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Population parameters and sustainable status of *lompa* fish *Thryssa baelama* (Forsskal, 1775) manage through *sasi* approach at Haruku Village

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Abstract

The harvesting season of *lompa* fish, *Thryssa baelama*, through *sasi*, indigenous knowledge in resources management, in Haruku Village has become a socio-cultural event that attracts many people. The *sasi* of *lompa* fish has been conducted for hundreds of years. Information on the bioecology aspect of *lompa* fish is limited, while this information is crucial for *lompa* fish sustainability through the *sasi* approach. This study aimed to investigate some population parameters of *lompa* fish, its sustainability status, and proposed a sustainable management strategy for the *lompa* fishery of Haruku Village. Fish population parameter covers length-weight relationship, growth pattern, size distribution, sex ratio, and the body condition index. The sustainability status was assessed following the Rapfish approach. Fisheries management strategy was performed using a conceptual model framework based on Driver Pressure State Impact Response. The research shows that the total length varies between 9.2–14.3 cm. A high relationship was found between total length and weight, and the growth pattern was an allometric negative. There was a difference in sex ratio between males and females, with females dominant. The body condition index varies over time, probably due to reproductive status. The overall sustainability status was at fair condition (61.60%), with the ecological domain having the highest sustainable status (71.07%) and considered sustain. In comparison, the technological domain had the lowest sustainability status (52.58%) and was considered fair sustain. There were seven management strategies proposed for sustainable management for the *lompa* fishery.

Keywords: Management strategy, Conceptual model, Driver pressure state impact response, *Sasi*, Indigenous knowledge

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Introduction

For the people of Haruku Village, baelama anchovy, locally called *ikan lompa*, has a solid cultural value (Hasan, 2017; Marjanto, 2015). The Haruku community protects this fish through *sasi* management, which according to the account to the Haruku Village people, started approximately in the year 1600s (Hasan, 2017; Karepisina et al., 2017) and took place to the present time (Harkes & Novaczek, 2002; Hasan, 2017; Karepisina et al., 2017; Persada et al., 2018). *Sasi* is a traditional indigenous knowledge in managing natural resources (Adhuri, 2004; Batiran & Salim, 2020; Kissya, 1995; Lellotery et al., 2007; Nikijuluw, 1995). The *sasi* approach is based on a broad set of rules and regulations based on customary law (adat) that govern the use of natural resources (Harkes, 1999; Harkes & Novaczek, 2002; Soselisa, 2019).

The baelama anchovy is considered a marine species, pelagic, and presumably schooling at depths of 0–50 m. This fish is commonly found inshore in bays, lagoons, harbors, mangrove pools, and estuaries, thus apparently tolerating lowered salinities. It contributes to general clupeoid catches but no specific fishery. This fish is used in some areas in the Pacific ocean as baitfish (Froese & Pauly, 2021; Shomura, 1977). The *lompa* fish is found to migrate into the river Laerisa Kayeli of Haruku Village regularly (Marjanto, 2015).

There are four types of *sasi* conducted in Haruku Village: marine *sasi*, river *sasi*, forest *sasi*, domestic *sasi*, where *lompa* fish *sasi* belong to marine *sasi* (Hasan, 2017; Karepisina et al., 2017). In the case of *sasi lompa*, close *sasi* usually lasts for one year or sometimes more. During the close *sasi*, *kewang*, the institution responsible for the management of *sasi*, will control and monitor the *sasi* area to ensure the effectiveness of *sasi*. Anybody caught trespassing the *sasi* will be penalized according to the *sasi* regulation. The *kewang* will decide when the *sasi* is lifted and announced to the community. The open *sasi* starts in the morning with traditional ceremonies performed the night before led by the *kewang* chief. Before the open *sasi* time, the river mouth was blocked with a net to protect the *lompa* fish from migrating out from the river. Haruku community with other visitors enter the river during open *sasi* and harvest the *lompa* fish with conventional fishing gear. The open *sasi* lasts for one day, the next day, the *sasi* is started again until the following year.

The study on the bioecology aspect of baelama anchovy is considered limited. Some of which are studies on productivity change in the *sasi* area in Haruku (Talakua, 2011), the ecology and management strategy of *lompa* fish, and Soselisa (2019) which mainly observes the open *sasi* and monitor the activity during open *sasi*. This short information shows that study on bioecology of *lompa* fish is scarce. Since limited bioecology information regarding the *lompa* fish, this study's objective was to investigate the population parameter and sustainability status of *lompa* fish and propose a sustainable management strategy through the ecosystem approach to fisheries based on the finding.

Materials and Methods

Study site and data collection

The study was conducted from 12 October 2020 to 14 December 2020 at the village of Haruku (Fig. 1). For baelama anchovy (*lompa*) fish population parameters, the sampling was done at two weeks intervals using a nylon cast net with a mesh size of 0.5 inches and a radius range of approximately 3.5 m. All the *lompa* fish caught were measured (total length –TL) to the nearest 1 mm, and body weight (W) to the nearest 1 g. All the *lompa* fish obtained were then sexed and separated into male and female. Male and female *lompa* fish obtained were then sub-sampled to examine ovary development through ovarian color change development and classified regarding the universal scale of five stages according to Effendie (1997) and Holden & Raitt (1974).

Length size distribution and length-weight relationship

For length size distribution, the fish size (total length) was sorted from smallest length size to largest length size and counted for the frequency of each class interval, and then displayed graphically. The length-weight relationship for *lompa* fish was calculated following Benedict et al. (2009); Froese (2006) with the formula of $W = aL^b$ where W is the wet weight (g), and L is the total length of the fish (cm), a is the constant or intercept, and b is the length exponent or slope. The $W = aL^b$ formula is a parabolic equation and then transformed into the linear form using a logarithmic approach: $lnW = lna + blnL$. The a and b values were then estimated using least-square regression following Zar (2014). The exponent b value obtained from the length-weight relationship was then applied to determine the fish growth patterns. The fish is assumed to have negative allometric growth when the b values were lower than 3, positive allometric growth if the b values were greater than 3, and isometric form of growth when $b = 3$ (Benedict et al., 2009). The *t-student* test was used to test whether the b is $= 3$ or b is $\neq 3$ (Pauly, 1984).

