The Philippine Journal of Fisheries 2026 NSAP Special Issue: 108 - 128
DOI: 10.31398/tpjf/33.3.2025C0012
September 2026

RESEARCH ARTICLE

# Assessment of the Effects of Fine Mesh Nets on the Stock Status of the Major Fish Stocks in FMA 11, Philippines

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ABSTRACT

The Visayan Sea and Guimaras Strait, which make up Fishery Management Area 11 (FMA 11) in the central Philippines, are major fishing grounds rich in marine resources and the focus of this study. FMA 11 is characterized by a multi-gear, multi-species fishery due to its shallow, highly productive waters. This study examines fishing gears that use fine mesh nets (mesh size <3 cm) at the bunt and assesses their impact on FMA 11 productivity. The objective is to evaluate how fine-mesh nets affect stock status and the fishery's overall health. Using catch and effort data, length frequency, and grid mapping collected from 2015 to 2024 across three regions (5, 6, and 7) within FMA 11, we estimated growth parameters, maturity, and mortality coefficients for 11 priority species. Additionally, we used the open-source applications EcoPath with EcoSim (EwE) and QuantumGIS to improve understanding of the fishery's status. Results indicate that most species in FMA 11 have exceeded reference points for both maturity and exploitation, revealing high juvenile catches and intense fishing pressure. Spatial mapping showed that commercial fishing gears frequently encroach into municipal waters, while overlapping use of municipal gears—especially fine mesh nets—has led to growth and recruitment overfishing. Simulations and gear distribution analyses from EwE suggest that reducing fishing effort by 40%—achieved through the removal of illegal, unreported, and unregulated (IUU) fishing gears and fine mesh nets—could allow biomass recovery and improve fish stocks in FMA 11 within approximately three years.

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Received: *November 27, 2025*
Accepted: *June 29, 2026*

**Keywords:** *FMA 11, fine mesh net, overfishing, reference points, harvest control rule*

## 1. INTRODUCTION

Fisheries Administrative Order (FAO) 263, series of 2019, mandates the establishment of Fisheries Management Areas (FMAs) to conserve and sustainably manage fisheries in Philippine waters (BFAR 2020). Section 8 of the amended Fisheries Code recommends the creation of Reference Points (RP), Harvest Control Rules (HCR), and Harvest Control Measures (HCM) as part of FMA implementation. The Philippines is divided into 12 FMAs, each with designated lead and member regions responsible for locally managing and implementing fisheries management initiatives. In line with the amended code's science-based policy approach, the Scientific Advisory Group (SAG) provides the scientific evidence necessary for policy formulation and implementation.

FMA 11 includes the Visayan Sea, Guimaras Strait, and the Tañon Strait Protected Seascape (TSPS). The Visayan Sea and Guimaras Strait, including their open fishing areas, are designated fishing zones. In contrast, TSPS is a legally established no-fishing zone under Presidential Proclamation 1234 (1998) and Republic Act 11038 (2019) of the Expanded National Integrated Protected Area System Act (ENIPAS). The vast fishing grounds of FMA 11, particularly the Visayan Sea, are highly biodiverse and rich in small pelagic, demersal, and benthic resources that contribute to the ecosystem's richness (Pauly 2004). It is also one of the country's major fishing grounds,

supplying substantial fishery resources and supporting income and livelihoods across the entire value chain (Zaragoza et al. 2004; Armada 2004; Guanco et al. 2009).

The fishing grounds within FMA 11, including the Visayan Sea and Guimaras Strait, are highly productive areas supported by critical marine habitats. However, this abundance has led to decades of overfishing, with fishing effort steadily increasing in both commercial and municipal sectors and often remaining unregulated (Silvestre and Ganaden 1987). According to Guanco et al. (2009), growth and recruitment overfishing have contributed to the decline in fish stocks, although the exact causes were not clearly identified.

Fishing with fine mesh nets is a traditional practice in tropical countries, primarily targeting small-sized aquatic species (Monteclaro and Abunal 2013). Fine mesh nets, defined by a mesh size of less than 3 cm, are commonly used in the Visayan Sea and nearby fishing grounds. Regalado et al. (2023) observed boat seines equipped with fine mesh nets operating off Concepcion, Iloilo, mainly capturing post-larvae and early juveniles of species from the Engraulidae and Clupeidae families. Monteclaro and Abunal (2013) reported that juvenile fish made up about 39% of the catch from beach seines in the Northern Panay Gulf, with Clupeids as the dominant group. Similarly, research in Jordan, Guimaras found that filter nets primarily capture juveniles and fish larvae (Santander and Monteclaro 2018).

These studies collectively show that fine-mesh nets capture immature fish, preventing them from maturing—a process known as growth overfishing. Growth overfishing reduces the average size of fish caught and depletes target species, which are often replaced by smaller, fast-growing fish (Armada 2004). The resulting scarcity of adult fish reduces species recruitment, ultimately causing declines in overall fish production and economic returns (Banicod et al. 2021).

Given the documented adverse effects of fine mesh net use in a fishing ground already considered heavily exploited (Hermes et al. 2004; Guanco et al. 2009; Bagsit et al. 2021; Regalado et al. 2023), it is crucial to identify the specific fishing gears that significantly contribute to overfishing in FMA 11.

This study aims to provide scientific information to support policy formulation, implementation, and fisheries management initiatives in FMA 11 for sustainable fisheries.

Specifically, in order to assess the status of stocks, several key aspects of the fishery will be used as reference. This information includes estimating the distribution of sizes for catches of major fish species in reference to length at maturity, determining the levels of fishing exploitation among the major fish species, an inventory of fishing gears and their relative distribution, identification of fishing areas of operation with emphasis on fine-meshed gears, as well as simulation of the effects of removal and non-removal of gears using fine-meshed nets.

In addition, data collection on fish catch landings was not conducted in the Tañon Strait since it is classified as a protected seascape.

## 2. MATERIALS AND METHODS

### 2.1 Study site

FMA 11, shown in Figure 1, is located in the central Philippines, between latitudes 9°21'31.37" and 9°58'54.28" North and longitudes 122°28'38.49" and 123°17'29.45" East. It covers approximately 2,038,600 hectares and is bordered by the provinces of Masbate (Region 5); Capiz, Northern Iloilo, North-central Negros Occidental, and Guimaras (Region 6); and Northwestern Cebu and Negros Oriental (Region 7), encompassing 90 coastal municipalities and cities.

