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RESEARCH ARTICLE

Assessment of the Implementation of the Adjustment of the Sardines Closed Fishing Season in East Sulu Sea, Basilan Strait and Sibuguey Bay (BAC 255 s. 2014)

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ABSTRACT

Sardinella lemuru constitutes 77% of the total landed catch in Fishery Management Area -4 from 2015 to 2024. This assessment of stock status has utilized length-based data, applying statistical models including the FAO-ICLARM Stock Assessment Tool (FiSAT), Length-Based Method and Gear (LBAR), and Froese Indicators to estimate the Exploitation Ratio (E), Length at First Maturity (L_{m50}), Fishing Pressure (F/M), and Catch Selectivity. FiSAT estimated E between 0.52–0.69 (average: 0.60), while LBAR ranged from 0.41–0.79. The highest exploitation ratio was recorded from 2020 to 2023, with a significant decline in 2024 (E = 0.56), down from 0.69 in 2023 ($p < 0.001$). This decline is attributed to the adjustment of the closed season implementation, from December 1–March 1 to November 15–February 15, in accordance with the peak seasonal spawning period of the stocks, which runs from October to February, with the highest peak in November, as reported by the results of NSAP 9 Reproductive Biology. The ratio of Fishing Mortality to Natural Mortality remained high across models: 1.48–2.19 in FiSAT and 1.60–3.74 in LBAR, with the highest values from 2020 to 2023 reflecting the increasing trend in fishing pressure; however, a significant decrease was noted in 2024 ($p < 0.05$). FiSAT estimated L_{c50} between 14.1–15.72 cm (2015–2023), with a significant improvement in 2024 to L_c = 15.01 ($p = 6.25 \times 10\text{-}05$), while LBAR provided a much wider range. Froese indicated that mature catches ranged from 36.89% to 63.91% over a 10-year time frame, with a highly significant mature catch in 2024 ($p < 0.001$). This stock assessment reveals high exploitation and fishing pressure on *S. lemuru*. However, recent policy adjustments suggest a positive impact on the stock, as seen in the significant decline in the E ratio in 2024.

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1. INTRODUCTION

The FMA-4 encompasses the waters of the Southeast and Northeast Sulu Sea, upon which the fishery industry of Zamboanga Peninsula is dependent. According to the Food and Fertilizer Technology Center (FFTC) in 2017, the FMA-4 is responsible for about 77% of sardine production in the Philippines from 2015 to 2024, signifying the area's richness in fishery resources. The total landed catch in FMA 4 and is generally caught by purse seines (Ignacio 2025). The location and extent of FMA-4 are shown in Figure 1.

Sardinella lemuru is a small pelagic fish that forms schools and exhibits strong migratory behavior, found mostly in tropical waters. Previously, *S. lemuru* was mistakenly identified as *S. longiceps* in the Philippines (Philippine Statistics Authority 2019; Williams and Willette 2011). Locally, Bali sardinella is also known as "tuloy." Although some fisheries reports,

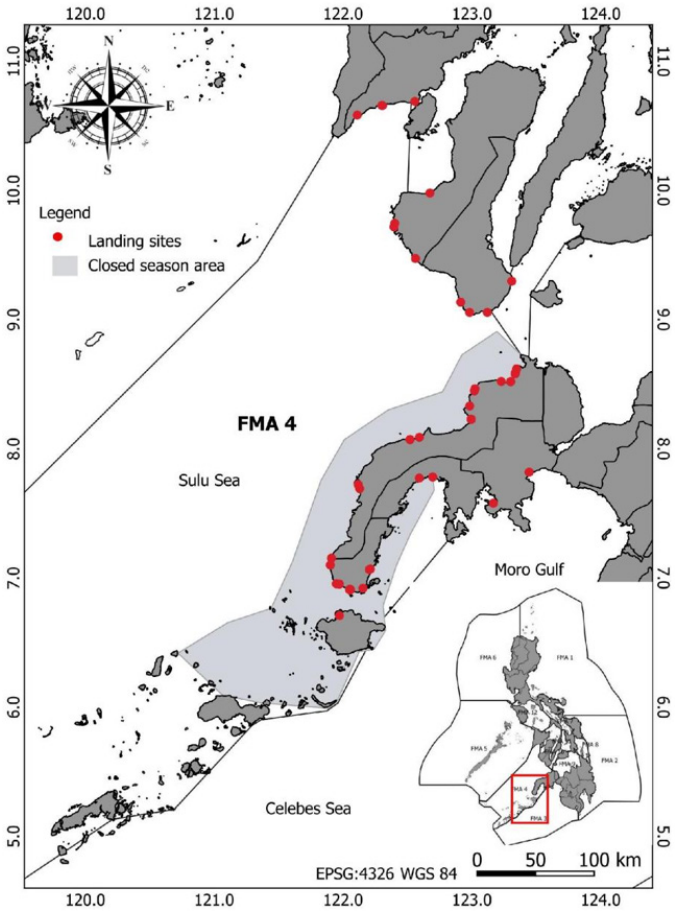

Figure 1. Map of Fishery Management Area 4.