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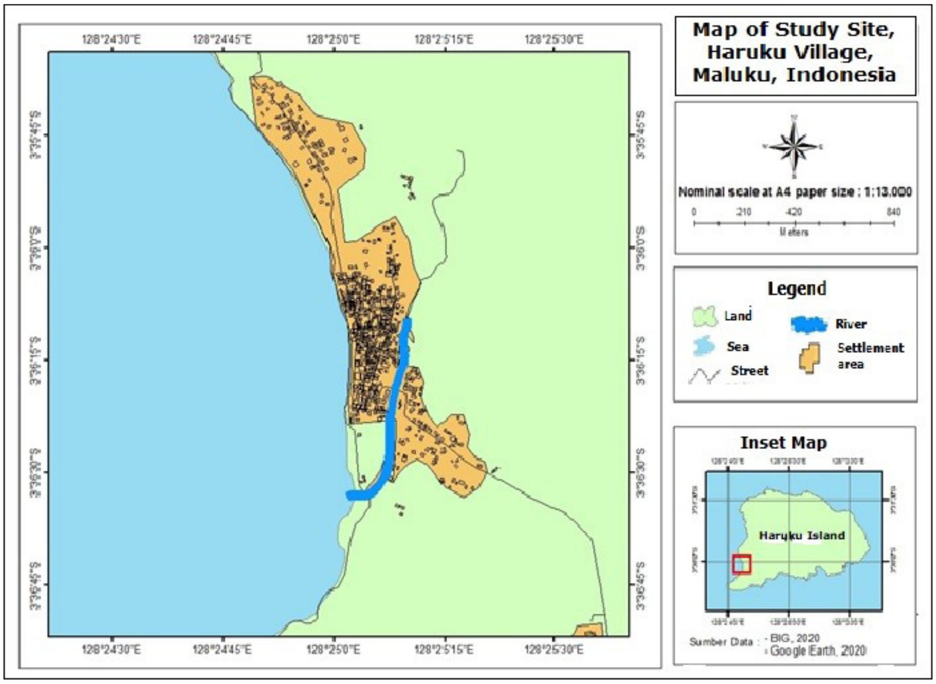

Fig. 1. Map of the study site, Haruku Village.

Sex ratio, condition factor, and maturity stage

The sex ratio was calculated by comparing males to females caught based on the sampling period and was tested for similarity using *the Chi-Square* test (Steel & Torrie, 1980; Zar, 2014). The condition factor (*Kn*) of *lompa* fish was predicted using the formula proposed by Froese (2006) and King (2007) with the following formula: CF = Ŵ/W where: Ŵ - observed mean weight; W predicted mean weight = aL^b. The maturity stage analysis was conducted in relation to the open *sasi* period. For the *lompa* fish maturity stage, I was considered immature, II and III as maturing, IV as mature, and V as spent (Holden & Raitt, 1974).

Sustainability status and management strategy

For sustainability status of *lompa*, the Rapid Appraisal for Fisheries (RAPFISH), a Multi-Dimensional Scaling Analysis approach was used according to Pitcher (1999); Kavanagh & Pitcher (2004). Four domains were used for sustainability analysis covering ecological, socio-economic, technological, and institutional. The attribute for the four domains was based on Rapfish attributes (Pitcher et al., 2013) with some modifications. The attribute's name for each dimension, the number of the attribute for each dimension, and the score of each attribute are listed in Table 1.

All attributes used were then scored on the 3 to 4 Likert scale basis starting from good to bad level (Pitcher & Prekshot, 2001; Pitcher et al., 2013). Scoring guidelines are based on the Rapfish analysis for fish sustainability status (Pitcher & Preikshot, 2001; Pitcher et al., 2013). Data for sustainability analysis was obtained from a questionnaire distributed to 50 respondents comprising the local people, local village government, and *kewang* staff. All data obtained were then tabulated, and the median was used to calculate the score obtained from all respondents' answered. The sustainability analysis was done through the RAPFISH software (Kavanagh & Pitcher, 2004), running under Microsoft Excel software version 10. The sustainability status will then be expressed on a scale from 0% (bad) to 100% (good) (Kavanagh & Pitcher, 2004; Pitcher & Preikshot, 2001). The sustainability classification was based on small-scale fishery's ecosystem approach to fishery management (Pitcher et al., 2009).

The Driver-Pressure-State-Impact-Response (DPSIR) conceptual model framework was used to propose a sustainable management plan. This approach has been indicated as a helpful approach in analyzing human and natural systems (Gari et al., 2015; Martin et al., 2018; Mazumder et al., 2016). Since there

Table 1. Sustainable dimension and each of their attribute, score, and criteria used in sustainability status of *lompa* fish

Dimension	Attribute	Scoring	Good	Bad
Ecology	1. Exploitation status	4, 3, 2, 1, 0	4	0
	2. Species change	3, 2, 1, 0	3	0
	3. Fish size	3, 2, 1, 0	3	0
	4. Discard	4, 3, 2, 1, 0	4	0
	5. Range of colapse	4, 3, 2, 1, 0	4	0
	6. Migratory range	4, 3, 2, 1, 0	4	0
	7. Habitat/ecosystem	3, 2, 1, 0	3	0
	8. Gonad maturity	3, 2, 1, 0	3	0
	9. Bycatch	3, 2, 1, 0	3	0
Socio-economy	1. Limited entry	4, 3, 2, 1, 0	4	0
	2. Poverty level	4, 3, 2, 1, 0	4	0
	3. Change in benefit	3, 2, 1, 0	3	0
	4. Other source of income	3, 2, 1, 0	3	0
	5. Market system	3, 2, 1, 0	4	0
	6. Equity in benefit	3, 2, 1, 0	3	0
	7. Social net working	3, 2, 1, 0	3	0
	8. Local indigenoues knowledge	3, 2, 1, 0	3	0
	9. Time of decision	3, 2, 1, 0	3	0
	10. Change in fisheries	3, 2, 1, 0	3	0
	11. Conflict status	3, 2, 1, 0	3	0
Technology	1. Change in fishing capacity	0, 1, 2, 3, 4	0	4
	2. Change in boat size	3, 2, 1, 0	3	0
	3. Change in trip length	4, 3, 2, 1, 0	4	0
	4. Gear selectivity	3, 2, 1, 0	3	0
	5. Gear side effect	3, 2, 1, 0	3	0
	6. Aggregating device	2, 1, 0	2	0
	7. Fish handling	3, 2, 1, 0	3	0
	8. Change in fisshing effort	3, 2, 1, 0	3	0
Institutional	1. Governance quality quality	4, 3, 2, 1, 0	4	0
	2. Legality	3, 2, 1, 0	3	0
	3. Regulation	4, 3, 2, 1, 0	4	0
	4. Reporting	3, 2, 1, 0	3	0
	5. Surveilance/Monitoring	3, 2, 1, 0	3	0
	6. Protection	3, 2, 1, 0	3	0
	7. Village by law	3, 2, 1, 0	3	0
	8. Management plan	3, 2, 1, 0	3	0

Source: Pitcher & Preikshot (2001) ; Pitcher et al. (2013).

were 36 variables used in sustainability analysis, to simplify the connectivity interaction among variables in the conceptual model framework, only one variable from each dimension with the highest sensitivity was used to construct the model (Natan et al., 2021). The conceptual model produced was then used as a management strategy for the sustainability of *lompa* fish.