FMA 11, is bounded by three political regions (5, 6, and 7) covering four provinces: Cebu, Iloilo, Masbate, and Negros Occidental. Table 1 and Figure 2 shows the 49 NSAP-monitored landing sites broken down by region, province, and coastal municipalities/cities. Each area has an assigned field enumerator to record daily landings of catch and effort, species composition, biological measurements of major species, and the area of operation using a grid map. Each monitored fish landing site was categorized as major (fish ports) or minor (primarily municipal fish landings).

### 2.2 On-field data collection

Data collection follows the NSAP protocol of two consecutive sampling days (Santos et al. 2017). Supplemental data such as fishing location grid codes is also recorded.

Length was measured as total length (TL) in centimeters (cm) using a scale, from the tip of the snout to the tip of the caudal fin. For the reproductive biology data, individual length in cm, weight in grams, sex, and gonadal stages were determined. Dissection was performed to identify sex, and the five-point scale (İşmen 2003) of gonadal maturity development was used to determine gonad stages. After gonadal stage

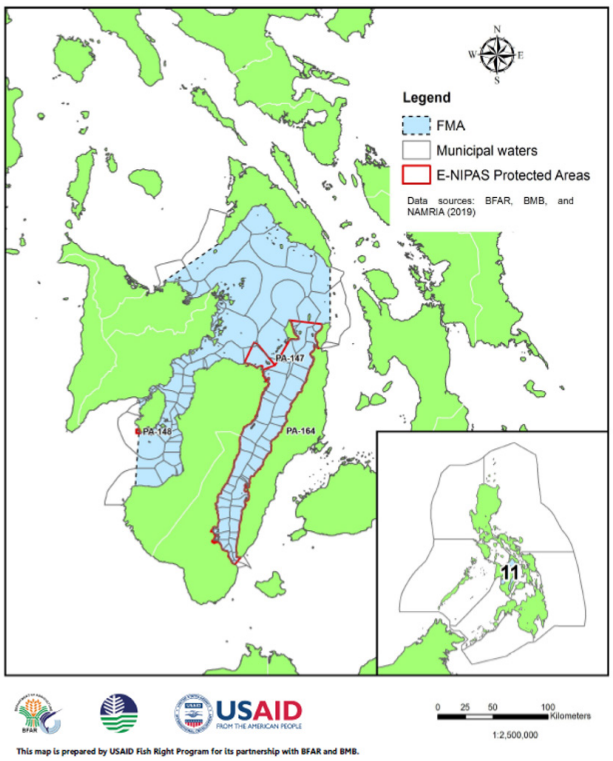



Figure 1. Map showing the location of FMA 11 and its bordering islands in the central part of the Philippines.

Table 1. List of municipalities covered by FMA 11 with established NSAP monitoring sites as of CY 2024.

| Region | Coastal City/ Municipalities | Number of monitored sites | Classification |
|---|---|---|---|
| 5 | Balud, Masbate | 2 | Minor |
| | Cawayan, Masbate | 2 | Minor |
| | Milagros, Masbate | 3 | Minor |
| | Placer, Masbate | 3 | Minor |
| 6 | Ajuy, Iloilo | 4 | Major |
| | Banate, Iloilo | 1 | Minor |
| | Barotac Viejo, Iloilo | 1 | Minor |
| | Batad, Iloilo | 1 | Minor |
| | Carles, Iloilo | 3 | Major |
| | Concepcion, Iloilo | 2 | Major |
| | Estancia, Iloilo | 2 | Major |
| | Iloilo City | 1 | Major |
| | San Dionisio, Iloilo | 2 | Minor |
| | Panay, Capiz | 1 | Minor |
| | Pilar, Capiz | 4 | Major |
| | Pontevedra, Capiz | 1 | Minor |
| | President Roxas, Capiz | 1 | Minor |
| | Roxas City, Capiz | 3 | Major |
| | Cadiz City, Negros Occidental | 2 | Major |
| | EB Magalona, Negros Occidental | 1 | Minor |
| | Manapla, Negros Occidental | 1 | Minor |
| | Sagay City, Negros Occidental | 1 | Minor |
| | Victorias City, Negros Occidental | 1 | Major |
| 7 | Bantayan, Bantayan Island | 1 | Minor |
| | Madridejos, Bantayan Island | 1 | Minor |
| | Daanbantayan, Cebu | 2 | Major |
| | Medellin, Cebu | 1 | Major |
| | Sta. Fe, Cebu | 1 | Minor |

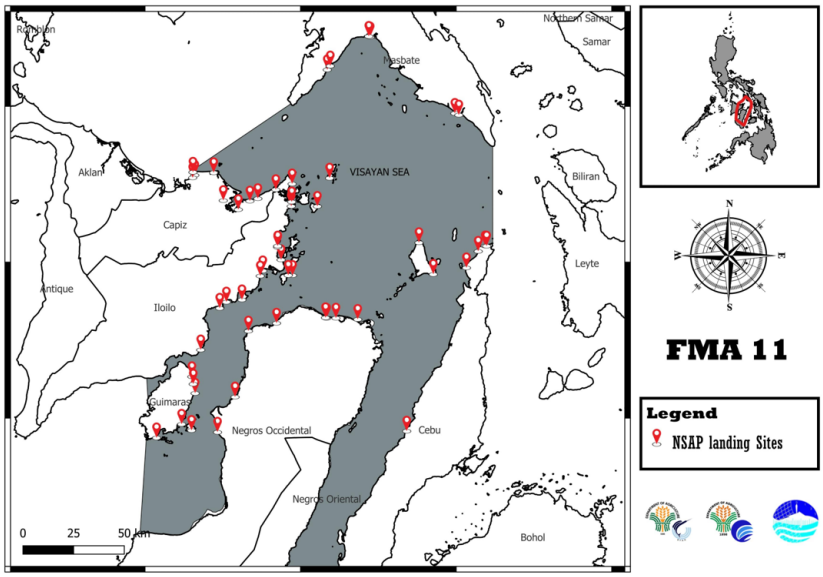



Figure 2. Map showing the fish ports and fish landing centers monitored in FMA 11 from 2015 to 2024.

identification, gonads were extracted and weighed using the gram unit.