such as the National Stock Assessment Program (NSAP) atlas, distinguish sardine species in specific areas, catch data are often combined and reported under the broader category of "small pelagic fishes," which can obscure species-specific trends (Barut et al. 2017; Santos et al. 2017). However, this term is used broadly to refer to multiple sardine species, not just *S. lemuru*. In fact, "tamban" may refer to at least eight different sardine species, including several under the genus Sardinella such as but not limited to *S. fimbriata, S. gibbosa, S. hualiensis* and Amblygaster species (e.g., *A. clupeoides, A. leiogaster, A. sirm*) (Froese and Pauly 2021; Williams and Willette 2011).

The stock structure of *Sardinella lemuru* in the Philippines remains uncertain, highlighting the need for additional research to support stock-specific management (Sustainable Fisheries Partnership 2021). To address concerns on long-term sustainability of sardine resources, the first conservation initiative was implemented in 2011 through Joint Administrative Order (JAO) No. 1, s. 2011, which established a three-year closed fishing season and designated conservation areas to protect sardine stocks which was originally scheduled from December 1 – March 1 and was peer reviewed by scientists from BFAR, academe and industry experts (NFARMC 2023). Following this implementation, the Bureau of Fisheries and Aquatic Resources Administrative Circular (BAC) 255, series of 2014, was formulated to align with the objectives of the JAO, aiming to protect *S. lemuru* during its peak spawning months and to promote resource sustainability.

The positive impact of fishing regulations on the sardine fishing and processing industries in the Zamboanga Peninsula in recent years bodes well for the conservation of fish species across the Philippines. Numerous major fishing grounds border the country, many of which are considered ecologically threatened, making closed fishing seasons an increasingly expected strategy (Narvaez 2017).

Despite twelve years of implementation, recent assessments indicate persistently high exploitation rates, suggesting continued pressure on sardine stocks. In 2023, the implementation period of the closed season was adjusted to November 15 to February 15 to better coincide with the peak spawning season and enhance protection during this critical reproductive phase, based on the results of NSAP 9 Reproductive Biology. This study investigates the biological impact of the adjustment of the period of implementation of the sardine closed fishing season in East Sulu Sea, Basilan Strait, and Sibuguey Bay on the status of sardine stocks in FMA-4.

This study aims to generate a comprehensive stock assessment of S. lemuru in Fisheries Management Area (FMA) 4. Specifically, it seeks to: (1) Determine the stock status of S. lemuru by estimating fishing mortality, natural mortality, and exploitation ratios using multiple length-based analytical models (FiSAT, LBAR, Froese Sustainability Indicators, and LBSPR); (2) Evaluate the selectivity patterns and spawning potential of the stock by analyzing length at first capture, proportion of mature individuals, and spawning potential ratio (SPR) in relation to established biological reference points (Target, Trigger, and Limit); and (3)Assess the effectiveness of management interventions, particularly the implementation of the adjusted closed fishing season,

in promoting stock recovery and sustaining sardine resources in FMA-4 by evaluating changes (or trends) in the sardine's biological performance indicators across the 10-year period.

The scope of this study covers the sardine fishery within Fisheries Management Area 4 (FMA-4), encompassing the waters of the Southeast and Northeast Sulu Sea, which are recognized as the primary fishing grounds for the sardine industry in Zamboanga Peninsula. The analysis focuses on *S. lemuru*, the dominant species, which accounts for approximately 77% of total landings in the region. Data analyzed span 10 years from 2015 to 2024 and were collected by the National Stock Assessment Program (NSAP) for Regions 9, 6, and 7 through systematic landing-site monitoring.

The study is limited to monitored catches and biological data from all fishing gears, primarily from commercial purse seine operations, which account for the bulk of sardine landings in the area. It does not extend to other sardine species or to small pelagic fishes that may also contribute to local fisheries. Furthermore, while the assessment provides insights into exploitation status, growth, and recruitment patterns, it does not incorporate broader environmental factors such as oceanographic variability, plankton productivity, or climate change, which may also influence sardine population dynamics.

