The Philippine Journal of Fisheries 2026 NSAP Special Issue: 159 - 170
DOI: 10.31398/tpjf/33.3.2026C0003

September 2026

RESEARCH ARTICLE

Stock Assessment of *Sardinella lemuru* (Bleeker, 1853) and *Sardinella gibbosa* (Bleeker, 1853) in Fisheries Management Area 9 (Bohol Sea), Philippines

Edward B. Yasay, Princess Mae T. Cena*, June Gabriel P. Pagalan, Mary Jory L. Fajardo, Janellah Michelle V. Pangan, Zaldy A. Villariza, Rolando C. Salvador Jr.

Bureau of Fisheries and Aquatic Resources, National Stock Assessment Program, Regional Office No. 10, Macabalan, Cagayan de Oro, Misamis Oriental, 9000, Philippines

ABSTRACT

Small pelagic fishes, including sardines, anchovies, and mackerel, form the backbone of the Philippines' capture fisheries, accounting for over 44% of total production from 2018 to 2023. Among these, *Sardinella lemuru* (Bali sardine) is the leading species, with significant contributions from *Sardinella gibbosa* (Goldstripe sardine). This study assesses the population and exploitation of *S. lemuru* and *S. gibbosa* using catch and effort data collected through the National Stock Assessment Program (NSAP) from 2014 to 2023 in Fisheries Management Area (FMA) 9. Results show that commercial gears, especially bagnet and ring net, account for most sardine landings, with *S. lemuru* comprising 49% and *S. gibbosa* 2% of the total catch. Peak abundance seasons varied by species, with *S. lemuru* peaking from June to September and *S. gibbosa* from March to April, reflecting different spawning and migration patterns. Growth and mortality analyses revealed high fishing pressures on both species, with exploitation rates exceeding sustainable thresholds (E > 0.5). Only 4.8% of *S. lemuru* and 18.6% of *S. gibbosa* in the catch had reached maturity, highlighting growth overfishing and the risk of recruitment overfishing. Current catch patterns threaten long-term stock sustainability and underscore the urgent need for science-based fisheries management measures in FMA-9. These include protecting juvenile fish and enforcing gear and seasonal regulations to ensure sustainable sardine fisheries and secure livelihoods in the area.

*Corresponding Author: *nsap.r10@bfar.da.gov.ph*
Received: *January 23, 2026*
Accepted: *June 29, 2026*

Keywords: *Small pelagic fishes, Sardinella, stock assessment, capture fisheries, Bohol Sea*

1. INTRODUCTION

In the Philippines, small pelagic fishes primarily include roundscads (*Decapterus spp*., Carangidae), anchovies (*Stolephorus* spp., Engraulidae), sardines (*Sardinella* spp., Clupeidae), and mackerels (*Rastrelliger* spp., Scombridae) (Zaragoza et al. 2004). From 2018 to 2023, small pelagic species contributed 44.2% of overall capture fisheries production, with Bali sardinella (*Sardinella lemuru)* as the leading contributor (BFAR 2023). The majority of sardine production is in Region IX, which is part of Fisheries Management Area 9 (FMA-9), commonly known as the Bohol Sea (BFAR 2023; Philippine Statistics Authority 2016).

Serving as foundational species in marine food webs, sardines play a vital role in ecological systems by supporting predators such as tuna, seabirds, and marine mammals. Sardines enhance the marine ecosystem's primary productivity by distributing nutrients through feeding and excretion, while population fluctuations driven by environmental variability influence the abundance of other marine species. Aside from having ecological importance, sardines also hold significant economic value. According to the Bureau of Fisheries and Aquatic Resources, over 800,000 fisherfolk are engaged in sardine capture fishing, accounting for almost 50% of the 1.7 million registered fisherfolk nationwide. As one of the Zamboanga Peninsula's most abundant fishery resources, sardines are processed through canning and bottling, providing employment and livelihood to local communities and contributing to the nation's food security (Narvaez et al. 2017).

However, sardine production has declined in recent

years. Campos et al. (2024) reported that sardine species, particularly *S. lemuru,* has a high mortality rate ($Z = 14.6\ yr^{-1}$), indicating a high exploitation ratio ($E = 0.85$) in FMA 7. The Philippine Statistics Authority also showed a decrease in sardine production from 2020 to 2024 (PSA 2023; PSA, 2024). Several factors have been identified as potential contributors to this decline, including overfishing, habitat degradation, and changing oceanographic conditions (Willette et al. 2011). Overfishing, often driven by the high demand for sardines both locally and internationally, has put significant pressure on sardine stocks.

Based on published information on sardines, most studies have focused on *S. lemuru*, with limited attention to *S. gibbosa*. Additionally, comprehensive stock assessments for either species remain unavailable, particularly across the full extent of FMA-9. Given that *S. lemuru* is included in the list of authorized species for export to the European Union and other global markets, up-to-date stock assessments within FMA-9 are critical to inform science-based fisheries management and ensure sustainable sardine fisheries in the area. This study aims to provide biological information on the status of *S. lemuru* and *S. gibbosa* in FMA-9.

2. MATERIALS AND METHODS

The National Stock Assessment Program (NSAP) within FMA-9 conducted systematic random sampling of biological and catch-effort data from designated landing sites across the five (5) member administrative regions (Regions 7, 8, 9, 10, and CARAGA) of the FMA.

2.1 Study area

Study areas within FMA-9, which encompasses the central-eastern waters of the Philippines, were selected based on total landings, species diversity, and accessibility. Sampling stations included key fishing ports and landing centers in Region 7 (Central Visayas), Region 8 (Eastern Samar), Region 9 (Zamboanga Peninsula), Region 10 (Northern Mindanao), and Region 13 (CARAGA). The study covered eleven (11) provinces, twelve (12) major key fishing grounds, and sixty-seven (67) sardine landing sites.

NSAP sardine landing sites in FMA-9. Maps of sampling stations were generated using GIS tools to ensure spatial consistency (Figure 1).