After field enumerators collected all data types, Region 6 data was encoded through the ODK (Open Data Kit) Collect Application, with the KoboToolbox server as the cloud storage for all encoded data. Data analysts subsequently download the data through the ODK Database.

Because the regions encode and store data differently, data consolidation uses a single data matrix. Data consolidation, conducted annually, is done in order to ensure information is systematically presented into a single and unified dataset, minimize errors, and enable better analysis and processing to come up with an FMA-wide working data file and subsequently come up with consolidated results.

### 2.3 Data management

#### 2.3.1 Length frequency data treatment

Length frequency data collected from monitored sites were transferred to a Microsoft Excel spreadsheet that serves as a common template for Regions 5, 6, and 7. This template enabled error tracking, editing, data reconciliation, sorting, and filtering, carried out using the pivot table function and descriptive statistical processes. The template also supports daily data raising and monthly merging for the 11 priority species listed in Table 2.

#### 2.3.2 Biological data

Eleven sets of length-frequency data on the species listed in Table 2, covering ten years, were processed. Actual length-frequency data were weighted on each sampling day using the equation:

$$Rf = \frac{\text{Total weight of sub-sampled species}}{\text{Total weight landed of the species}} \quad \text{eqn.1}$$

The resulting Rf values were multiplied by the actual length frequency in each class interval per sampling day and accumulated monthly to obtain the resulting raised frequency. Comparisons of length frequency were made to determine the size range prior to first maturity. The same datasets were then uploaded and processed using the FAO-ICLARM Stock Assessment Tool (FiSAT) version 1.2.2 (Windows) to estimate population parameters.

Rapid assessments validating the size distribution of target species caught by fine-meshed gears were undertaken by obtaining samples from the landed catch at the monitored landing sites. Sub-samples obtained were subjected to species identification. For each identified species, individual lengths were measured using a centimeter gauge. Each data point was then systematically documented and recorded accordingly.

Table 2. List of species as population indicators of FMA 11 and their corresponding gear sources analyzed during data consolidation, covering CY 2015 to 2024.

| Species | English name | Length frequency data gear source |
|---|---|---|
| *Atule mate* | Yellowtail scad | (13) BSGNF, Cast net, DGN, DIN, DS, EGN, HL, MWT, PS. RNFF, ScN, SSGN, TB |
| *Selar crumenophthalmus* | Bigeye scad | (14) BSGNF, BSLL, DGN, DS, FP, FT, HL, MHL, MWT, OT, PS, RN (Arong), SSGN, SpGC |
| *Selaroides leptolepis* | Yellow stripe scad | (26) BgN, Cast net, CT, DIN, EGN, FC, FS/MH, FT, MCN, MHL, MWT, OT, PS, RLN, RN(Arong), RNFF, SN, SqP, TB, BSGNF, DGN, DS, RNAC, ScN, SLN, SSGN |
| *Rastrelliger brachysoma* | Short/Chub mackerel | (10) BSGNF, Cast net, DGN, DS, EGN, MHL, MWT, OT, PS, SSGN |
| *Rastrelliger kanagurta* | Indian mackerel | (14) BgN, BSGNF, BSLL, Cast net, DGN, DS, EGN, FP, HL, MHL, MWT, OT, PS, SSGN |
| *Sardinella gibbosa* | Gold-stripe sardine | (24) BgN, BS, BSGNF, Cast net, DGN, DIN, DS, EGN, FC, FT, MCN, MHL, MWT, OT, PS, RHS, RLN, RN(Arong), RNAC, RNFF, ScN, SLN, SSGN, TB |
| *Sardinella lemuru* | Bali sardine | (17) BgN, BrN, BSGNF, BSLL, Cast net, DGN, DS, EGN, FC, MHL, MWT, OT, PS, RHS, RN(Arong), RNAC, SSGN |
| *Scolopsis taenioptera* | Lattice monocle bream | (24) BS, BSGNC, BSGNF, BSLL, Cast net, CP, CT, DGN, DGNm, DIN, DS, EGN, FP, FT, HL, HLM1, MHL, MWT, OT, PS, RHS, RNFF, ScN, SpGC |
| *Saurida tumbil* | Greater lizardfish | (8) BSGNF, BSLL, DGN, DS, FC, H, OT, SSGN |
| *Upeneus asymmetricus* | Asymmetrical goatfish | (6) BSGNF, DGN, DS, FP, OT, SSGN |
| *Upeneus moluccensis* | Goldband goatfish | (7) BSGNF, BSLL, Cast net, DGN, DS, SSGN, SpGC |

#### 2.3.3 Fishing gears and effort inventory

A census of fishing vessels was conducted from April to July 2025 simultaneously in NSAP Regions 5, 6, and 7. The census monitored all fish landing centers in both NSAP-monitored and unmonitored sites using a Key Informant Interview (KII) process. Data collected included profile information, brief demographics (including male and female separation), gear characteristics, and boat specifications. Data collection also included initial measurements to estimate the tonnage of the boats used.

#### 2.3.4 Fishing areas

FMA 11 uses a grid system for 2024, starting in the western part of FMA 11 within Region 6 as the test area, to map the fishing operation area using the most recent data collected. Assigned field enumerators use grid maps and ask fishers to point to a specific location by physically marking the map or identifying the grid cell coordinates. Once field enumerators identify a fishing area, they record the location using grid codes. Each grid code corresponds to a unique 2 km x 2 km grid box and is written in the following format:

[Grid Code: Alphanumeric format: Column/ Longitude (Letter) – Row/Latitude (Number)]

a. Major grid number: refers to the larger grid area with multiple 2 km x 2 km boxes in the grid map. Assigned major grid numbers for the FMA 11 range from 500 to 592.

b. Column letter: any letter from A to Y

c. Row name: any number from 1 to 25

In every fishing operation, field enumerators record grid codes. These grid codes determine the specific longitude and latitude coordinates of fishing activities. The collected coordinates are then imported into the Quantum Geographic Information System (GIS) open-source application to generate mapping information for FMA 11.

### 2.4 Data analysis

#### 2.4.1 Size distribution

Using the pivot table function in Microsoft Excel, raised length frequency data of the 11 priority species were grouped into 5 cm length class intervals, with corresponding mid-lengths for each class. The Length at first maturity ($L_m$), defined as the length at which 50% of the fish population reached reproductive maturity, was estimated from the proportion of mature individuals in the data set. The estimates were fitted and calculated using a logistic curve (Paloheimo and Cadima 1964) as:

$$P = \frac{1}{1 + \exp(S_1 + S_2 \times L)} \quad \text{eqn. 2}$$

Where P is the proportion of mature individuals within a length class, $S_1$ is the intercept, $S_2$ is the slope, and L is the midpoint length.