Sardines represent both an economic driver and a food security staple in the Philippines, particularly in Region IX, where *S. lemuru* forms the backbone of the fishery industry. This study is significant because it provides updated, evidence-based insights into the sustainability of sardine stocks in FMA-4. By applying multiple length-based stock assessment models, the research enhances the robustness and reliability of its findings, reducing the limitations of relying on a single analytical approach.

The outcomes of this study will directly inform fisheries management policies and provide a scientific basis for refining existing conservation measures such as the closed fishing season. Moreover, the findings will benefit policymakers, industry stakeholders, and local fishing communities by ensuring that sardine exploitation aligns with long-term ecological sustainability and economic viability. In the academic and scientific context, this work contributes to the growing body of literature on Philippine sardine fisheries, offering data and insights that may guide future research and management frameworks across other FMAs.

2. METHODOLOGY

The current study adapted the standardized protocols of the National Stock Assessment Program (NSAP) under the National Fisheries Research and Development Institute (NFRDI) and implemented them in collaboration with the Bureau of Fisheries and Aquatic Resources (BFAR) Regional Field Offices (Santos et al. 2017). NSAP enumerators collected daily catch and effort data from designated landing sites in FMA-4, focusing on both the commercial and municipal fishing sectors.

2.1 Study site

The study was conducted at selected fish landing sites in FMA 4, South and East Sulu Sea. Figure 1 shows the Map of the selected fish landing sites.

2.2 Data collection

Daily catch and effort data were collected from major landing sites within FMA-4. Biological sampling involved measuring total lengths of *S. lemuru* to the nearest centimeter. Sampling focused on commercial purse-seine and municipal landings.

2.3 Analytical Models.

FiSAT II was employed to estimate growth parameters, total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E).

LBAR was used to assess exploitation rates and fishing mortality through probability distribution analysis of fish lengths.

Froese Indicator**s** were applied to determine the proportion of mature and immature individuals in the catch, using published maturity benchmarks (L_{m50}).

LBSPR was utilized to calculate the spawning potential ratio (SPR), an indicator of reproductive capacity relative to fishing pressure.

Reference Points**.** Stock status indicators (E, F/M, average length, proportion mature, SPR) were evaluated against Target, Trigger, and Limit reference points established for *S. lemuru*. These biological reference points provided the decision framework for interpreting whether the stock was sustainably exploited, approaching overfished status, or already overfished.

Data Analysis. Trends in fishing mortality, selectivity, maturity composition, spawning biomass, and CPUE were analyzed across the 2015–2024 dataset. Results were interpreted in relation to the adjusted closed fishing season implemented in 2023 to evaluate its potential impact on sardine stock recovery.

3. RESULTS

Table 1 shows the top species landed from 2015-2024. The graph shows that the majority of the landed species in Region 9 is *S. lemuru,* which makes up 77% of the entire catch, followed by *Decapterus macrosoma* (7%), *Selar crumenophthalmus* (4%), *Rastrelliger kanagurta* (2%), and *Amblygaster sirm* (2%), while other species make up about 8%.

Table 1. Top species landed in 2015-2024.

Species	Catch (mt)	Percentage (%)
Sardinella lemuru	1,821,795.65	77
Decapterus macrosoma	175,184.36	7
Selar crumenophthalmus	90,407.17	4
Rastrelliger kanagurta	47,999.72	2
Amblygaster sirm	44,864.15	2
Other species	190,362.15	8
Total	**2,370,613.20**	**100**

Figure 2 illustrates the monitored volume of landed catches (MT) in Region IX annually. As observed, the year 2020 had the highest monitored landed catches, totaling an estimated 300,000 MT, compared to the previous and following years, with a positive recovery in 2024 due to changes to the closed fishing season schedule in 2023.

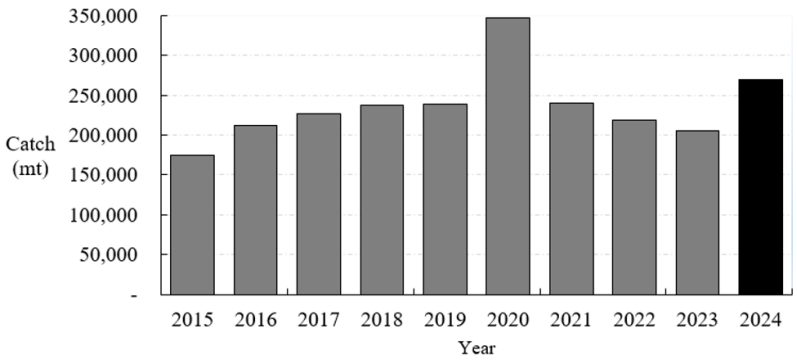

Figure 2. Monitored catches per year in Region IX.