2.2 Sampling and data collection

NSAP technical data enumerators collected data at the sixty-seven (67) landing sites within FMA-9 using NSAP standard sampling protocols. Data were collected every other two days regardless of Saturdays, Sundays, and holidays (Santos et al. 2017). Each sampling day's information included the total

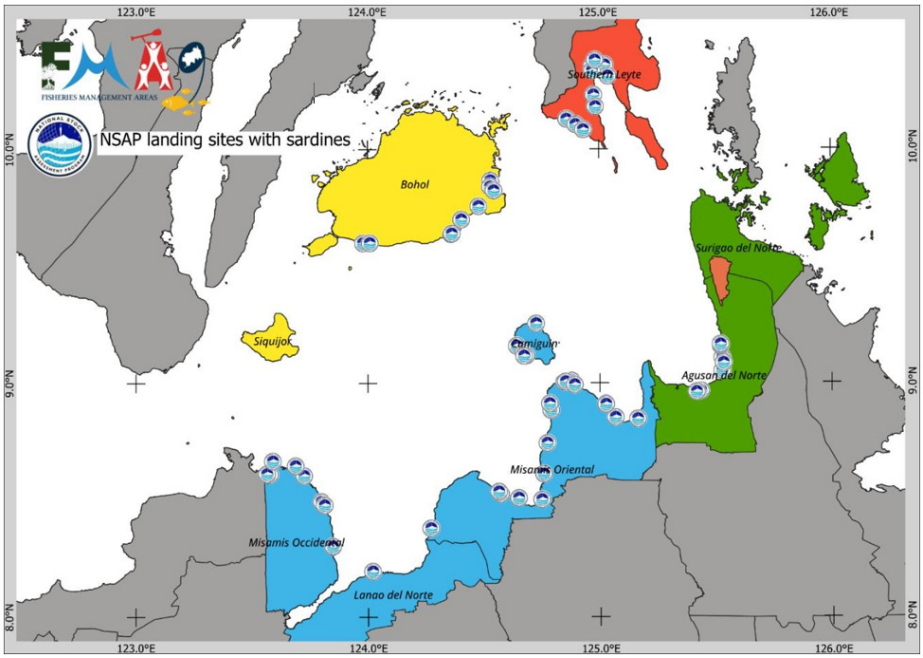

Figure 1. The map of FMA 9 with NSAP Landing Sites with Sardines using QGIS software version 3.22.11.

number of fishing boats landing in commercial or municipal fisheries, gear type and effort (hours, hauls, days, hooks, etc.), total catch production per fishing operation, and the species and length (total length) composition of landings. Accordingly, landings data were obtained by randomly sampling fish from fish containers sorted by species and weighted by each species component to determine the total weight of each species in the landings (Calicdan et al. 2017) . All these statistics gathered are recorded in a logbook and transferred to an NSAP standard form (hard copy) and encoded in Excel form (soft copy). Data is submitted to the regional office every 15th day of the following month.

2.3 Data processing and analysis

The status of sardine fish stocks in FMA-9 using data from January 2014 to December 2023 was evaluated using various biological indicators, obtained through the scientific methods listed below:

2.3.1 Fishing gear landings contribution

Landings by each fishing gear were ranked from highest to lowest based on their contribution to total landings by summing the catch of all species per gear from 2014 to 2023.

2.3.2 Species composition and relative abundance

The species composition of the landings by each gear type used by municipal and commercial fishing boats was determined on-site. The relative abundance of each species was then assessed based on its percentage contribution to the overall landings.

2.3.3 Seasonality of sardine species

Sardine seasonality was determined using the NSAP recorded landings data from 2014 to 2023. Seasonality was examined based on periods or months with high landings. Seasonality was identified using Microsoft Excel (Pivot) analysis.

2.3.4 Catch per Unit Effort (CPUE)

Catch Per Unit Effort (CPUE) measures the relative abundance of a target species by indicating how many fish are caught for a given amount of fishing activity or effort. CPUE is calculated by dividing the total landings by the total fishing effort. The enumerator sampled each boat's total landing weight and effort, measured as the number of fishing trips per month. The recorded data were then processed using RStudio (version 2025.05.1).

2.3.5 Population parameters

Biological parameters of sardine species in FMA-9 were estimated using the FAO-ICLARM Stock Assessment Tool (FISAT) software (Gayanilo et al. 1996). The software includes the Electronic Length Frequency Analysis (ELEFAN) routines to estimate the parameters of the von Bertalanffy Growth Function (VBGF). The asymptotic length (L_∞) and the growth constant (K) value were estimated via the K- scan routine of ELEFAN I, wherein the K-value is chosen to provide the "best fit" for the available length-frequency data of the species. Moreover, three (3) indicators were used to deal with overfishing: (i) percentage of mature fish in catch, with 100% as the ideal target; (ii) percentage of species with optimum length in catch, with 100% as the ideal target; and (iii) percentage of 'mega-spawners' in catch, with 0% as the ideal target and 30–40% as a reasonable target if no upper size limit exists (Froese 2004).

3. RESULTS AND DISCUSSION

3.1 Fishing gear landings contribution

Sardine fishers from various localities use specific gear types suited to catching sardines. Based on the current FMA-9 analysis, the sardine capture sector consists of two main types of fishing: municipal and commercial. In the commercial sector, the primary gears used are Bagnet (BN) and Ring Net (RN). In the municipal sector, commonly used gears include Encircling Gillnet (EGN), Surface Gillnet (SGN), Scoop Net (SN), and Multiple Hook and Line (MHL). Sardine production in FMA-9 is primarily driven by the commercial sector, contributing 81% from Bagnet (BN) and 10% from Ring Net (RN). Municipal gears, such as Drift Gillnet (DGN), contribute 6%, while the remaining 3% comes from other municipal gears, including EGN, SGN, SN, and MHL (Figure 2 and Table 1). According to the Regional Licensing Section (RLS) of BFAR and consolidated data from the NSAP through the Boat and Gear Inventory (BGI) and enumeration, the gear inventory in FMA-9 includes 58 units of Bagnet (BN), 100 units of Ring Net (RN), 129 units of Encircling Gillnet (EGN), 1,119 units of Drift Gillnet (DGN), and 215 units of Scoop Net (SN).