The same raised length frequency data were also used for the processing of Froese's method. For each of the 11 priority species, the mid-lengths were classified relative to the length at first maturity ($L_m$) to determine whether individuals were mature or immature. Froese (2004) underscores that overfishing consists of two components: (i) recruitment overfishing that occurs when there is diminished capacity of fish to reproduce a new cohort of fishable population and (ii) catching the fish before they can fully realize their growth potential, called growth overfishing. These can be detected by three simple indicators: (i) percentage of mature fish in the catch, with 100% as the target; (ii) percentage of specimens with optimum length in the catch, with 100% as the target; and (iii) percentage of 'mega-spawners' in the catch, with 0% as the target.

This study focuses on the first indicator: the percentage of mature fish in the population. The principle behind indicator (i) is "Let them spawn," measured by the percentage of mature sizes in the catches, a concept that fish are allowed to reproduce before they are caught. Length at first capture ($L_c$), mean length, and length at first maturity are compared to validate whether indicator 1 conforms to this principle. In the absence of an empirical value for length at first maturity using the logistic curve principle, an arbitrary value will be used by plotting the growth parameters of the species in the life history tool in FishBase (Froese and Pauly 2025).

### 2.4.2 Growth and mortalities

The asymptotic length ($L_\infty$) is the length that a species would reach if it lived indefinitely, while the growth coefficient (k) is a measure of the rate at which the maximum size is attained (Bertalanffy 1938, as cited in Edmond et al. 2017).

Growth parameters were determined first by estimating $L_\infty$ (asymptotic length) using the Powell-Wetherall method (Gayanilo and Pauly 1997) based on the equation of Beverton and Holt (1956):

$$Z = k((L_\infty - L) / (L - L')) \quad \text{eqn. 3}$$

Where Z is the total instantaneous mortality, k is the growth coefficient, L is the mean length, $L_\infty$ is the asymptotic length, and L' is the initial length of the sample.

The estimated value of $L_\infty$ was further processed in ELEFAN I (Electronic Length Frequency Analysis) (Gayanilo and Pauly 1997) to verify $L_\infty$ and k. Analysis of the estimation of growth parameters and mortality used the von Bertalanffy (1934) growth equation:

$$Lt = L_\infty (1 - e^{-k(t-to)}) \quad \text{eqn. 4}$$

Where Lt is the length of fish at age t, e is the base of the Napierian logarithm, while to is the hypothetical age the fish would attain at length zero.

Mortality and exploitation rate were then calculated using the equation:

$$Z = M+F \quad \text{eqn. 5}$$

Where Z is the instantaneous total mortality, M is the instantaneous natural mortality due to predation, aging, and other environmental causes, and F is the instantaneous fishing mortality caused by fishing.

Furthermore, M was estimated using Pauly's (1984) empirical formula:

$$\text{Log } M = 0.654 \text{ Log } k - 0.28 \text{ Log } L_\infty + 0.463 \text{ Log} T \quad \text{eqn. 6}$$

where $L_\infty$ and k are the Von Bertalanffy Growth Function (VBGF) growth parameters, and T is the annual mean habitat temperature (°C) of the water in which the stock in question lives.

Expanding the equation for mortality would lead us to the computation of the exploitation rate using:

$$E = F/Z \quad \text{eqn. 7}$$

where E is the exploitation rate; using the equation from growth parameters and mortalities, prediction of recruitment patterns and virtual population analysis could be estimated using the routines found in FiSAT II programs (Gayanilo and Pauly 1997).

The exploitation rate is the proportion of the number or biomass removed by fishing. It indicates whether the stock is $E < 0.5$ or $E > 0.5$, suggestive of overexploitation (Ingles and Pauly, 1984), based on the assumption that fish are optimally exploited when $F = M$ or $E = 0.5$ (Gulland 1983, as cited in Edmond et al. 2017).

The probability of capture ($L_c$) is an important parameter because it clearly indicates the estimated real size of fish in a fishing area that are vulnerable to a specific gear. The probability of capture is computed from the length-converted catch curve. A selectivity

curve was generated using a linear regression fit, which was used to estimate the final values of $L_{25}$, $L_{50}$, and $L_{75}$ (Edmond et al. 2017). $L_{50}$ is a commonly monitored reproductive trait that provides the sex-specific length at which 50% of fish are expected to develop gonads near the spawning period (Mainguy et al. 2024). The probability of capture and $L_{50}$ in this study were computed using the FISAT II package.

#### 2.4.3 Fishing effort inventory

Data collected from the census of boats and gears will be used as the primary input to determine fishing gears using fine mesh. This provides the overall picture of fishing gear typology and how it affects information derived from biological parameters. This will answer the question, "how many of them and where" they operate in FMA 11.

#### 2.4.4 Fishing operation grid mapping

Data derived from the census and those collected from monitored catch and effort landed will be plotted to visualize where each gear type operates within FMA 11. The frequency bubble was used to create visual representations using the CY 2024 data sets.

#### 2.4.5 Trophic systems modeling and simulation

Ecopath with Ecosim (EwE) is free software designed for the straightforward construction, parameterization, and analysis of mass-balance trophic models of aquatic and terrestrial ecosystems (Christensen et al. 2005). Data required to design a trophic model are biomass (B), production/biomass (P/B), consumption/biomass (Q/B), diet composition (DC), ecotrophic efficiency (EE), and fishery landings (Y), summarized by the Ecopath master equation (eqn. 8), which was used to construct an ecosystem model for the Visayan Sea. The model was then used to simulate various Visayan Sea scenarios, following Bacalso et al. (2023).

$$(P/B)_i * B_i = Y_i + B_j *(Q/B)_j * (DC)_{ji} + E_i + (B/A)_i + (P/B)_i * (Bi)_i (1-EE_i) \quad \text{eqn. 8}$$