The driver (D) component in the DPSIR conceptual model is the socio-cultural event in the harvesting season (open *sasi*) of *lompa* fish, while the pressure (P) components are the number of people participating in the harvesting season and karoro

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and mosquito net fishing gear used in the harvesting. The highest sensitivity variable towards sustainability of *lompa* fishery from leverage analysis of ecology, social-economy, technology, and institutional dimension was then used as state (S) variable of DPSIR model framework. The impact (I) component is the condition of *lompa* fish in the *sasi* system. The impact can be in fish population decline, decrease in economic benefit, social conflict, etc. (Balzan et al., 2019; Kell & Luckhurst, 2018; Mazumder et al., 2016). The response (R) component is the attempt proposed to be implemented by the *kewang*, the institution responsible for managing the *sasi*, in the form of a program or strategy to overcome the impact. The response can be at the level of D, P, S, and I. for the management instruments (Balzan et al., 2019; Díaz et al., 2018).

The relationship between all variables forming causal-effect diagrams in the DPSIR conceptual model was split up into the different elements within the DPSIR framework. Each variable was then analyzed in detail based on finding and literature review to establish a causal-effect relationship within the DPSIR (Elliott et al., 2017; Mazumder et al., 2016; Zador et al., 2017). Every management action which will be taken in association with *lompa* fishery was identified and broken down into different parts, introducing them in the conceptual framework and connecting as responses to the driving forces, pressures, states, or impacts (Elliott et al., 2017; Zador et al., 2017).

Results

During the research period, the total numbers of *lompa* fish sampled amounted to 508 individuals, with a minimum total length size of 9.2 cm and maximum size of 13.4 cm, and an average size of 11.2 cm (SD ± 0.78). Fig. 2 shows the frequency distribution of *lompa* fish sampled during the study period. This figure shows that *lompa* fish with a total length between 11.0–11.4 cm was the dominant size (27.47%).

The relationships between the length and weight of female and male *lompa* fish are shown in Fig. 3. This figure shows that the relationship was quite strong, with the correlation coefficient *r* equal to 0.9475 for females and 0.9462 for males. This relationship was tested with the analysis of variance, and Table 2 shows the result. The $F_{calc.}$ is > than $F_{critc.\ (\alpha 2:0.05)}$ signifying a highly significant correlation. The increase in length at some point will increase the weight of the fish. No information was available for *T. baelama*. The only available information considered close to baelama anchovy was from *T. dussumieri* from the coast of Ratnagiri, India, with a positive relationship (Pawase et al., 2020).

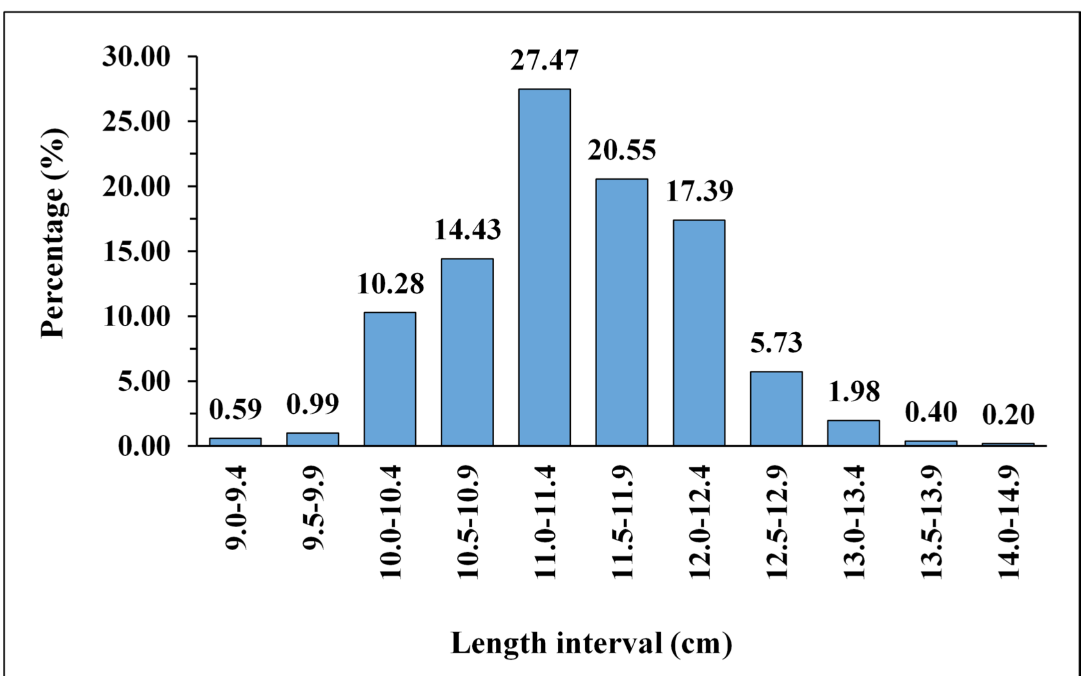

Fig. 2. Length size frequency distribution of *loma* fish.