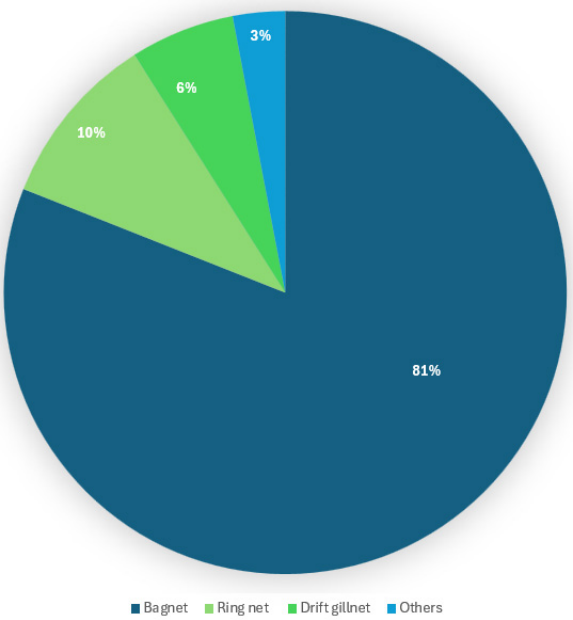

Figure 2. Percent contribution of major fishing gear in FMA-9.

Based on the estimated number of sardine fishers per major fishing gear in FMA-9, Drift Gill Net (DGN), Scoop Net (SN), and Ring Net (RN) were each used by over 3,000 fishers. This suggests that the majority of fishers operate in both municipal and commercial fishing sectors. In contrast, the Bagnet, which contributes 81% of the total sardine catch in FMA-9, is used by only about 1,500 fishers. This indicates that the gear is highly efficient and has higher catchability than other gear types. Additionally, it can be noted that many fishers in FMA-9, particularly in the municipal sector, tend to shift to other gear types or modify existing ones to improve efficiency and reduce costs.

3.2 Species composition and relative abundance

In 2018, Bali sardines (*S. lemuru*) accounted for the second-largest share of total commercial fishing production at 20.5%, following skipjack tuna, which led with 24.2%. The Philippine Statistics Authority recorded two major sardine species: Bali Sardines, or *S. lemuru*, formerly known as Indian Sardines, and Goldstripe Sardinella, and *S. gibbosa*, formerly known as Fimbriated Sardines (BFAR 2020). NSAP data in FMA-9 from 2014 to 2023 show that, over the past 10 years, the sardine fishery has ranked highest in landings in FMA-9, comprising 51% (Figure 4) of the total catch in the Bohol Sea area. However, over the years, the sardine stock has been subjected to overfishing. Meanwhile, *S. lemuru* contributed the most, accounting for 49% of the total landed catch among the top 10 species (Figure 5).

The combined contribution of the other top 10 species is 28%, which includes *S. gibbosa* at 2%. Species outside the top 10 contribute 23%, including other small pelagic and demersal species (Figure 5). Together, the two sardine species account for the majority of total landings in FMA-9, highlighting their significant role in FMA-9 fisheries production. This dominance underscores the need for effective management measures to ensure the sustainability of these key species.

3.3 Seasonality of sardine species

Sardines are among the country's most commercially important pelagic species, accounting for 25% of total commercial fisheries production in 2018. Because they are inexpensive yet rich in protein, sardines are among the most accessible fish species for Filipinos (BFAR 2020). Landings data from FMA-9 from 2014 to 2023 showed different peak seasons for

Table 2. *S. lemuru* landings per month for C.Y. 2014 – 2023 in FMA-9.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	1.1	1.2	1.6	1.3	39.2	48.9	173.4	285.6	251.8	164.5	214.6	65.5
2015	66	99.8	291.1	173.6	445.1	390.3	424.8	354.7	374	201.5	117.5	72.8
2016	145	225.1	205.2	167.9	158	82.7	333.9	210.4	317.7	227.5	202.1	109.3
2017	61.9	58.4	49.7	208.5	111	315.6	229.3	295.4	214	240.8	271.6	52.8
2018	26.1	60.6	195	155.1	44.8	202.8	142.9	125.2	113.2	84.8	70.5	52.4
2019	40.9	19.4	27.2	39.9	53.4	65.7	133.1	116.7	137.1	211.1	45.5	92.8
2020	58	31.2	89.9	113	91.9	104.2	146.2	143.8	115.5	166.8	212.5	127.3
2021	133.4	80.2	79.7	47.4	65.1	244.9	296.9	258.2	265.4	198.9	176	57.9
2022	149.3	205.2	189.4	128.5	86	62.2	42.4	5.5	4.1	5.1	2.3	2.5
2023	4.2	2.2	4.5	17.4	75.2	9.8	5.3	1.8	1.3	1.8	5	1.6
Mean	**68.6**	**78.3**	**113.3**	**105.3**	**117**	**152.7**	**192.8**	**179.7**	**179.4**	**150.3**	**131.8**	**63.5**

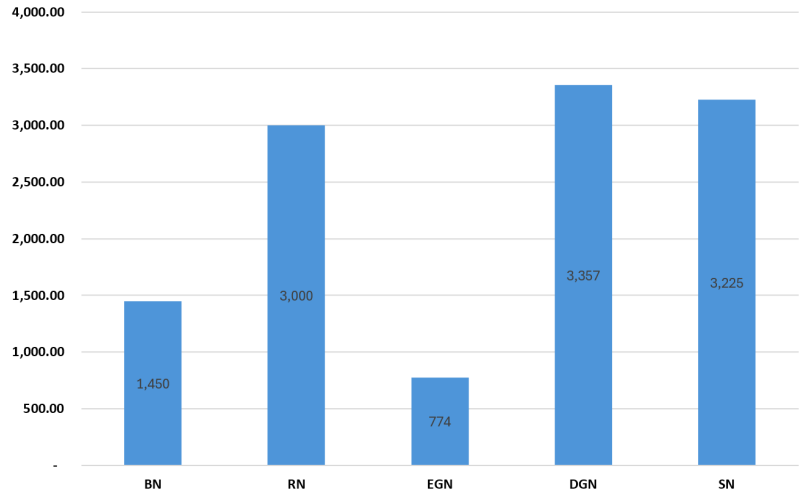

Figure 3. Estimated number of sardine fishers per major fishing gear in FMA-9.

