. On the other hand, the depletion of biomass stocks occurs due to excessive effort that surpasses the maximum limit. Moreover, the value of catch or growth declines over time due to the carrying capacity value (k), which denotes the maximum capacity of the environment to absorb biomass, the high intrinsic growth rate (r), and the availability of biomass food in the environment.

When fish stocks in unexploited biomass are left undisturbed, they tend to increase in size to a certain extent and reach their maximum weight of natural equilibrium once they have attained their full potential. It is assumed that the biotic and abiotic factors influencing the expansion of fish stocks will remain consistent. The growth rate of fish stocks is influenced by three factors: natural mortality, an increase in total individuals (individuals that are ready to grow into large stocks), and rejuvenation (small fish entering the stock), with the weight of fish biomass reduced by natural mortality and predation. As per Schaefer's model of surplus production, a large population is required to generate net increases in biomass (Cook et al. 2021). In summary, the *D. macrosoma* population in the eastern waterways of Aceh Province has reached its maximum potential for exploitation. If the allocation of effort is equal to the situation in 2020, the sustainable management scenario of shortfin scads for the next decade (2021-2030) will result in the highest biomass stocks in 2030.

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مقاله کامل

مدیریت صیادی پایدار در استان آچه: تجزیه و تحلیل پتانسیل ماهی‌های اسکاد باله‌کوتاه (*Decapterus macrosoma*) در آب‌های ساحلی شرقی آچه، مطالعه موردی

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چکیده: ماهی‌های اسکاد باله‌کوتاه (*Decapterus macrosoma*) مرسوم‌ترین ماهی‌های مورد استفاده در آبراه‌های شرقی آچه هستند. این گونه به‌طور قابل‌توجهی در توسعه اقتصادی شیلات آچه نقش دارند و میزان بقای آن را به یک شرط اجتناب‌ناپذیر تبدیل می‌کنند. این مطالعه بین نوامبر ۲۰۲۱ و ژانویه ۲۰۲۲ انجام شد. این توصیف کیفی برای کسب اطلاعات در مورد وضعیت ماهی‌ها در دریاهای شرقی آچه و چگونگی مدیریت پایدار آنها طراحی شده است. داده‌ها از طریق مصاحبه‌های فشرده و مطالعات پیشین به‌دست آمده است. دفتر دریایی و شیلات استان آچه آمار صید ماهیان آچه را از سال ۲۰۰۶ تا ۲۰۲۰ که ضروری است، ارائه می‌دهد. تولید مازاد و مدل‌سازی سیستم پویا براساس برنامه STELLA 9.0.2 تجزیه‌وتحلیل شدند. نتایج نشان داد که مقدار وضعیت بهره‌برداری (URy) از ماهی‌های اسکاد باله‌کوتاه ۸۰٪ بوده است. سناریوی مدیریت پایدار شیلات *D. macrosoma* برای دهه بعدی (۲۰۳۱-۲۰۲۱) پیش‌بینی می‌کند که ذخایر زیست‌توده در سال ۲۰۳۰ با تخصیص تلاش‌های ماهیگیری مشابه تلاش ۲۰۲۰، که ۱۰۸ درصد بود، به‌حداکثر خود خواهد رسید. بنابراین، منبع شیلاتی *D. macrosoma* به‌طور کامل مورد بهره‌برداری قرار گرفته است. اجرای تلاش‌های ماهیگیری، معادل تلاش ۲۰۲۰، پایداری ذخایر زیست‌توده را تا سال ۲۰۳۰ تحت تأثیر قرار می‌دهد.

کلمات‌کلیدی: زیست‌توده، تلاش ماهیگیری، ماهی اسکاد باله‌کوتاه، پایداری، نرخ بهره‌برداری