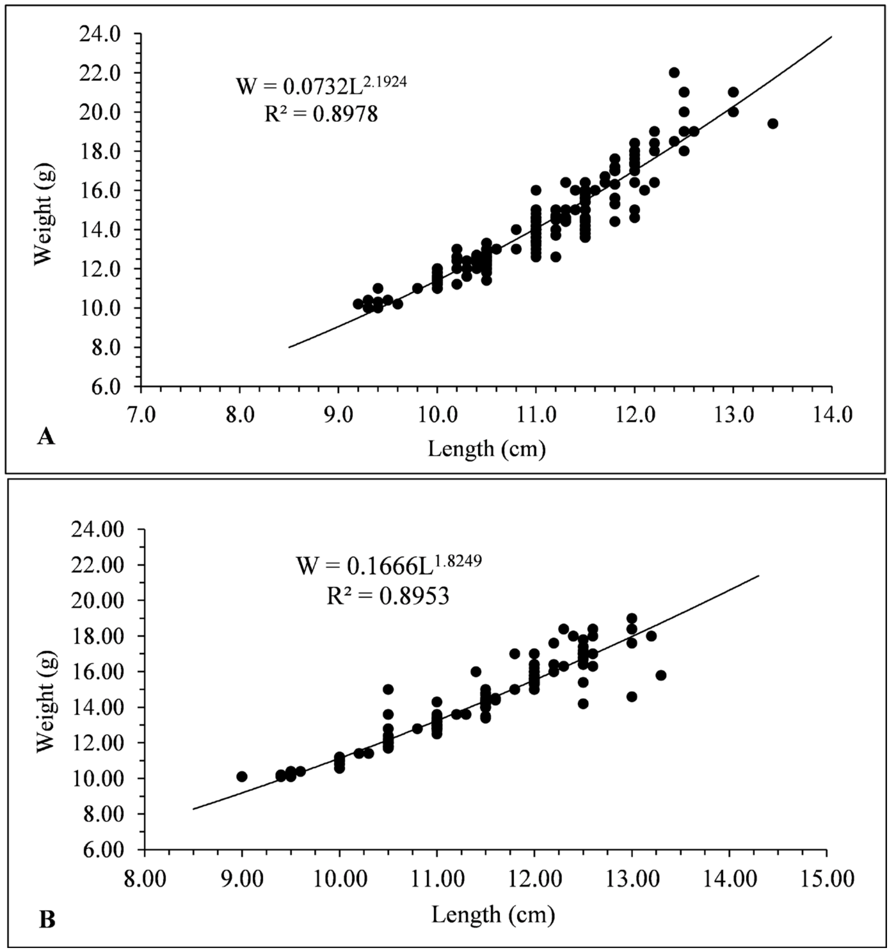

Fig. 3. Relationship between total length and weight of female (A) and male (B) baelama anchovy (*lompa*).

Table 2. Anova for regression between total length and weight of female and male of anchovy baelama (*lompa*)

Female	*df*	*SS*	*MS*	$F_{calc.}$	*Significance F*	$F_{crit.}$
Regression	1	1,223.0462	1,223.0462	2,288.35	1.2326E-137	6.726
Residual	283	151.2542	0.534467			
Total	284	1,374.3004				
Male	*df*	*SS*	*MS*	$F_{calc.}$	*Significance F*	$F_{crit.}$
Regression	1	774.7687	774.7687	2,177.6090	2.0887E-116	5.093
Residual	221	78.6293	0.3558			
Total	222	853.3980				

The length-weight relationship was also performed on a monthly basis, and the result is shown in Table 3. This table shows that the length-weight relationship based on a monthly basis has a high correlation coefficient range from 0.8816 to 0.9757, and between sex was 0.9475 for females and 0.9462 for males, where the *b* value range from 1.8249 to 2.2183. The *t-student* test for growth pattern analysis shows that all the $t_{calc.}$ value was > t_{crit}(α2:0.05) (Table 3), explaining that $b \neq 3$ indicates that the baelama anchovy had an allometric growth and, more precisely, a negative allometric growth pattern meaning the length

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Table 3. The length-weight relationship of baelama anchovy (*lompa*) based on monthly sampling and sexes

Sampling period	Ind. number	$W = aL^b$	R^2	r	*p*-value	$t_{calc.}$	$t_{crit.}$
Total	508	$W = 0.14471L^{1.8969}$	0.8002	0.8957	3.3E-180	20.754	1.649
October	158	$W = 0.1113L^{1.9887}$	0.9520	0.9757	7.6 E-102	22.854	1.976
November	168	$W = 0.1893L^{1.7913}$	0.7772	0.8816	1.23E-680	12.708	1.975
December	182	$W = 0.0684L^{2.2183}$	0.8392	0.9161	3.1E-720	8.247	1.973
Female	285	$W = 0.0732L^{2.1924}$	0.8978	0.9475	1.2E-137	12.429	1.968
Male	223	$W = 0.1666L^{1.8249}$	0.8953	0.9462	2.1E-116	23.239	1.971

growth is a tendency lower than weight growth.

A total number of 508 baelama anchovy individuals were sampled during the studied period between October to December 2020. The sample comprises 223 males and 285 females. Table 3 shows the sex ratio of baelama anchovy from Haruku Village. From the analysis, it was found that *X2calc.* = 11.7894 > *X2critc*(a2):0.05 = 11.070 meaning there is a difference between male to female. Fig. 4. displays the pooled relative condition factor (*Kn*) of baelama anchovy based on a fortnight interval from October to December 2020. This figure shows a change in relative condition factor over time, and varied between 0.99986–1.00519.

Table 4. shows the number and percentage of occurrence of female *lompa* fish at a length interval of 5mm. This table shows that the *lompa* fish was found at different maturity stages at various length sizes. It was also found that the *lompa* fish with length intervals between 11.5–11.9 had a high number of fishes at stage IV (mature) and V (spent) (38.14%). No *lompa* fish at a length size interval of 9.0 to 9.4 cm was found in any stage of maturity.

From the ecological sustainability status of *lompa* using 9 attributes, the Rapfish analysis shows that the ecological sustainability of *lompa* fish was 71.07% from the 100% sustainable scale (Fig. 5A). This status is considered to sustain according to the ecosystem approach to fisheries management (Pitcher et al., 2009). The Monte Carlo scatter plot (Fig. 5B) shows the Rapfish ordination's stability shown by the plot's clumpiness. The stress value from Rapfish analysis was 0.1418, which is < 0.25, indicating the high goodness of fit of the test (Clarke et al., 2014). From all attributes used, the most sensitive attribute to the sustainability of *lompa* fish was the range of collapse (*Root Mean Square* = 4.34).

The range of collapse attribute assesses if there is evidence of geographic range reduction of fish population in the past ten years (Pitcher et al., 2013). There is no information regarding this attribute available yet. However, an increase in the number of people harvesting the *lompa* fish and the use of karoro and mosquito nets could lead to unsustainable conditions. High fishing intensity has been considered a cause of fisheries depletion or collapse of global fish stock (Hilborn et al., 2020; Hutchings & Reynolds, 2004). Other distinguishing features apart from fishing intensity, habitat destruction, pollution, climate change, and other environmental factors also affect the stock abundance and fisheries depletion (Camara & Santero-Sánchez, 2019; Hauge et al., 2009). The square correlation (R^2) was 0.9507, meaning 95.07% of the nine attributes used in the ecology domain have explained the sustainability of *lompa* fish. Therefore, other distinguishing features have less impact on the *lompa* fishery sustainability.