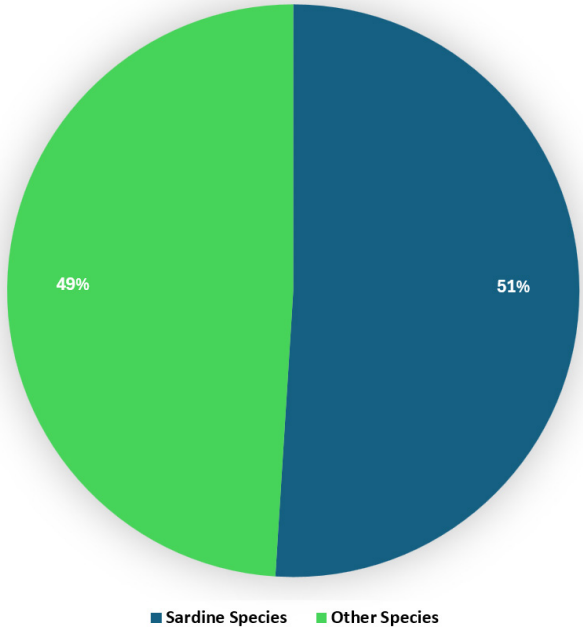

Figure 4. Percent contribution of sardines in FMA-9.

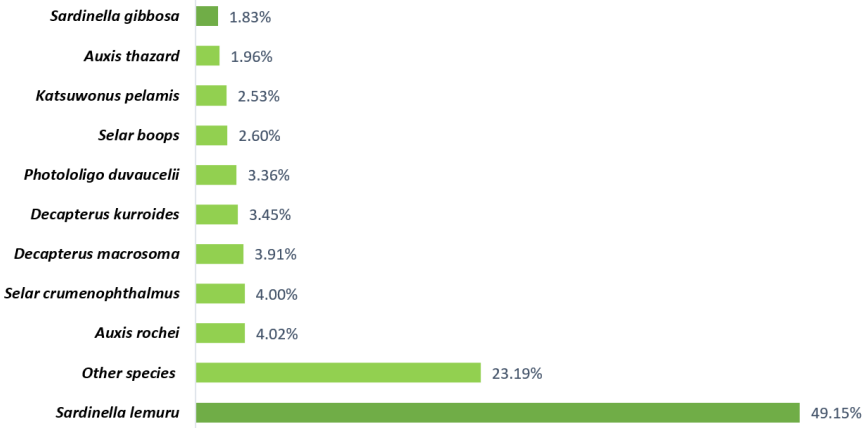

Figure 5. Percent contribution of top species in FMA-9.

the two sardine species. For *S. lemuru*, the peak season occurred from June to September (Figure 6 and Table 2). Production peaks and spawning in sardines have been reported to coincide with the southwest monsoon in many parts of the Philippines (Dalzell et al. 1990; Olano et al. 2009 ; Willette et al. 2011). However, other reports indicate that peak spawning and recruitment of the dominant species *Sardinella lemuru* occur during the northeast monsoon in the Moro Gulf and Sulu Sea (Willette et al. 2011; De Guzman et al. 2012).

Oceanographic investigations along this marine corridor explain the interconnectivity of the Surigao Strait as the source of Pacific Ocean water entering the Bohol Sea, then flowing to the Zamboanga Peninsula, where a major upwelling zone occurs. The Bohol Sea also receives water from the Sulu Sea on the west through the Dipolog Strait. The area's topography and unique 'double estuarine type' circulation pattern gave rise to a highly productive upwelling system on the Zamboanga side. Large nutrient inputs from major river systems in the Bohol Sea (i.e., Cagayan River, Tagoloan River, and Agusan River) also drive phytoplankton and sardine production in Butuan Bay on the eastern side of the Bohol Sea. Riverine input is believed to influence sardine production in the Bohol Sea year-round (De Guzman et al. 2015).

Seasonality in *S. gibbosa* catches appears from March to May (Figure 7 and Table 3). Guanco et al. (2009) observed that sardine species, including *S. gibbosa*, exhibit recruitment pulses from February to September in the Visayan Sea. The observation that *S. gibbosa* catches tend to occur from March to April

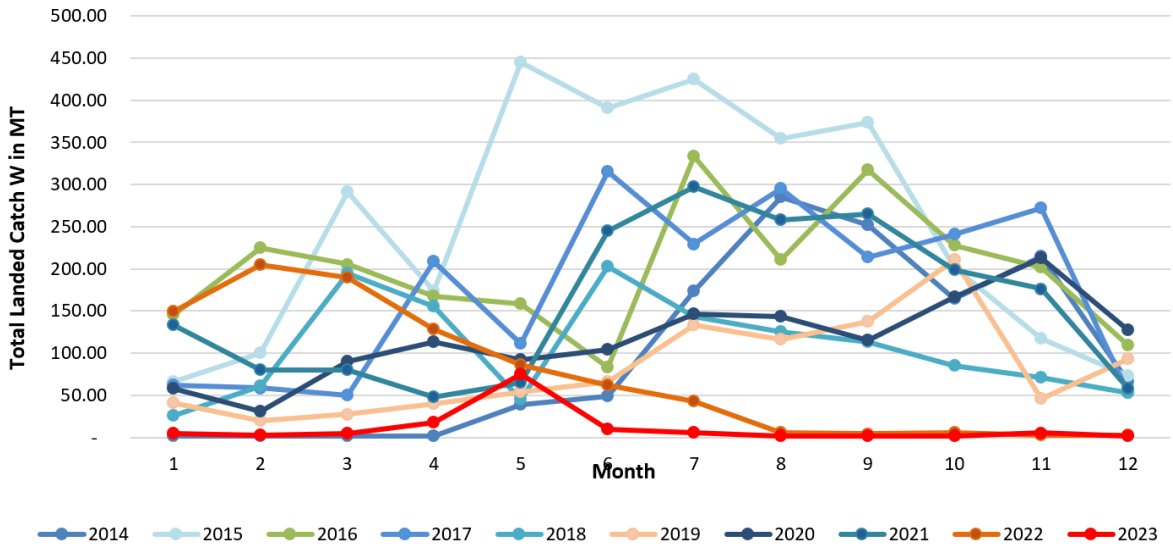

Figure 6. Seasonality of *S. lemuru* landings per month for C.Y. 2014-2023 in FMA-9.