Table 2 shows the FMA 4 Management Board-approved reference points for *S. lemuru*. Categorized as Target, Trigger and Limit reference points. The exploitation ratio (E) limit is set to 0.7, while the ideal exploitation ratio (target) is 0.5 (50%). The trigger reference points, which prompt the need for management action for recovery stock status to the target level and avoid reaching the limit, are between 0.5 and 0.7, which means not more than 0.5 but less than 0.7. Fishing Mortality/Natural Mortality (F/M) follows the same structure, with 2.5 as the limit, 1.0 as the ideal or target, and the trigger should not be more than 1.0 and less than 2.5. The average length of sardines that is considered ideal to catch (L_{m90}) was established at 17 cm in total length, and the limit, which is based on the length at first maturity (L_{m50}), is at 15 cm; anything lower than 15 is considered unsustainable. For percent mature, which refers to the mature individuals in the catch based on L_{m50} at 15cm, the target is 80%, and the limit is 50%. For the spawning potential ratio (SPR), the target is set at 45%, which means that at least 45% of the cohort should have spawned before they are harvested, while the limit is set at 20%

Table 3 presents estimates of the exploitation ratio (E) using FiSAT and LBAR. The reason for using 2 different models was to validate the results by comparing them. FiSAT results range between 0.52–0.69, with an observed decline in 2024 (see Table 3), while LBAR results range between 0.42–0.79, which also exhibited a significant decline in the same year ($p < 0.05$).

This decline in both the exploitation and fishing pressure suggests that the adjusted closed season under BAC-255 – shifted from December 1–March 1 to

Table 2. Reference points for *Sardinella lemuru*.

Performance Indicator	Reference Points		
	Target	Trigger	Limit
Exploitation Ratio (E)	0.5	>0.5 but <0.7	0.7
F/M	1	>1.0 but <2.5	2.5
Average length	Lm_{90} or 17 cm TL	<17cm but >15 cm	L_{m50} or 15 cm TL
Percent Mature	80%	<80% but >50%	50%
Spawning Potential Ratio (SPR)	45%	<45% but >20%	20%

Table 3. Performance indicators through FiSAT and LBAR.

Performance Indicators	Model/ Method used	Results									
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Exploitation ratio (E)	FiSAT	0.59	0.57	0.52	0.59	0.6	0.63	0.69	0.63	0.65	0.56
	LBAR	0.52	0.5	0.42	0.46	0.62	0.66	0.77	0.79	0.7	0.51
F/M	FiSAT	1.46	1.32	1.1	1.47	1.48	1.73	2.19	1.69	1.88	1.26
	LBAR	1.07	1	0.72	0.87	1.6	1.93	3.29	3.74	2.29	1.02

November 15–February 15, based on peak seasonal spawning period from October to February with the highest peak in November (NFARMC 2023; Ignacio 2025) as per NSAP reproductive biology data – may have a direct effect to the observed changes. It can be observed that from 2019 to 2023 (a five-year interval), the exploitation ratio ranged from 0.60 to 0.69, and a change occurred in 2024, dropping the E ratio to 0.56 (See Table 3).

However, due to the lack of iterations showing a consistent decline across years, these changes cannot be considered significant. While it can be viewed as a positive result, drawing a conclusive narrative would introduce bias rather than provide a definitive interpretation.

These results were observed to have a disparity in terms of comparison. This is because these models treat data differently: FiSAT accounts for length–frequency distributions over time, whereas LBAR emphasizes the probability distribution of lengths rather than just fitting growth curves visually (Gayanilo et al. 2006). LBAR is more sensitive to length data input because it relies directly on the shape and distribution of length-frequency data to determine cohort structure. Its analysis of relative abundance across size classes essentially estimates the probability that the fishable population spans multiple cohorts. Due to this, small variations in length distribution can disproportionately affect the results. The same goes for the results with F/M: in FiSAT, the range is 1.10-2.19, while LBAR gives an entirely different range (0.72-3.74). These results show the significance of comparative analysis across multiple iterations of different models to evaluate and further validate adjustments.