The Rapfish analysis was performed to other remaining sustainable dimensions (socio-economy, technical, and institutional), and the results are summarised in Table 5. From this table, it was clear that only the ecological dimension was considered to sustain; the other three dimensions were considered fair sustain according to the ecosystem approach to fisheries management (Pitcher et al., 2009). The sensitive attribute can either foster or inhibit the biological sustainability of the resources (Pitcher et al., 2013). Of 9 attributes in the ecological domain, the migratory range has high sensitivity (RMS = 4.34). This attribute assesses any evidence of geographic reduction of the fish population in 10 past years Pitcher et al., 2013). The majority of the respondents responded that almost no sign of geographic reduction of *lompa* fish. Economically the *lompa* fish is not a target fish in fisheries. The only report that this fish is used as baitfish in skipjack fishery. Another source of income as the most sensitive attribute (RMS = 5.75) is more likely related to the income loss by local Haruku Village if the *sasi* event. The most sensitive attributes were gear selectivity (RMS = 11.37) and gear side effect (RMS = 11.08). A more detailed explanation is described in the discussion section.

The *sasi* institution in many villages has in decline or even

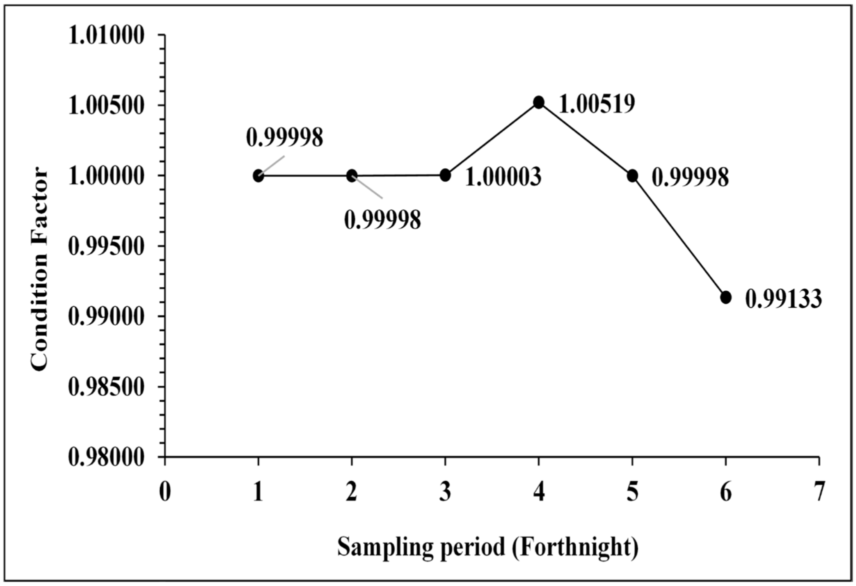

Fig. 4. The condition factor (*Kn*) of baelama anchovy (*lompa*) during study period.

Table 4. Sex ratio of baelama anchovy (*lompa*) from Haruku Village

Sampling period	Male	Female	M/F	x^2
1	38	53	0.7358:1	1.5119
2	34	45	0.8333:1	1.2947
3	37	51	0.7451:1	3.3575
4	35	53	0.6731:1	1.1879
5	32	55	0.6923:1	4.1940
6	40	35	1.1429:1	0.2433
Total	223	285	0.7825:1	11.7894

disappeared. Of 63 villages studied, 19 villages have permanent loss of the *sasi*, and others are weak in the implementation (Harkes & Novaczek, 2002; Novaczek et al., 2001). In many coastal villages in Maluku, the community still depends on fish resources. Ineffective fish resources management has pushed the locals to fish outside their traditional fishing ground. A conflict sometimes arises between traditional fishers with commercial and even industrial ones. The need for effective conservation and management is more urgent than ever. Therefore, *sasi*, as an indigenous knowledge in the management of natural resources, needs to be preserved.

The conceptual model framework developed through the DPSIR approach was used to develop the sustainable management plan of *lompa* fishery from Haruku Village. The driver component (D) is the harvesting season (open *sasi*) of *lompa* fish. As a social and cultural event, the *sasi* has attracted many people not from the local community of Haruku but also neighbouring villages and even people from Ambon city. There is no information about the number of people who participate but visually, quite a sizable number of people. The pressure (P) in this fishery comes from mosquito and karoro net used to harvest the *lompa* fish. At the same time, the state (S) component is the system of the *lompa* fishery (ecology, socio-economy, technical, institutional) affected by the pressure.

Fisheries sustainability is a multidimensional human endeavour with socio-economic, technological, and institutional implications. Therefore, the sustainable management of the fisheries should incorporate an analysis of the full social-economy, ecological, technical, and institutional before proposing a sustainable management strategy (Ernst et al., 2013; Weber et al., 2019). The causal-loop diagram approach based on DPSIR was used to develop a sustainable management strategy for the *lompa* fishery. Fig. 6 shows the conceptual model framework based on the DPSIR approach incorporating ecological, socio-economy, technical, and institutional dimensions established for the sustainable management strategy of the *lompa* fishery.

In the last 10–15 years, the number of people participating in the *lompa* fish harvesting season, locally called *buka sasi*, has increased significantly (personal communication). This event has become a socio-cultural festival that attracts many people (Soselisa, 2019). As the number of people participating in the

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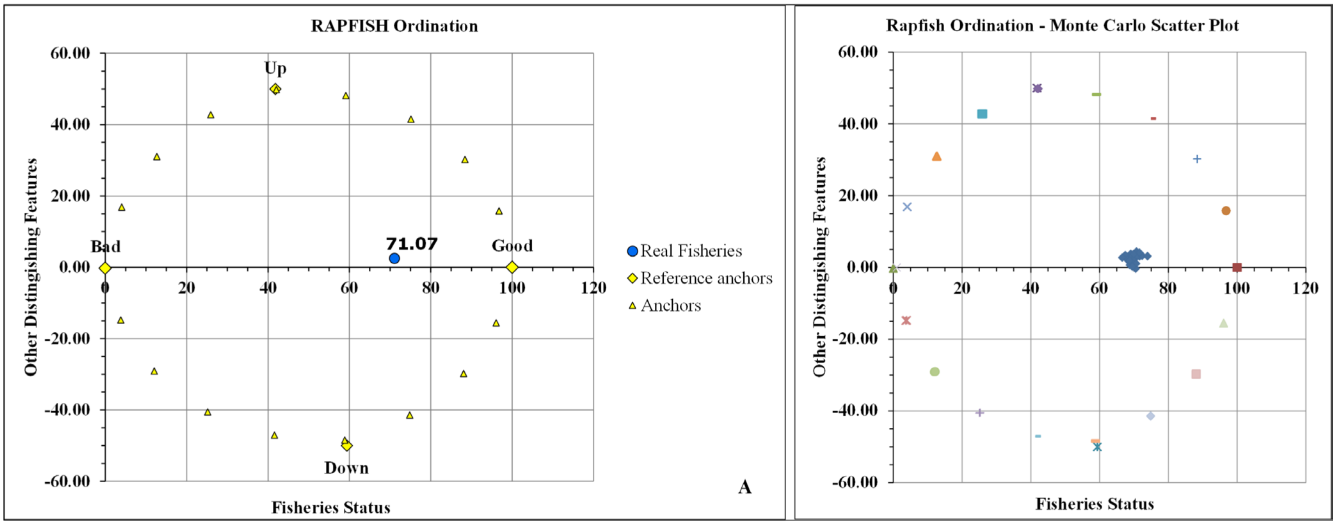

Fig. 5. Rapfish ordination (A) and Monte Carlo Scatter Plot (B) analysis of ecological sustainability status of baelama anchovy (*lompa*) fishery at Haruku Village.