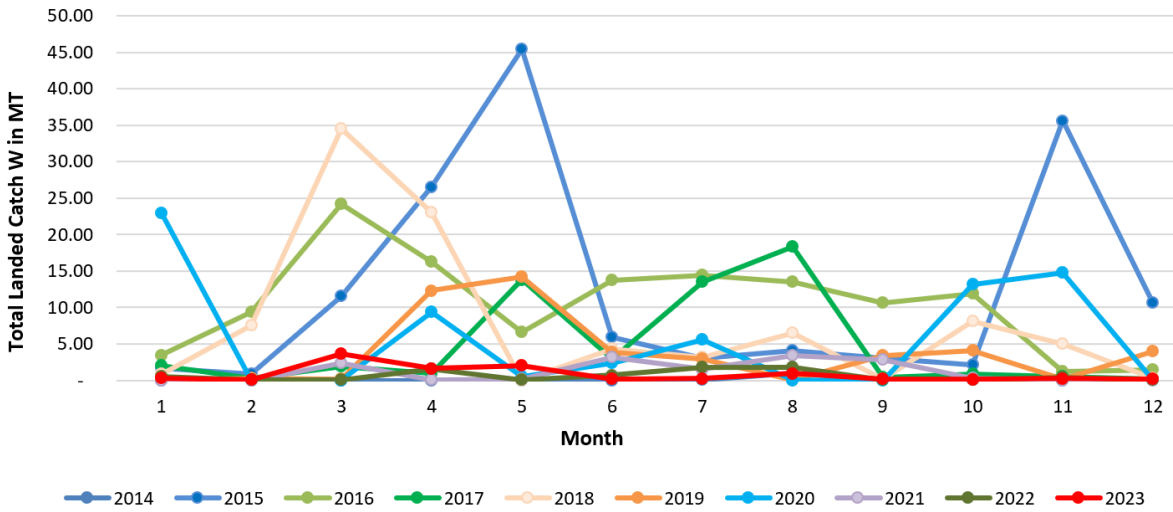

Figure 7. Seasonality of *S. gibbosa* per month, C.Y. 2014-2023 in FMA-9.

Table 3. *S. gibbosa* landings per month for C.Y. 2014 – 2023 in FMA-9.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	1.1	1.2	1.6	1.3	39.2	48.9	173.4	285.6	251.8	164.5	214.6	65.5
2015	66	99.8	291.1	173.6	445.1	390.3	424.8	354.7	374	201.5	117.5	72.8
2016	145	225.1	205.2	167.9	158	82.7	333.9	210.4	317.7	227.5	202.1	109.3
2017	61.9	58.4	49.7	208.5	111	315.6	229.3	295.4	214	240.8	271.6	52.8
2018	26.1	60.6	195	155.1	44.8	202.8	142.9	125.2	113.2	84.8	70.5	52.4
2019	40.9	19.4	27.2	39.9	53.4	65.7	133.1	116.7	137.1	211.1	45.5	92.8
2020	58	31.2	89.9	113	91.9	104.2	146.2	143.8	115.5	166.8	212.5	127.3
2021	133.4	80.2	79.7	47.4	65.1	244.9	296.9	258.2	265.4	198.9	176	57.9
2022	149.3	205.2	189.4	128.5	86	62.2	42.4	5.5	4.1	5.1	2.3	2.5
2023	4.2	2.2	4.5	17.4	75.2	9.8	5.3	1.8	1.3	1.8	5	1.6
Mean	**68.6**	**78.3**	**113.3**	**105.3**	**117**	**152.7**	**192.8**	**179.7**	**179.4**	**150.3**	**131.8**	**63.5**

suggests a seasonal pattern likely tied to biological cycles such as spawning, feeding migrations, or environmental conditions that favor aggregation.

The goldstripe sardinella is the second most abundant sardine in the Philippine archipelago (Willette et al. 2011). Migratory patterns of *S. gibbosa* have been correlated with the availability and seasonality of planktonic prey in the environment (Nair 1973; Nyunja et al. 2002; Lazarus 1977). Biological data from the coast of India suggest a peak spawning period from early March to the end of May (Nair 1973; Sekharan 1969). The same pattern was observed for both *S. lemuru* and *S. gibbosa* in annual catches, with peak landings in 2015 (3,162 mt) followed by a significant decline in 2023 (140 mt).

3.3 Catch per Unit Effort (CPUE)

Catch per unit effort (CPUE) can vary seasonally because of changes in recruitment, growth, and mortality; however, these changes may not be consistent across species or within a species across habitats (Pope and Willis 1996; Richards et al. 1996). In FMA-9, higher CPUE values for both sardine species were recorded using bagnet in the years 2018, 2019, and 2021, suggesting greater catching efficiency during these periods. Bagnets contributed the bulk of sardine landings, particularly in Macajalar Bay and Iligan Bay (Annexes 1 and 2). However, catchability dropped significantly in 2020, likely due to the COVID- 19 pandemic, which restricted movement and prevented many fishers from going out to sea. Another contributing factor may have been the sharp increase in fuel prices during that period. Looking at the landings data, this species was largely absent from the major fishing grounds in FMA- 9, possibly due to migration or other environmental factors. However, it gradually reappeared in 2023.

Catchability can also increase over time as fleet efficiency improves. This efficiency may result from fishers gaining better knowledge of fish location and behavior or learning to operate their gear more effectively. Efficiency also improves as new technologies are adopted. For example, the use of echo sounders and fish finders enhances the ability to detect fish schools. Unusually high catches from certain boats may be explained by several factors: these boats may undertake longer fishing trips, as indicated by less frequent landings, or use larger or more efficient gear, such as deeper or longer nets. Catchability can also be significantly affected when a fleet shifts its target species. Generally, catchability increases for the new target species and decreases for the previously targeted one. For instance, increasing the depth of longline gear to target bigeye tuna has been shown to increase the catchability of that species while decreasing the catchability of yellowfin tuna (*Thunnus albacares*) (Suzuki et al. 1977; Bigelow et al. 2002). While the factors mentioned above are among the most common influences on the relationship between CPUE and abundance, many other variables may also impact catchability or the assumption that CPUE is proportional to stock abundance. These include shark damage to fish caught on hooks (Myers and Worm, 2003), gear saturation, gear interference, misreporting (Baum et al. 2003), stock structure (e.g., fishing multiple stocks together or only a portion of a stock), selective harvesting of more vulnerable individuals during early stages of the fishery (Gulland, 1974; Hilborn and Walters, 1992; Nakano and Bayliff, 1992), age- or size-specific selectivity, and individual variability in natural mortality.