## 3. RESULTS

### 3.1 Size distribution

Studies by several authors in different countries show that depletion of natural marine resources is faster than the stocks' ability to replenish their populations (Christensen et al. 2003). Results from this kind of study identify growth and recruitment overfishing (Froese 2004) as effects of fishing activities. Figure 3 shows the relationship among various length indicators, such as length at maturity ($L_m$), length at captivity ($L_{50}$), and average lengths (LBAR) of the major species caught in FMA 11. Results for *U. asymmetricus* are not presented due to insufficient data. Ideally, $L_m$ should be larger than $L_{50}$ and LBAR, indicating that fish can mature and reproduce before they are taken as part of the catch. As the figure indicates, catch sizes of *S. lemuru* showed that $L_{50}$ and LBAR are larger than $L_m$, indicating good condition. *S. leptolepis* and *S. gibbosa* showed almost the same sizes for $L_m$, $L_{50}$, and average length. *S. crumenophthalmus* showed the same sizes in the early years, while breaching LRP was observed in CY 2023 and 2024. In contrast, most species showed LRP breaches, with $L_{50}$ and LBAR below $L_m$, including *A. mate, R. brachysoma, R. kanagurta, S. tumbil*, and *S. taenioptera*, indicating recruitment overfishing.

The Froese indicator for the ratio of mature and immature sizes in this study followed an 80% TRP and 50% LRP as agreed by the members of the FMA 11 Scientific Advisory Group (SAG). Coming from an overfished state for decades, 100% mature-sized catches are far from an ideal target. Table 3, using the Froese indicator, showed that stocks following the set TRP include *A. mate* and *S. crumenophthalmus*. Stocks within the fair status include *S. leptolepis*, *R. brachysoma*, *S. gibbosa* and *S. lemuru*. Fish stocks breaching the LRP include demersal species such as *S. taenioptera*, *S. tumbil*, and *U. moluccensis*. Subsequent catching of small fish eventually leads to growth overfishing, which supports the premise of an overfished stock as stated previously.

Based on the processed length-distribution data, 41 fishing gear types are the sources shown in Figures 4 to 14. Mature sizes caught at 80% are set at TRP, at 50% classified as LRP, and values below 50% are classified as breaching LRP. Table 2 shows the various overlaps of fishing gears catching the major species. Across all major species, results showed that fishing gears catching the TRP level include selective gears such as gillnets and hook and lines. Those breaching and within LRP include a wide variety of fishing gear, including non-selective gear such as trawls, seines, traps, fine-meshed nets like RNAC or *Sinsuro*, barriers, lift nets, filter nets, cast nets, and spearfishing. Another point to consider is bycatch from all gear, including immature-sized individuals of any species in the catch.

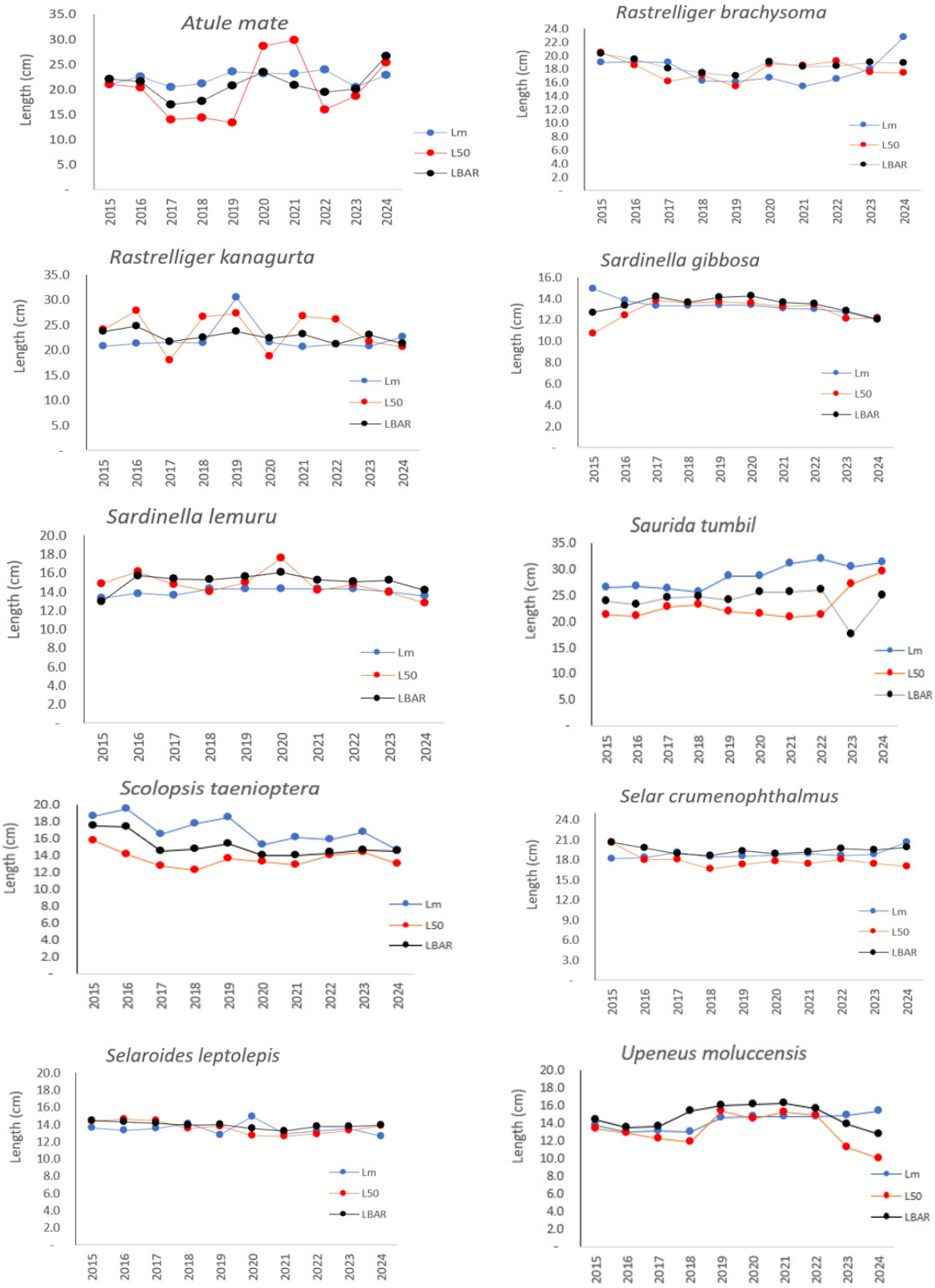
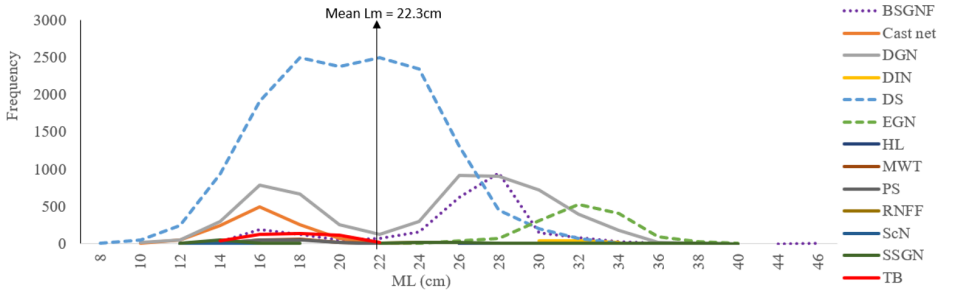