Table 5. Percent of female *lompa* fish with their maturity stage and approximate size group

Size group (mm)	Individu number		Maturity stage									
			Female					Male				
	F	M	I	II	III	IV	V	I	II	III	IV	V
9.0–9.4	0	0	-	-	-	-	-	-	-	-	-	-
9.5–9.9	2	2	-	2	-	-	-	1	1	-	-	-
10.0–10.4	2	1	-	1	1	-	-	-	1	-	-	-
10.5–10.9	3	2	1	-	1	1	-	-	1	1	-	-
11.0–11.4	20	7	8	3	8	1	-	-	2	4	1	-
11.5–11.9	39	13	-	-	5	12	22		1	1	3	8
12.0–12.4	10	7	2	-	-	-	8	1	1	-	2	3
12.5–12.9	4	4	1	-	-	-	3	1	1		1	1
13.0–13.4	1	1		-	-	-	1	-	-	-	1	-
Total	81	37	12	6	15	14	34	3	8	6	8	12
Percentage			10.17	5.08	12.71	11.86	28.81	2.54	6.78	5.08	6.78	10.17

harvesting season (open *sasi*) increases, the number of fishing units will also increase. The use of karoro and mosquito net, which is unselective fishing gear, will undoubtedly threaten *lompa* fish sustainability. Fishing can cause many disruptions in the ecosystem, such as fish population decline, change in the physical structure of the environment, reduction of a top predator, size sex, etc. (Breen et al., 2016; Camara & Santero-Sánchez, 2019; Porobic et al., 2019).

Non-selective fishing gears such as trawl nets and purse seines catch 74% of total juvenile and young fish without giving a chance to spawn at least once (Dineshbabu et al., 2012; Remesan et al., 2009). Nets made of very small netting will capture all sizes of fishes, a significant share of which are liable to be discarded. Such practices will affect the biodiversity of all the associated water bodies. The karoro net and mosquito net will certainly catch small *lompa* fish and produce bycatch/discard fish (Table 6).

Interviewed with local people of Haruku Village revealed that as long as they experience, almost no data collecting concerning the number of *lompa* fish harvested during the open

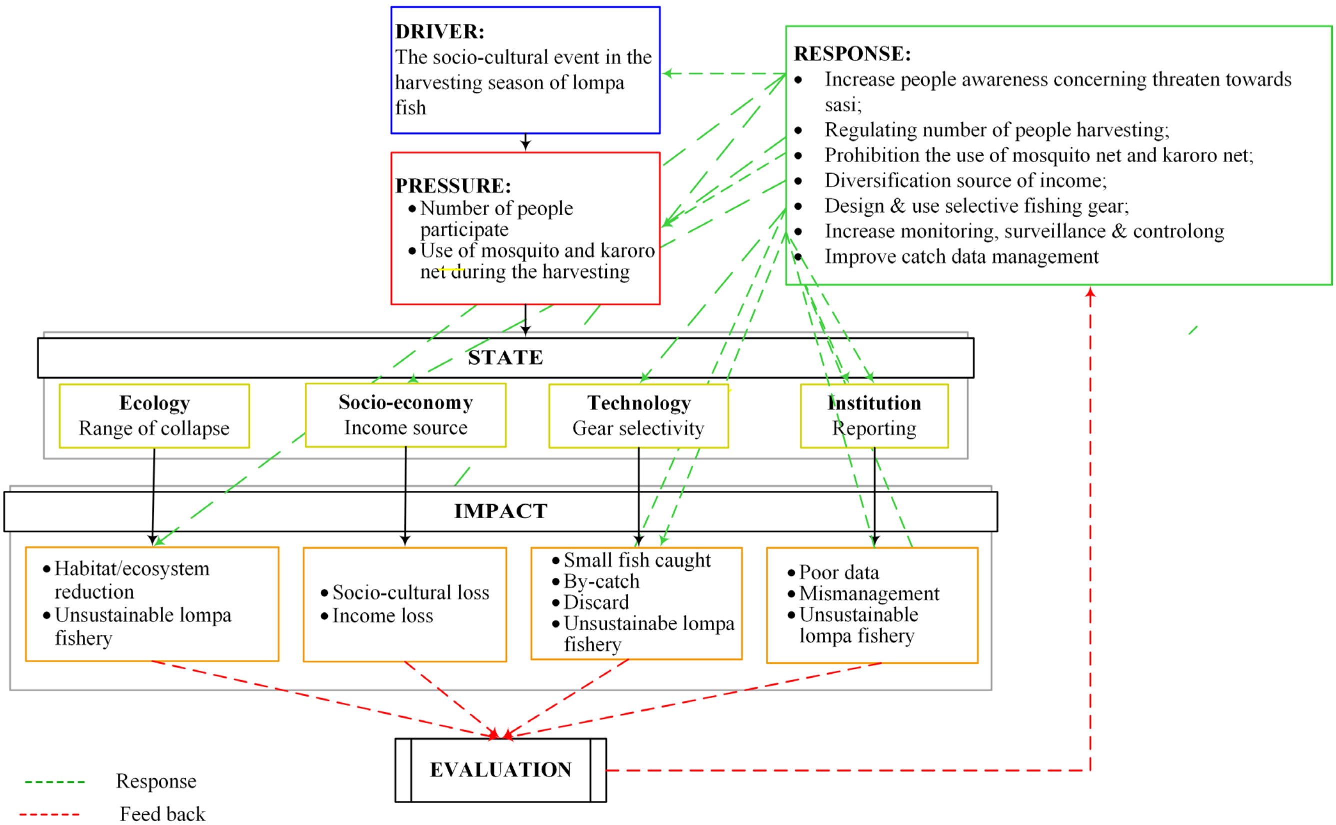

Fig. 6. The DPSIR conceptual model framework showing sustaianble management strategy for *lompa* fishery. DPSIR, driver-pressure-state-*impact*-response.