3.4 Population parameters of sardine species

The population parameters of *S. lemuru* and *S. gibbosa*, such as asymptotic length (L_∞), growth constant (K), fishing mortality (F), natural mortality (M), total mortality (Z), and exploitation ratio (E), were computed using the FiSAT II software. *S. lemuru* exhibited an L_∞ of 23.5 cm and a K value of 1.2 yr^{-1}. These values indicate a relatively fast-growing population that reaches near-maximum size within a short period. Compared with earlier estimates from Tayabas Bay (L_∞ = 21.15 cm; K = 0.48 yr^{-1}) and Palawan (L_∞ = 23.0 cm; K = 1.1 yr^{-1}), the present findings suggest higher growth performance, particularly in the K value. For *S. gibbosa*, the study generated an L_∞ of 20.4 cm and a K value of 1.2 yr^{-1}. Compared with earlier data from Tayabas Bay (L_∞ = 19.54 cm; K = 0.77 yr^{-1}), this species also showed a higher growth rate in the current study area, though the increase was more moderate than that observed for *S. lemuru*. The relatively smaller asymptotic length and high K value suggest that *S. gibbosa* follows a more opportunistic life history strategy, characterized by early maturation and short life cycles. Length-frequency data for *S. lemuru* and *S. gibbosa* were also analyzed to estimate total mortality (Z) and exploitation ratio (E) using the length-converted catch curve method implemented in FiSAT II. Figure 9 shows the corresponding results.

Both sardine species showed fishing mortality (F) values exceeding their respective natural mortality (M) values—a common indicator of exploitation under intense fishing pressure. Moreover, both species recorded exploitation ratios (E) above the commonly accepted threshold of 0.5, indicating that fishing accounts for more than half of total mortality and placing these populations at risk of overfishing. High estimates of total mortality (Z) and fishing mortality (F) for both species reflect unsustainable levels of exploitation. These elevated values suggest that current fishing capacity and practices are exerting significant pressure on the stocks, potentially reducing their long-term productivity if not properly managed. However, these species are known to be highly resilient to fishing pressure and have low extinction vulnerability due to their high fecundity and rapid growth rates (Froese and Kesner-Reyes 2002; Cheung et al. 2005).

Figure 8. Catch per Unit Effort (CPUE) of *S. lemuru* and *S. gibbosa* in year 2018-2023.

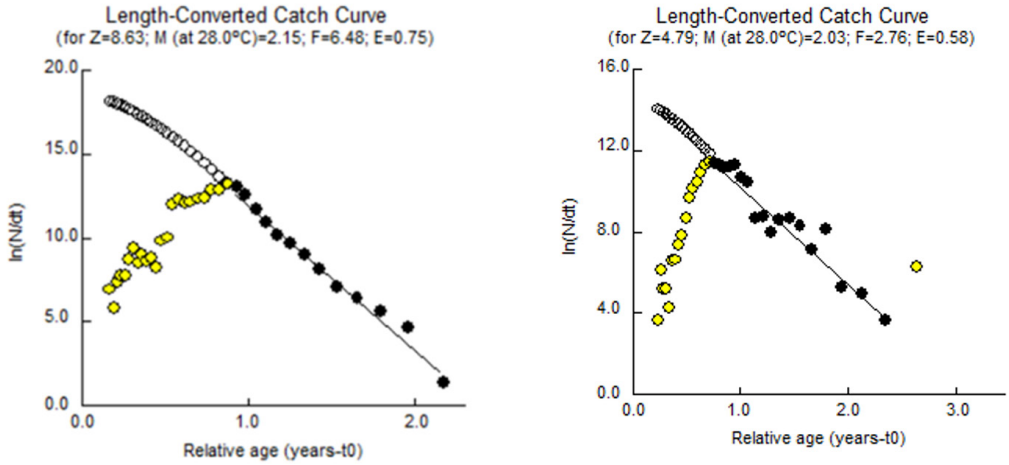

Figure 9. Length-converted catch curve analysis of *S. lemuru* (left) and *S. gibbosa* (right) in FMA -9.
Note: Z= Total Mortality, M=Natural Mortality, F=Fishing Mortality, E= Exploitation Rate

3.5 Performance sustainability

As 51% of the species caught in FMA-9 are composed of two sardine species, *S. lemuru* and *S. gibbosa*, it is evident that these species are under sustained high fishing pressure. The fishing mortality (F, yr^{-1}) values recorded for *S. gibbosa* and *S. lemuru* were 3.95 and 2.37, respectively, both indicating excessive exploitation rates well above the estimated natural mortality (M, yr^{-1}) levels and suggesting a significant risk of overfishing (Table 4).

Sardines reach sexual maturity at a relatively small body size (length at first maturity, L_m, between 12 and 15 cm SL) at about 4 to 6 months old. However, the proportion of mature individuals in catches from FMA-9 was only 18.6% for *S. gibbosa* and 4.8% for *S. lemuru*, both below the established reference point. This implies that many of the fish being caught are juveniles, posing a serious threat to the reproductive capacity and long-term sustainability of these stocks. Continuous harvesting of immature fish prevents stock replenishment from spawning, increasing the population's vulnerability to collapse. The most desirable fisheries management scenario is to allow 100% of individuals to reach maturity and spawn at least once before capture, ensuring healthy recruitment and rebuilding exploited stocks. The optimum length (L_{opt}), typically slightly larger than the length at first maturity, can be estimated from growth and mortality parameters or empirical equations (Froese and Binohlan, 2000) and serves as another key sustainability indicator. For *S. gibbosa* and *S. lemuru*, the percentages of catch falling within the optimum length range were 53.3% and 48.2%, respectively. While still far from the 100% target, these values indicate that a significant portion of the catch is below the optimal size for maximizing yield and maintaining a healthy population structure.