Figure 3 shows the exploitation ratio plotted as a scatter plot. It can be observed that the differences between the values derived from FiSAT and those derived from LBAR are relatively small, indicating proximity.

Figure 4 shows the F/M values plotted, which indicate fishing pressure. Compared with the plotted E ratio, the only difference observed in this graph was the significant difference between 2021 and 2022. This

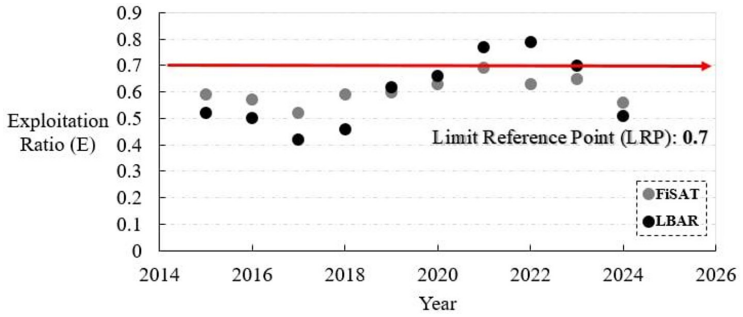

Figure 3. Plotted exploitation ratio derived from FiSAT and LBAR.

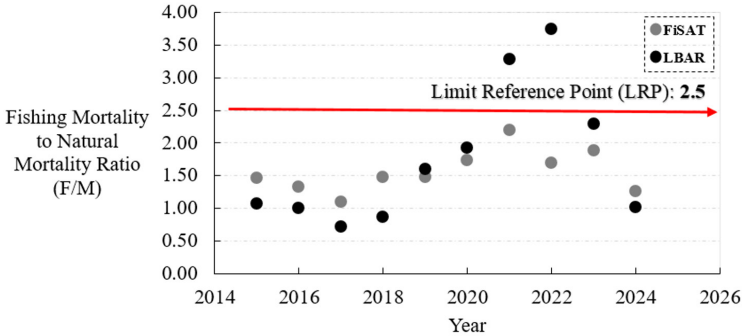

Figure 4. Fishing mortality or natural mortality indicating fishing pressure.

can entirely be attributed to the stated difference in how data is treated between FiSAT and LBAR.

Table 4 shows the Fishing Selectivity Indicators using FiSAT and LBAR. Results indicate that, since 2015, there has been a notable decrease in Length at First Capture (L_{c50}), but a significant increase in 2024 ($p = 6.25x10^{-05}$) using FiSAT. LBAR, on the other hand, shows consistency in the L_{c50} from 2019 to 2025, while a drop was observed in 2018. The average length given by LBAR ranged between 15.22 and 16.73.

Figure 5 shows a scatter plot of L_{c50} and Average Length. It is important to note that, as observed in the graph, there is no significant difference between the values provided by FiSAT and LBAR.

Table 5. The percent mature, immature, and Length optimum ($\%L_{opt}$) is based on the Length at First Maturity (L_{m50}). These results were derived from another model named FROE-SE. The model indicates that over 10 years, the percentage of mature individuals caught ranges from 36.89% to 63.91%, with a highly significant increase in mature catches in 2024 ($p = 1.01 \times 10\text{-}11$), while the percentage immature ranges from 36.09% to 63.11%.

Figure 6 shows the percentage of mature and immature catches. It can be observed that the years with the most mature catches are 2015, 2019, and 2024. Consequently, the years with the most juvenile catches are 2020 and 2018. There is a high number of juvenile catches, indicating growth overfishing.

Table 4. Fishing selectivity indicators.

Performance Indicators	Model/ Method used	Results (Lm =15.1, BFAR 9 NSAP 2021)									
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
L50/Lc	FiSAT	15.7	15.7	15.5	14.5	14.8	14.1	14.3	14	14.7	15
Length at first Capture	LBAR	15.3	16.3	14.8	13.8	15.3	15.3	15.3	15.3	15.3	15.3
Average Length	LBAR	16.3	16.7	16.1	15.2	16.1	16.1	15.9	15.8	16	16.4

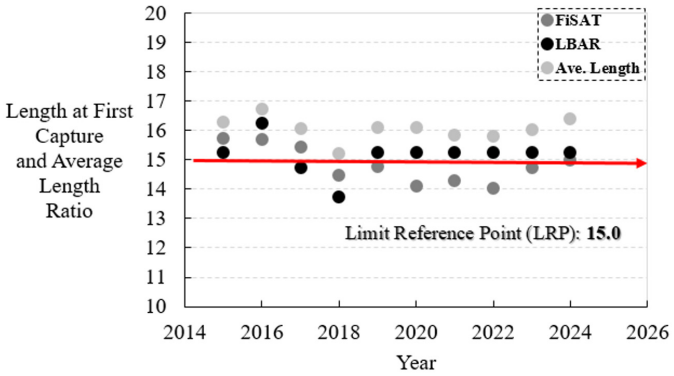

Figure 5. Plotted length at first capture and average length.