Table 6. Multidimensional sustainablility status of *lompa* fishery

Dimension	Sustainble status (%)	Stress	Square correlation	Sensitive attribute	RMS	Remark
Ecology	71.07	0.1418	0.9507	Range of collapse	4.34	Sustain
Socio-economy	69.64	0.1327	0.9527	Source of income	5.75	Fair sustain
Technology	52.58	0.1364	0.9403	Gear selectivity	11.37	Fair sustain
Institutional	53.11	0.1465	0.9463	Reporting	4.39	Fair sustain
Mean	61.60	0.1394	0.9475			Fair sustain

sasi. Field observation during the open *sasi* event in 2018 also confirmed no data collecting on the number of fish caught. This indicates a poor data condition on the management of *lompa* fish through the *sasi* mechanism. Failure to assess the status and productivity of fish stocks can increase the risk of stock collapse and lead to loss of social and economic benefits associated with sustainable yield. Limitations in data quantity and quality can lead to model misspecification and erroneous data treatments, potentially causing important changes in model outputs and subsequent mismanagement implications (Apel et al., 2013; Bradley et al., 2019).

Discussion

From Fishbase information (Froese & Pauly, 2021), it was found that the maximum total length of baelama anchovy (*T. baelama*) was 16.0 cm. However, from this study, the maximum length was 14.3 cm which is less than the maximum total length

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recorded from Fishbase. A workshop by NOAA on tuna baitfish shows that this fish is used as a baitfish and has a size between 7.5–15.5 cm total length (Shomura, 1977), while Marichamy (1970) on *T. baelama* from Andaman sea found the total length between 5.7–13.2 cm. These findings show a variation in length size, with the maximum total length size recorded being 14.3 cm. The differences could be due to the study site, which relates to environmental conditions, food availability, season (Jisr et al., 2018; Mazumder et al., 2016).

The pool correlation coefficient from the length-weight relationship of the *lompa* fish found from this study was 0.89577 with the coefficient of determination R^2 = 0.8022 ($p < 0.05$). The correlation coefficient of females and males was 0.9475 and 0.9462, and the coefficient of determination R^2 was 0.8978 and 0.8953, respectively. Other studies on the length-weight relationship found the correlation coefficient value between 0.9080 to 0.9751 of some fish species in tropical rainforest river in South-east Nigeria (Adaka et al., 2015); 0.9731 in *Leiognathus equulus* from Teluk Pabean of Western Java (Aditriawan & Runtuboy, 2017); 0.9925 to 0.9930 in *Selena dorsalis* from the continental shelf of Coast of Ivory of West Africa (Arra et al., 2018); between 0.2258 to 0.9476 in 9 fish species inhabiting the marine area of Eastern Mediterranean, Tripoly-Lebanon (Jisr et al., 2018). All these findings explain differences in the length-weight relationship, which might be due to species differences, geographical area, the number of samples used in the analysis (Adaka et al., 2015; Jisr et al., 2018).

From the length-weight relationship of *lompa* fish on a monthly basis, it was found that the *b* value varies between months, with the value range between 1.6093–1.9024. From 3,929 length-weight relationships analyzed, the *b* value range from 2.5 to 3.5, and only a few species outside this range (Froese, 2006). A study on the anchovy *Ciolia dussumieri* Valenciennes of the north coast of India found the *b* value for males was 2.74 and for females was 1.47 (Mahapatra et al., 2015). In the study on the length-weight relationship of fish inhabiting the marine area of the Eastern Mediterranean city of Tripoly, the *b* value found varies between 0.823 to 3.016 for 11 fish species (Jisr et al., 2018). The alteration in *b* value primarily arises from a change in fish weight affected by environmental factors like temperature, food supply, spawning conditions, and other factors like sex, age, fishing time and area, and fishing vessels (Bagenal & Tesch, 1978; Nair et al., 2021).

The study by Marichamy (1970) found that the sex ratio of *T. baelama* was dominated by a female. In the same study, the analysis by different size groups shows that the males dominating the female in size less than 90 mm, but on larger sizes of more than 100 mm, were dominated by a female. The overall sex ratio of *T. dussumieri* from the Ratnagiri coast, India, was 1:1.14, with females dominating the males (Pawase et al., 2020). Another study on *T. mystax* found the sex ratio of 1.26:1 with females dominating the male (Hoda, 1976), 1:0.93 of the same species (Kende et al., 2020; Pawase et al., 2020). A study on the sex ratio on African moonfish, *Selene dorsalis*, from West Africa shows the sex ratio of males to females was 1:0.97 (Arra et al., 2018). All these studies show a variation in sex ratio based on size, location, and sampling period. In fishes, sex is determined by genetics, the environment, or an interaction of both. Temperature is among the most important environmental factors affecting sex determination (Geffroy & Wedekind, 2020).

A fluctuation in relative condition factor was also found in *T. baelama* from the Andaman sea. The relative condition index fluctuated over time from 1968 to1970, with the value ranger from 0.800 to 1.100 (Marichamy, 1970). A study on other baelama fish (*T. dussumieri*) also shows a fluctuation of relative condition factor over time, with the value ranging from 0.900 to 1.07 (Pawase et al., 2020). The relative condition factor of ponyfish *L. equulus* from Pabean Bay of West Java, Indonesia, from April 2016 to March 2017 vary between 0.81 to 1.34 (Aditriawan & Runtuboy, 2017). Another study on the condition factor of African moonfish *S. dorsalis* found that combined sexes range from 1.45 to 2.39. For males range from 1.45–2.25, and for females from 1.51–2.39 (Arra et al., 2018). The condition factor (index) for nine species from the Eastern Mediterranean City of Tripoli-Lebanon ranges from 0.960 to 1.029 (Jisr et al., 2018). The condition factor state the well-being for the fish where fish with condition factor < 1 is considered not in good condition, while the condition factor is >1, meaning the fish is in good condition (Adaka et al., 2015; Arra et al., 2018; Jisr et al., 2018). This study and some other studies mentioned show a fluctuation in the condition factor of the fish. Many factors affect the condition factor of fish, including reproductive cycles, availability of food, as well as habitat, and environmental factors (De Giosa et al., 2014; Jisr et al., 2018).