Figure 3. Graphs showing the comparative length indicators as length at maturity (Lm), length at first capture ($L_{50}$), and average length (LBAR) of the major species in FMA 11 covering the years 2015 to 2024.

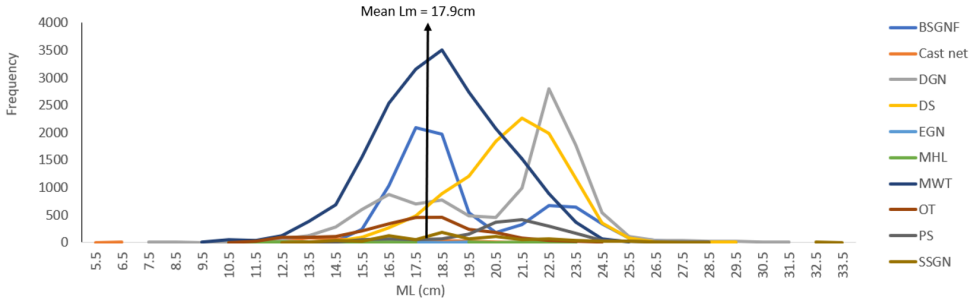
Table 3. Data showing the ratio of mature and immature sizes following the Froese ratio indicator, with TRP set at 80% mature-size catches, for the 11 major species of FMA 11 covering the period from CY 2014 to 2024.

| Species | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Target Reference Point (TRP) 80% mature | | | Limit Reference Point (LRP) 50% mature | | | | | | |
| *A. mate* | 65 | 38 | 11 | 14 | 34 | 50 | 25 | 11 | 33 | 99 |
| *S. crumenophthalmus* | 93 | 87 | 76 | 71 | 68 | 85 | 77 | 88 | 88 | 94 |
| *S. leptolepis* | 92 | 86 | 85 | 83 | 77 | 79 | 67 | 77 | 82 | 78 |
| *R. brachysoma* | 88 | 81 | 60 | 53 | 46 | 78 | 74 | 76 | 69 | 69 |
| *R. kanagurta* | 71 | 58 | 41 | 41 | 43 | 45 | 51 | 39 | 51 | 46 |
| *S. gibbosa* | 70 | 79 | 40 | 62 | 96 | 92 | 86 | 82 | 77 | 72 |
| *S. lemuru* | 56 | 72 | 65 | 78 | 87 | 92 | 76 | 83 | 85 | 78 |
| *S. taenioptera* | 33 | 25 | 15 | 11 | 14 | 37 | 16 | 18 | 12 | 41 |
| *S. tumbil* | 27 | 22 | 31 | 37 | 17 | 13 | 6 | 8 | 13 | 7 |
| *U. asymmetricus* | 20 | 37 | - | 42 | 58 | | | Data insufficient | | |
| *U. moluccensis* | 61 | 73 | 58 | 76 | 67 | 77 | 75 | 63 | 24 | 8 |



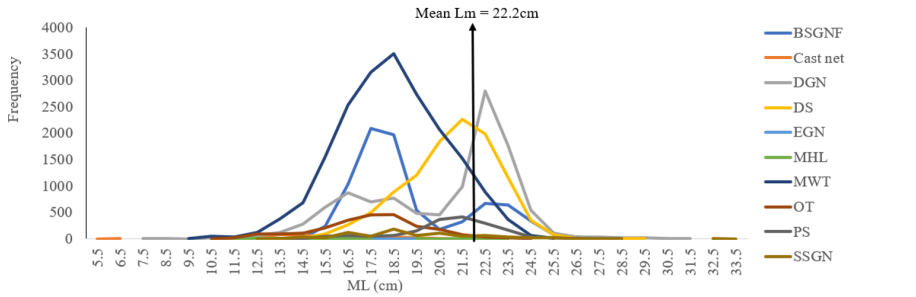

| *A. mate* | BSGNF | Cast net | DGN | DIN | DS | EGN | HL | MWT | PS | RNFF | ScN | SSGN | TB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Immature | 16% | 100% | 36% | 0% | 54% | 0% | 0% | 98% | 98% | 0% | 100% | 49% | 95% |
| mature | 84% | 0% | 64% | 100% | 46% | 100% | 100% | 2% | 2% | 100% | 0% | 51% | 5% |

Figure 4. Length distribution of *A. mate* from different gear sources caught in FMA 11 from 2015 to 2024.



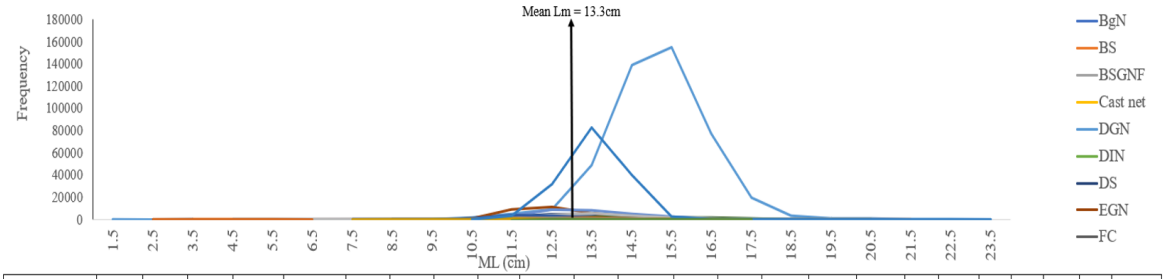

| *R. brachysoma* | BSGNF | Cast net | DGN | DS | EGN | MHL | MWT | OT | PS | SSGN |
|---|---|---|---|---|---|---|---|---|---|---|
| Immature | 16% | 74% | 19% | 4% | 81% | 80% | 27% | 37% | 8% | 24% |
| mature | 84% | 26% | 81% | 96% | 19% | 20% | 73% | 63% | 92% | 76% |

Figure 5. Length distribution of *R. brachysoma* from different gear sources caught in FMA 11, 2015 to 2024.