Table 5. Fishing selectivity indicators showing the percentage of mature and immature individuals.

Performance Indicators	Model/ Method used	Results (Lm 50 = 15.1 cm TL)									
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
% Immature	Froese	36.09	48.95	51.3	63.11	40.37	56.05	54.59	54.77	49.31	41.12
% Mature		63.91	51.05	48.7	36.89	59.63	43.95	45.41	45.23	50.69	58.88

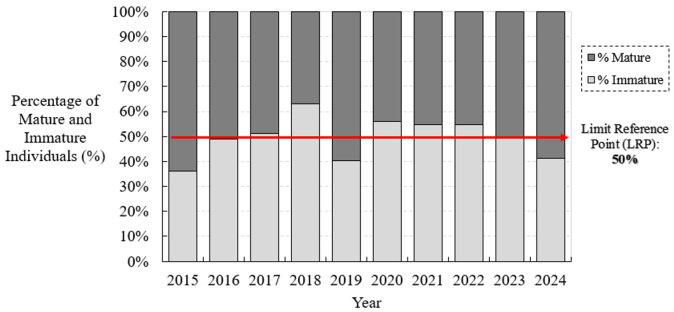

Figure 6. Percent mature and immature.

Table 6 presents biomass indicators, including spawning potential ratio (SPR) using Length-Based SPR (Hordyk et al. 2016) and catch per unit effort (CPUE). The method used to analyze the SPR was length-based. The LBSPR approach estimates spawning potential ratio directly from length-frequency data and has been shown to perform well in many data-poor fisheries (Hordyk et al. 2015a; Prince et al. 2015a) while CPUE focused on catches per Purse Seine vessel per day (based only on Region 9 data for CPUE). The results show that LBSPR exhibits low spawning biomass, indicating recruitment overfishing (see Table 1), and has a notable decrease from 2020 to 2023, while CPUE was observed to be decreasing, indicating overcapacity.

Figure 7 shows that the estimated Spawning Potential Ratio (SPR) of 2022–2024 increased from 20% to 33%, indicating a gradual improvement in the reproductive capacity of the stock. However, despite this positive trend, the SPR remained below the 45% Target Reference Point, suggesting that continued management measures are needed to achieve the desired stock status.

4. DISCUSSION

The assessment of *S. lemuru* in FMA-4 (2015–2024) using FiSAT, LBAR, FROE-SE and LBSPR consistently indicates unsustainable exploitation, a conclusion that aligns with broader studies on the species' life history and fishery dynamics. The spawning potential ratio (SPR) was inferred from catch length composition using established relationships among life-history parameters, fishing mortality, and reproductive output (Hordyk et al. 2015b; Prince et al. 2015b). The results exhibit elevated fishing pressure, declining CPUE, domination of small/immature fish in landings, and low spawning biomass, which signals both growth and recruitment overfishing. These signals are consistent with length-based indicators: elevated F or F/M values indicate that removals exceed natural mortality and productivity, while decreasing CPUE reflects declining stock abundance or overcapacity in the fishery.

Published work on the reproductive biology and maturity of *S. lemuru* provides direct biological context for these assessment results. Studies in the Philippines have estimated length at first maturity (L_{m50}) for females near 15.89 and (Lm_{95}) 17.50 cm (Ramos & Roque, 2023; NFRDI, 2021), and have documented distinct spawning seasons peaking in late to early months in some localities, specifically between November up until January, where catches contain a high proportion of fish below the observed L_{m50}, the fishery is likely subject to growth overfishing because individuals are removed before they contribute fully to spawning biomass. The results of the analysis tell us that L_{m50} = 15.1, which places the observed dominance of small sizes in landings squarely in the risk zone for growth overfishing when compared to published maturity estimates.

Beyond maturity, recent studies have emphasized the importance of early-life growth and environmental drivers for recruitment success in *S. lemuru*. Work linking larval growth variability to habitat conditions in the Sulu Sea and Zamboanga upwelling system shows that year-class strength in *S. lemuru* is strongly modulated by conditions affecting larvae and early juveniles; poor early growth or suboptimal conditions can reduce survival and

Table 6. Biomass indicators.