Among population parameters of fish like length-weight relationship, sex ratio, gonadosomatic index, and length at first maturity, the maturity of the fish is one of the vital parameters in fishery management. The information derived from the aspect of fish maturity is valuable for estimating spawning potential and recruitment prediction of a fish stock, which is essential in managing the fish (Arra et al., 2018; Nair et al., 2021). Unfortunately, the information of population parameters of *lompa* fish is very scarce. This study is most probably the first study on the population parameters of the *lompa* fish. For the maturity index, Marichamy (1970) has the information on the maturity stage of *T. baelama* and revealed that the baelama anchovy with the size above 125 mm was found in either mature or spent. It was also presumed that the length at the first maturity of this species was 107 mm. A study on the female Hamilton's anchovy (*T. hamiltonii*, Gray, 1835) found that length at first maturity was 171.05 mm (Kamal et al., 2020). Another study on *T. mystax* of the Tuticorin coast, east coast of India, found that the first maturity was 122 mm for females (Nallu Chinnappan & Jeyabaskaran, 1991).

All the information on the maturity of the anchovy fish, in general, explains that the maturity, in particular length at first maturity, was varied between species, area, sex, and time. This study displays that many *lompa* individuals were found in the mature stage and spent. The harvesting season (open *sasi*) of *lompa* fish is usually scheduled in October but was postponed since the environmental condition was unsuitable (Kissya, personal communication). If the harvesting season could have been done, it could not be a proper time since much *lompa* fish is in their spawning season. More research should be conducted covering another period of time to get a more explicit description of the maturity index of the fish and spawning peak seasons, also the size at first maturity.

The sustainability status of fish stock is vital in fisheries management. On the global scale, the state of marine fishery resources, based on FAO's long-term monitoring of assessed marine fish stocks, has continued to decline. The proportion of fish stocks within biologically sustainable levels decreased from 90% in 1974 to 65.8% in 2017 (FAO, 2020). Information on the sustainability of *lompa* fish is very limited; the only study on this fish status was reported by Soselisa (2019) that the fish is under threat, while Talakua (2011) had reported a change in habitat productivity of the *lompa* fish ecosystem. The study conducted by Soselisa (2019) is mainly based on observing fishing gear used during open *sasi* and some interviews with people participating in the open *sasi* event. The conclusion was based on the assumption of the side effect of unselective fishing gear (karoro net and mosquito net) used in harvesting *lompa* fish. In comparison, this study covers four dimensions in sustainability analysis comprise 36 attributes. The most sensitive attribute for each domain is different (Table 5). However, the highest one is gear selectivity, indicating the effect of using a mosquito net and karoro net in harvesting the *lompa* fish has high negative sensitivity towards sustainability of *lompa* fish.

The present study shows that the overall sustainability of *lompa* fish was 61.60% from 100% sustainable scale and was considered fair sustain according to the ecosystem-based to fisheries management for small-scale fishery (Pitcher et al., 2009). Factors contributing to this sustainability were a fishing gear side effect and reporting, especially the number of fish caught during harvesting season. A study on the catch rate of two-banded seabream *Diplodus vulgaris* in the Mediterranean shows a negative impact on catch rate due to environmental change and fishing pressure (Baptista et al., 2016). Other factors that could affect the sustainability status of fisheries are the use of non-selective fishing gear, fishing pressure, IUU fishing, good governance and, the conflict between fisher for the same species and fishing ground (Dunbar et al., 2021; FAO, 2020). In the case of the *lompa* fishery, the fishing pressure shown by the increase in the number of people participating and fishing gear selectivity is the main factor threatening *lompa* fish sustainability.

The main driver (D) in the *lompa* fishery is the harvesting season, or locally called "*buka sasi*." This event is conducted once a year and recently attracted many people from Haruku Village and neighbouring villages and Ambon. There is no exact information on the number of people who participate directly in harvesting the fish, but quite sizeable. Another issue in the harvesting season is unfriendly fishing gear, namely mosquito net and karoro net (mini beach seine with small mesh size) used during harvesting season. These two main issues, the number of people participating in the harvesting season and fishing gear used, then used to construct the conceptual model with DPSIR to propose the management strategy for sustainable *lompa* fish (Fig. 6).

Based on the causal loop diagram displayed on DPSIR conceptual model framework (Fig. 6), the management strategies taken are to increase the awareness of the community regarding a threat faced by *lompa* fish during the *lompa* fish harvesting event, regulating the number of people participate in the harvesting event, prohibiting the use of mosquito net and karoro net, diversification of source of income of the local community, design and use of friendly fishing gear, increase monitoring, surveillance, controlling, and improve catch management data. Regulating the number of people and the gear used is essential for sustainable management fishery (Angel et al., 2019; Nilsson et al., 2018). The introduction of new selective fishing gear,

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monitoring, controlling, and surveillance which provide essential data (Bahri et al., 2021; McDonald et al., 2017), will be used to evaluate the *lompa* fishery condition and develop an adaptive management strategy.

Since the Haruku community does not entirely depend on the *lompa* fish due to their other income sources, this condition should be maintained or even diversified. The income of the Haruku community and the social and culture of the community should be monitored and evaluated regularly. A response should be taken in the response when there is a sign of alteration in these components. It is recognized that fisheries sustainability is a multidimensional human endeavor with socio-economic, technological, ethical, or institutional implications. Social responsibility by the community (stakeholder) participation also increases the sustainability of the resources (Camara & Santero-Sánchez, 2019; Halls et al., 2017).

For the technology and institutional domains, the sustainable management strategy derived for *lompa* fish sustainable management cover prohibits the use of mosquito net and karoro net, introduces selective fishing gear, and establishes regular monitoring, surveillance, and control (MSC). The information obtained from the MSC will then be used to evaluate the *lompa* fishery status and then establish a management strategy if required. Monitoring, controlling, and surveillance is an aspect of oceans and fisheries management often overlooked, but in reality, it is key to the successful implementation of any planning strategy. These components are an integral and vital component for implementing fisheries management plans (Cremers et al., 2020; Flewwelling, 2001).

Conclusion

This study shows that most *lompa* fish length intervals are between 10.0–11.4 cm. A high positive relationship was found between total length and weight with a growth pattern of negative allometric. There is a difference between the sex ratio of males to females, with females dominating the *lompa* fish composition. There was a variation in body condition index over time and variation that could be due to reproductive status. There was also a variation in maturity index, with mature and spent stage having the highest percentage. The average sustainability status of *lompa* fish managed through the *sasi* approach was fair sustained. The ecological domain had the highest sustainable status, while the technological domain had the lowest. According to the DPSIR conceptual model framework, seven strategies were proposed for sustainable management for the *lompa* fishery. More research should be conducted to cover spawning season and length and body size composition to predict length at first maturity.

Competing interests
No potential conflict of interest relevant to this article was reported.

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Availability of data and materials
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate
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