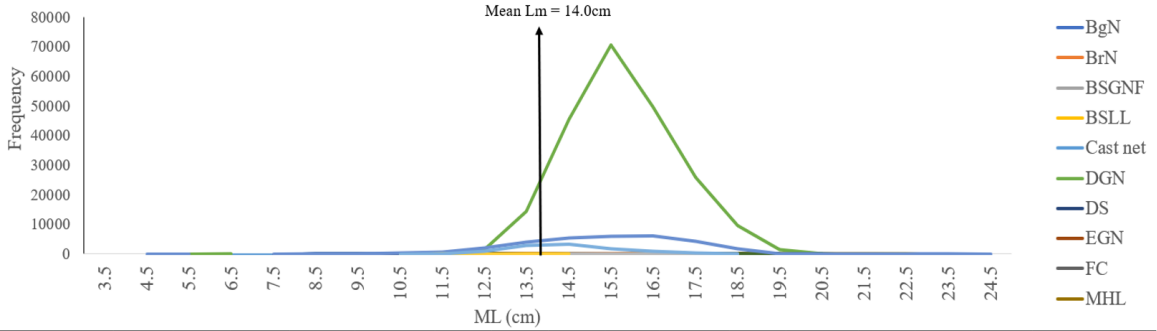

| *R. kanagurta* | BgN | BSGNF | BSLL | Cast net | DGN | DS | EGN | FP | HL | MHL | MWT | OT | PS | SSGN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Immature | 33% | 0% | 65% | 100% | 1% | 10% | 3% | 100% | 9% | 49% | 65% | 69% | 30% | 1% |
| Mature | 67% | 100% | 35% | 0% | 99% | 90% | 97% | 0% | 91% | 51% | 35% | 31% | 70% | 99% |

Figure 6. Length distribution of *R. kanagurta* from different gear sources caught in FMA 11, covering 2015 to 2024.



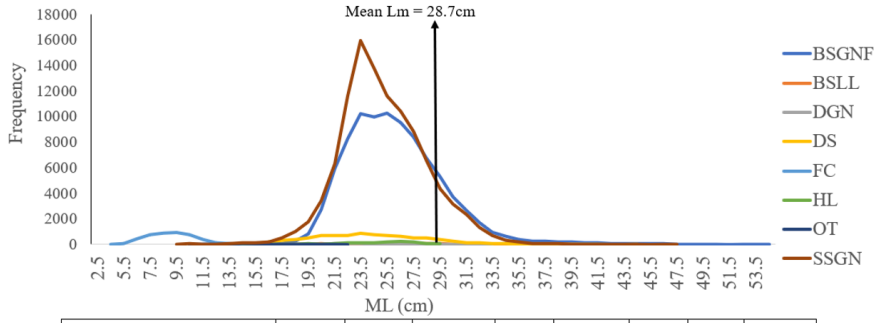

| *S. gibbosa* | BgN | BS | BSGNF | Cast net | DGN | DIN | DS | EGN | FC | FT | MCN | MHL | MWT | OT | PS | RHS | RLN | RN | RNAC | RNFF | ScN | SLN | SSGN | TB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Immature | 56% | 92% | 32% | 83% | 3% | 9% | 47% | 73% | 61% | 49% | 75% | 33% | 43% | 44% | 32% | 0% | 96% | 63% | 82% | 57% | 50% | 89% | 21% | 15% |
| Mature | 44% | 8% | 68% | 17% | 97% | 91% | 53% | 27% | 39% | 51% | 25% | 67% | 57% | 56% | 68% | 100% | 4% | 37% | 18% | 43% | 50% | 11% | 79% | 85% |

Figure 7. Length distribution of *S. gibbosa* from different gear sources caught in FMA 11, covering 2015 to 2024.



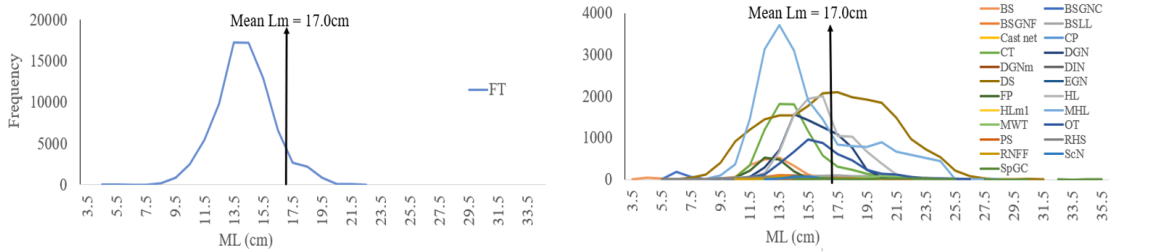

| *S. lemuru* | BgN | BrN | BSGNF | BSLL | Cast net | DGN | DS | EGN | FC | MHL | MWT | OT | PS | RHS | RN | RNAC | SSGN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Immature | 0.4% | 63% | 0.4% | 0% | 86% | 7% | 69% | 65% | 52% | 0% | 5% | 21% | 23% | 7% | 0% | 90% | 38% |
| Mature | 99.6% | 38% | 99.6% | 100% | 14% | 93% | 31% | 35% | 48% | 100% | 95% | 79% | 77% | 93% | 100% | 10% | 62% |

Figure 8. Length distribution of *S. lemuru* from different gear sources caught in FMA 11, 2015 to 2024.