Performance Indicators	Model/ Method used	Results									
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
SPR	LBSPR	0.36	0.45	0.42	0.38	0.38	0.32	0.23	0.2	0.25	0.33
CPUE	Catch/boat/day (PS)	40.66	38.9	40.95	28.46	23.78	28.73	19.5	20.55	15.4	18.95

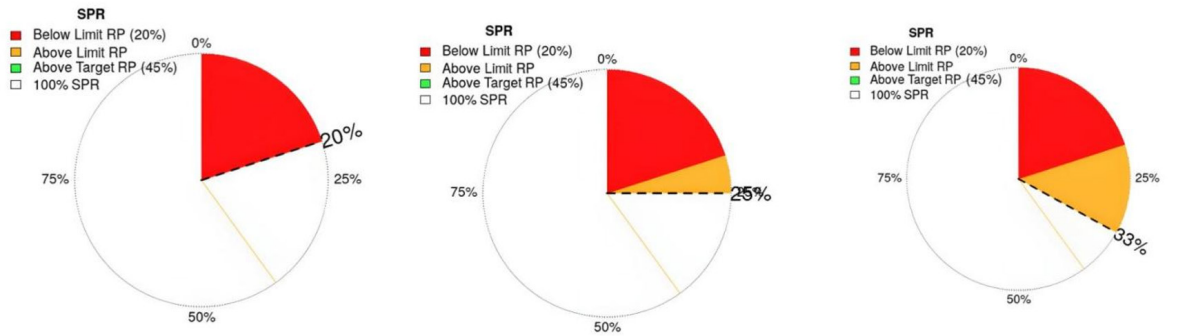

Figure 7. Shows the reference points for Spawning Potential Ratio.

subsequent recruitment (Parducho & Palomares, 2014). Thus, reduced spawning biomass (as signaled by LBSPR outputs) is particularly concerning because even small reductions in spawning output can interact with environmental variability to produce dramatic declines in recruitment and landings in subsequent years. This mechanistic link between spawning biomass and recruitment is important when interpreting low SPR outputs: low reproductive capacity is not only an immediate stock metric but also a leading indicator of poor future recruitment under variable environments.

Equally concerning is the decline in spawning biomass, as highlighted by the LBSPR model. The report indicates that spawning stock biomass has fallen below sustainable thresholds, signaling recruitment overfishing. This means that the reproductive potential of the stock has diminished to levels that may compromise its ability to replenish itself in future years. The combined indicators for fishing mortality, catch size composition, and spawning biomass suggest that the fishery is already beyond the Trigger reference points and, in some cases, approaching the Limit reference points defined in the management framework. These results imply that the stock is no longer being exploited within sustainable boundaries, and management intervention is urgently required.

The species' broader biology and distributional context further reinforce the assessment implications. *S. lemuru* is an abundant coastal pelagic that forms large schools and has been a key component of small-pelagic fisheries in the Philippines. The species has experienced historical misidentifications and changes in reported landings and stock delineations (Willette et al. 2011), which complicate the interpretation of long-term trends but do not alter the immediate biophysical mechanisms linking small-size-dominated catches and low SPR to unsustainable exploitation. Regional reviews underline the economic importance of *S. lemuru* to coastal communities and the sensitivity of sardine fisheries to overfishing and environmental variability (Oceana Philippines, 2021). These broader observations support a precautionary management response when multiple indicators concur on overexploitation.

The results from previous years statistically show that the stocks are approaching overexploitation (Fishery Management Area 4 Management Board 2025); however, it is also important to note that the adjusted closed fishing season has a positive impact on the stock status. Seasonal fishing closures are recognized as effective management measures for protecting fish during spawning periods and promoting stock sustainability (FAO 1997). It is also of significance to note that fishing regulations are globally recognized as key conservation measures for preserving fishery resources, especially for controlling overfishing and protecting species during their spawning seasons (Sadovy et al. 2005; Arendse et al. 2007; Hargraves 2011; Cohen et al. 2013; Chimba and Musuka 2014). Among the various fisheries management strategies, closed fishing seasons are commonly adopted by governments, local authorities, and coastal communities to conserve and enhance fish stocks and other marine resources. Seasonal closures and the regulated harvesting of fishery products have become widely accepted and practical ways to sustain both ecosystems and local livelihoods (Cohen et al. 2013). This approach has primarily been implemented in response to declining coastal resources, as evidenced by reduced yields or fish catches, which have had significant social and economic impacts on affected communities. In principle, fishing regulations offer biological, ecological, and industrial benefits (Campos et al. 2003; Mardle et al. 2004; Failler and Pan 2007) by ensuring the conservation of sardine species and supporting the sustainability of the entire sardine sector. As observed in the results, there are notable changes in terms of exploitation, fishing pressure, and even spawning potential ratio. Although a conclusive and well-supported claim cannot be drawn from these changes, they can still be considered significantly positive compared to previous years.