4. CONCLUSION

The sardine fishery in FMA-9 contributes significantly to regional production, with commercial gears such as bagnet and ring net accounting for over 90% of sardine catches. *S. lemuru* and *S. gibbosa* dominate the species catch composition, making up 51% of the total landings. However, recent data reveal signs of overexploitation. Both species exhibit high fishing mortality (F) exceeding natural mortality (M), low percentages of mature individuals in the catch, and suboptimal representation within the target size range. Seasonal patterns and environmental drivers like upwelling and riverine inputs influence sardine abundance, but overall catch per unit effort (CPUE) has shown instability, partly due to external factors such as the COVID-19 pandemic and fuel costs. Performance indicators suggest both species are under intense fishing pressure, with exploitation rates above sustainable thresholds, including high juvenile catch. Despite their inherent resilience, these stocks' long-term viability is at risk unless management interventions are implemented. These should include reducing juvenile catch, aligning harvests with optimal size classes, improving gear selectivity, and implementing seasonal fishing controls to ensure stock recovery and sustainability.

ACKNOWLEDGMENT

The author expresses sincere gratitude to the Regional Directors of the Bureau of Fisheries and Aquatic Resources (BFAR) Regions 7, 8, 9, 10, and 13 for their unwavering support and cooperation throughout this study. Special thanks are also extended to the National Stock Assessment Program (NSAP) Project Leaders, Data Analysts, and NSAP Technical Enumerators whose dedicated work made this research possible. Their contributions were instrumental in achieving this assessment's objectives.

Table 4. Biological indicators of *Sardinella gibbosa* and *Sardinella lemuru* in FMA 9.

Species	Analysis	Performance Indicator (PIs)	Reference Points (RPs)			Status Result
			Limit	Trigger	Target	
Sardinella gibbosa	**LBAR**	**Fishing Mortality (F/M)**	**2**	**1**	**0.5**	**3.95**
	FROESE	**% Mature**	**50% and less**	**51-89%**	**90-100%**	**18.62%**
		+ - 10% L_{opt}	**80% and less**	**81-99%**	**100%**	**53.3 %**
		% Megaspawner	**30-40%**	**20-30%**	**0%**	**37.23%**
Sardinella lemuru	**LBAR**	**Fishing Mortality (F/M)**	**2**	**1**	**0.5**	**2.37**
	FROESE	**% Mature**	**50% and less**	**51-89%**	**90-100%**	**4.82%**
		+-% L_{opt}	**80% and less**	**81-99%**	**100%**	**48.21%**
		% Megaspawner	**30-40%**	**20-30%**	**0%**	**7.81%**

Above all, the author offers heartfelt thanks to Almighty God for granting the wisdom, patience, and passion to complete this paper in the most meaningful way. All honor and glory belong to Him.

AUTHOR CONTRIBUTIONS

Yasay EB: Supervision. **Cena PMT**: Project administration, Data curation, Writing-Original draft preparation. **Pagalan JGP**: Data curation, Map Visualization, QGIS. **Fajardo MJL:** Data curation and formal analysis, Writing-Original draft preparation. **Pangan JMV**: Formal analysis, writing-review & editing. **Villariza ZA:** Data curation and formal analysis, writing-review & editing. **Salvador RC:** Data curation and formal analysis, writing-review & editing.

CONFLICTS OF INTEREST

The author(s) have no potential conflicts of interest in the conduct and publication of this study.

ETHICS STATEMENT

The authors obtained an authorization/ permit/consent allowing the data collection of fishing gear, weight, and length of fish samples from the Bureau of Fisheries and Aquatic Resources (BFAR) within the Fisheries Management Area (FMA) -9, namely: BFAR Regional Office 7, 8, 9, 10, and CARAGA.

REFERENCES

Allen, G.R. (2008). Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *18*(5), 541–556. https://doi.org/10.1002/aqc.880

Baum, J.K., Myers, R.A., Kehler, D.G., Worm, B., Harley, S.J., & Doherty, P.A. (2003). Collapse and conservation of shark populations in the northwest atlantic. *Science*, *299*(5605), 389–392. https://doi.org/10.1126/science.1079777

Bigelow, K.A., Hampton, J., & Miyabe, N. (2002). Application of a habitat-based model to estimate effective longline fishing effort and relative abundance of Pacific bigeye tuna (Thunnus obesus). *Fisheries Oceanography*, *11*(3), 143–155. https://doi.org/10.1046/j.1365-2419.2002.00196.x

Bureau of Fisheries and Aquatic Resources. (2020). National Sardine Management Plan. Department of Agriculture Bureau of Fisheries and Aquatic Resources; PCA Building, Elliptical Road, Diliman, Quezon City, Philippines.

Bureau of Fisheries and Aquatic Resources. (2023). Philippine Fisheries Profile. Department of Agriculture Bureau of Fisheries and Aquatic Resources; Fisheries Building Complex, BPI Compound, Visayas Ave., Quezon City, Philippines.

Campos, W.L., Barut, N.C., & Santos, M.D. (2024). Assessment of the status of sardine fisheries in the Philippines: A review of current trends and management strategies. National Fisheries Research and Development Institute (NFRDI), Department of Agriculture – Bureau of Fisheries and Aquatic Resources (DA-BFAR), Quezon City, Philippines.

Carpenter, K.E., & Springer, V.G. (2005) . The center of the center of marine shore fish biodiversity: The Philippine Islands. *Environmental Biology of Fishes*, *72*(4), 467–480. https://doi.org/10.1007/s10641-004-3154-4

Cheung, W.W.L., Pitcher, T.J., & Pauly, D. (2005). A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. *Biological Conservation*, *124*(1): 97–111. https://doi.org/10.1016/j.biocon.2005.01.017

Bureau of Fisheries and Aquatic Resources. (2022). Philippine Fisheries Profile. Department of Agriculture Bureau of Fisheries and Aquatic Resources; Fisheries Building Complex, BPI Compound, Visayas Ave., Quezon City, Philippines.