Taken together, the multiple-model agreement (FiSAT, LBAR, Froese Indicator, LBSPR) that fishing pressure is high, CPUE is decreasing, catches are biased toward immature fish, and spawning biomass is low is consistent with the species' known maturity, recruitment dynamics, and documented sensitivity of recruitment to early-life conditions. Although 2024 showed signs of improvement due to the adjusted closed fishing season, it is undeniable that the synthesis of these parameters strengthens the interpretation that growth overfishing and recruitment impairment are occurring in the waters of FMA-4 and that immediate management action is warranted to reduce fishing mortality, protect the juvenile population, and protect spawning biomass.

5. CONCLUSION

The assessment of *S. lemuru* in Fisheries Management Area 4 indicates that the stock is highly exploited. The combined evidence of elevated fishing mortality, a persistent decline in catch-per-unit-effort (CPUE), the predominance of immature individuals in the catch, and reduced spawning biomass

demonstrates that the current level of fishing pressure is unsustainable.

When benchmarked against the established Target, Trigger, and Limit Reference Points (RPs), the stock consistently remains at the trigger level, suggesting that precautionary management actions are warranted. While the year 2024 exhibited notable improvements in stock indicators, this positive trend remains fragile and may not be sustained if present exploitation rates persist.

Unless effective measures to reduce fishing pressure are implemented, the long-term sustainability of the sardine stock and the socio-economic stability of the fisheries sector and dependent communities will remain at risk.

6. RECOMMENDATION

Given the persistently high exploitation of *S. lemuru* in FMA-4, the existing closed fishing season should be augmented with complementary management measures to ensure long-term stock sustainability. Specific recommendations are as follows:

Strengthen gear regulations. Adoption and strict enforcement of minimum mesh size limits, or alternatively, the application of seasonal gear restrictions for gears targeting juveniles, to reduce the capture of immature individuals and promote recruitment to the spawning stock.

Control fishing effort . Establishment of measures such as limits on fishing days, trips, or vessel operations to reduce fishing mortality across the year or a moratorium on fishing vessels and gears targeting sardines and other small pelagic species.

More dynamic seasonal closure. The existing closed fishing season should be periodically reviewed and adjusted to better align with the biological spawning condition of sardines, ensuring maximum protection of spawning individuals during peak season.

Enhance monitoring, control, and surveillance (MCS). Strengthened enforcement mechanisms are required to improve compliance and ensure the effectiveness of both existing and new measures.

Improve stock monitoring. Regular collection of biological and fisheries-dependent data is necessary to track stock status and provide science-based inputs for adaptive management.

Develop a comprehensive harvest strategy. Integration of the closed season with gear restrictions, effort controls, dynamic closure adjustments, and continuous monitoring into a formal Harvest Strategy Framework, aligned with reference points, to secure long-term sustainability and socio-economic resilience.

Strengthened community engagement and livelihood support. Long-term sustainability will require active community engagement and support for fishers through alternative livelihood programs, ensuring compliance and reducing the socio-economic costs of management measures. By combining scientific evidence with practical enforcement and stakeholder participation, the sardine fishery in FMA-4 can be recovered.

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AUTHOR CONTRIBUTIONS

Ignacio DB: Supervision, Conceptualization and Design of the Study, Analysis and/or interpretation of data, and Revision. **Lague VM**: Acquisition of data, Analysis and/or interpretation of data, Writing-original draft, and Revision. **Revillas CB**: Acquisition of data, Analysis and/or interpretation of data, and Revision. **Kunting AK:** Project Supervision. **Mesa SV:** Analysis and/or interpretation of data, and Revision. **Garcia JH**: Analysis and/or interpretation of data, and Revision. **Flores NAL:** Analysis and/or interpretation of data, and Revision.

CONFLICTS OF INTEREST

The authors declare no actual, potential, or perceived conflict of interest for this study.

ETHICS STATEMENT

The authors affirm that all international, national, and institutional guidelines for the care and use of laboratory animals have been diligently followed and adhered to.

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