Dalzell, P., Corpuz, P., Arce, F., & Ganaden, S. R. (1990). Philippine small pelagic fisheries and their management. *Aquaculture Research*, *21*(1), 77–94. https://doi.org/10.1111/j.1365-2109.1990.tb00384.x

De Guzman, A.B., Jimenez, C.R., Abrea, R.A., Garcia, J.P., Recamara, D.B., Flores, M.H., Arnejo, M.M., Molina, D.L., Dela Peña, J.D. &

Gimena, M.D.S. (2015). Sustaining the sardine fisheries industry through understanding spatio-temporal dynamics in the Zamboanga Peninsula and Bohol Sea system (SarDyn). Project 2 Terminal Report. MSU Naawan. DOST- PCAARRD. 77 pp.

De Guzman, A.B., Jimenez, C.R., Sajot, C.E., Herrera, L.L., Madula, J.H., Flores, M.H., Garcia, J.P., Salinas, A.R., & Macario A.C. (2012). Climate Change Vulnerability of Coastal Fisheries in Mindanao. Project 6 of the Remote Sensing Information for Living Environments and Nation-wide Tools for Sentinel Ecosystems in our Archipelagic Seas (RESILIENT SEAS) Program for Climate Change. Final Report. Department of Science and Technology (DOST). 60p.

Froese R. 2004. Keep it simple: three indicators to deal with overfishing. Fish Fish. 5(1):86–91. doi:10.1111/j.1467-2979.2004.00144.x

Froese, R., & Binohlan, C. (2000). Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fish Biology 56:758-773.

Froese, R., & Kesner-Reyes, K. (2002). Impact of fishing on the abundance of marine species. ICES CM 2002/K:12. ICES (International Council for the Exploration of the Sea) Council Meeting Papers.

Guanco, M.R., Mesa, S.V., Belga, P.B., & Nuñal, D.P.M. (2009). Assessment of the commercial fisheries of Western and Central Visayan Sea. National Stock Assessment Project, Bureau of Fisheries and Aquatic Resources.

Gulland, J. (1974). Catch per unit effort as a measure of abundance. Collective Volume of Scientific Papers, International Commission for the Conservation of Atlantic Tunas (ICCAT), 3: 1–11.

Hilborn, R., & Walters, C. J. (1992). Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. Chapman and Hall, New York. 570 pp.

Lazarus, S. (1977). Observations on the food & feeding habits of *Sardinella gibbosa* from Vizhinjam. Indian Journal of Fisheries, 24, 107–112

Myers, R.A., & Worm, B. (2003). Rapid worldwide depletion of predatory fish communities. Nature, 423, 280–283.

Nair, R. (1973). Indian sardines (their biology & fishery). CSIR Zoological Monograph (2). CSIR, New Delhi

Nakano, H., & Bayliff, W. H. (1992). A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1981–987. Inter-American Tropical Tuna Commission Bulletin, 20: 187–237.

Narvaez, D. A., Armada, N. B., Catedrilla, R. D., & De Jesus, B. J. (2017). Sardine management in the Zamboanga Peninsula: A policy and institutional analysis. WorldFish and Bureau of Fisheries and Aquatic Resources (BFAR).

Nyunja, J., Mavuti, K., & Wakwabi, E. (2002). Trophic ecology of *Sardinella gibbosa* (Pisces: Clupeidae) & Atherinomorous lacunosus (Pisces: Atherenidae) in Mtwapa Creek & Wasini Channel, Kenya. Western Indian Ocean Journal of Marine Science 1: 181–189.

Philippine Statistics Authority. 2016, January. Philippine fisheries situation report: January to December 2015. Quezon City, Philippines: Philippine Statistics Authority.

Philippine Statistical Analysis. (2025) . 2022 to 2024 Regional Value of Production in Agriculture and Fisheries.

Pope, K.L., & Willis, D.W. (1996). Seasonal influence on CPUE data for largemouth bass, bluegills, and channel catfish in Midwestern lakes. North American Journal of Fisheries Management, 16(3), 614–623.

Richards, L.J., Schnute, J.T., & Olsen, N. (1996). Visualizing catch-per-unit-effort data. Canadian Journal of Fisheries and Aquatic Sciences, 53(4), 743–752. https://doi.org/10.1139/f95-223

Rivera, E., Bendaño, A., Bognot, E. D. C., Gonzales, F., Torres, F. S. B. Jr., Santos, M. D., & Lopez, G. D. V. (2017). Reproductive biology of common small pelagic fishes in Manila Bay, Philippines. The Philippine Journal of Fisheries, 24(1), 47–60.

Sekharan, K. (1969). Spawning concentrations of the sardine, *Sardinella gibbosa* (Bleeker), off the north Andhra coast in March-April 1969. Indian Journal of Fisheries 16: 156–160.

Short, F., Carruthers, T., Dennison, W., & Waycott, M. (2007). Global seagrass distribution and diversity: A bioregional model. Journal of Experimental Marine Biology and Ecology, 350, 3- 20.

Suzuki, Z., Warashina, Y., & Kishida, M. (1977). The comparison of catches by regular and deep tuna longline gears in the western and central equatorial Pacific. Bulletin of the Far Seas Fisheries Research Laboratory, 15: 51-89

Veron, J.E.N., DeVantier, L.M., Turak, E., Green, A.L., Kinimonth, S., Stafford-Smith, M., & Peterson, M. (2009). Delineating the Coral Triangle. Galaxea, 11, 91–100.

Wells, F.E. (2002). Centres of species richness and endemism of shallow-water marine mollusks in the tropical Indo-West Pacific. Proceedings of the 9th International Coral Reef Symposium. P. 941–945.

Willette, D.A., Bognot, E.D.C., Mutia, M.T.M. & Santos, M.D. (2011). Biology and ecology of sardines in the Philippines: A review. Department of Agriculture - Bureau of Fisheries and Aquatic Resources (DA-BFAR), National Fisheries Research and Development Institute (NFRDI) Technical Paper Series XIII (1). Quezon City, Philippines. 20 pp.

Zaragoza, E.C., Pagdilao, C.R., & Moreno, E.P. (2004). Overview of the small pelagic fisheries, pp. 32-37. In Department of Agriculture - Bureau of Fisheries and Aquatic Resources (DA-BFAR). In turbulent seas: The Status of Philippine marine fisheries. Coastal Resource Management Project, Cebu City, Philippines, 378 pp.

© 2026 The authors. Published by the National Fisheries Research and Development Institute. This is an open access article distributed under the CC BY-NC 4.0 license.