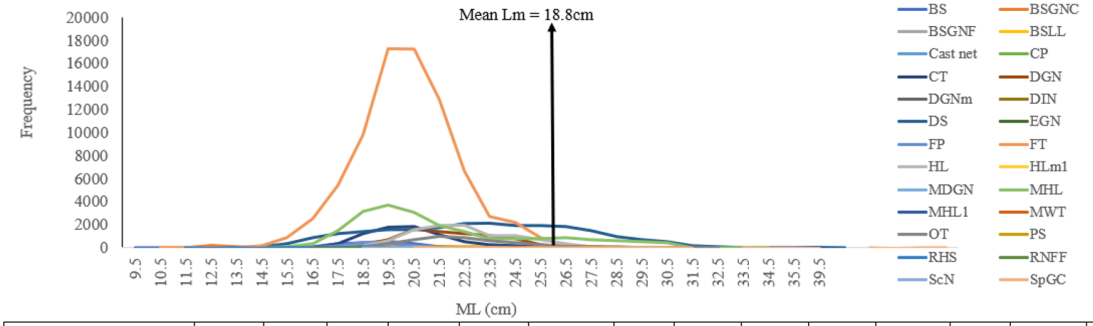

| *S. tumbil* | BSGNF | BSLL | DGN | DS | FC | HL | OT | SSGN |
|---|---|---|---|---|---|---|---|---|
| Immature | 74% | 69% | 91% | 81% | 100% | 89% | 100% | 82% |
| Mature | 26% | 31% | 9% | 19% | | 11% | | 18% |

Figure 9. Length distribution of *S. tumbil* from different gear sources caught in FMA 11, 2015 to 2024.



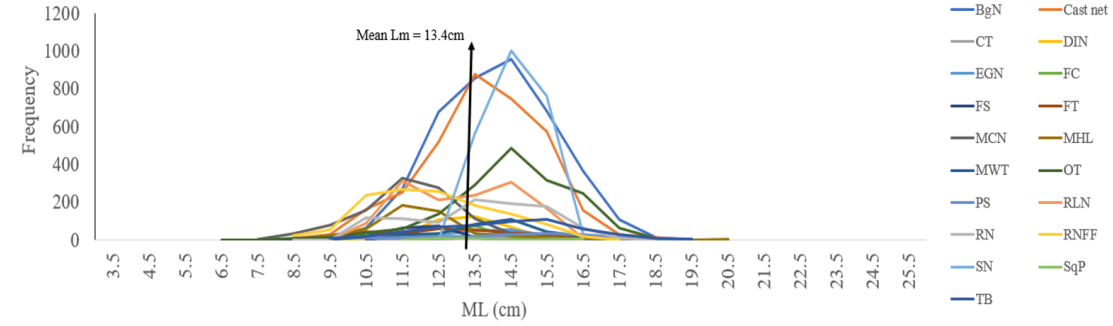

| *S. taenioptera* | BS | BSGNC | BSGNF | BSLL | Cast net | CP | CT | DGN | DGNm | DIN | DS | EGN | FP | FT | HL | HLm1 | MHL | MWT | OT | PS | RHS | RNFF | ScN | SpGC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Immature | 99% | 84% | 73% | 31% | 66% | 98% | 90% | 71% | 24% | 98% | 48% | 97% | 96% | 92% | 66% | 87% | 73% | 32% | 65% | 71% | 100% | 89% | 96% | 18% |
| Mature | 1% | 16% | 27% | 69% | 34% | 2% | 10% | 29% | 76% | 2% | 52% | 3% | 4% | 8% | 34% | 7% | 27% | 68% | 35% | 29% | 0% | 11% | 4% | 82% |

Figure 10. Length distribution of *S. taeniptera* from different gear sources caught in FMA 11, 2015 to 2024.



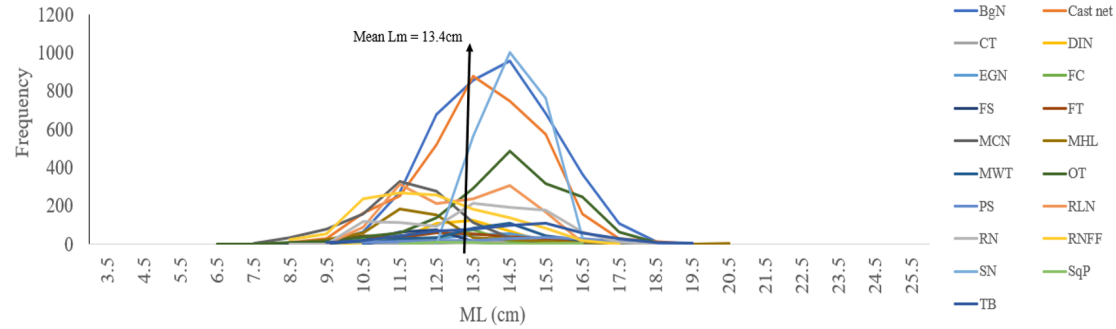

| *S. crumenophthalmus* | BSGNF | BSLL | DGN | DS | FP | FT | HL | MHL | MWT | OT | PS | RN | SSGN | SpGC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Immature | 11% | 0% | 1% | 11% | 22% | 100% | 45% | 4% | 36% | 28% | 25% | 28% | 13% | 46% |
| Mature | 89% | 100% | 99% | 89% | 78% | 0% | 55% | 96% | 64% | 72% | 75% | 72% | 87% | 54% |

Figure 10. Length distribution of *S. taeniptera* from different gear sources caught in FMA 11, 2015 to 2024.

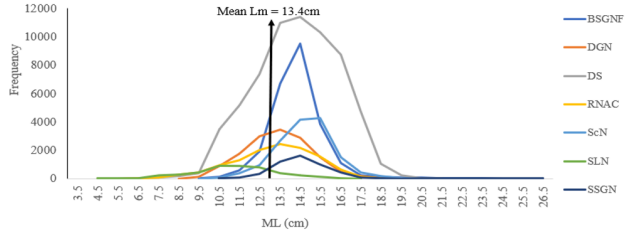



| *S. leptolepis* | BgN | Cast net | CT | DIN | EGN | FC | FS | FT | MCN | MHL | MWT | OT | PS | RLN | RN | RNFF | SN | SqP | TB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Immature | 25% | 29% | 15% | 42% | 31% | 50% | 91% | 52% | 85% | 81% | 19% | 16% | 25% | 46% | 33% | 66% | | 39% | 27% |
| Mature | 75% | 71% | 85% | 58% | 69% | 50% | 9% | 48% | 15% | 19% | 81% | 84% | 75% | 54% | 67% | 34% | 100% | 61% | 73% |

Figure 11. Length distribution of *S. crumenophthalmus* from different gear sources caught in FMA 11, covering 2015 to 2024.

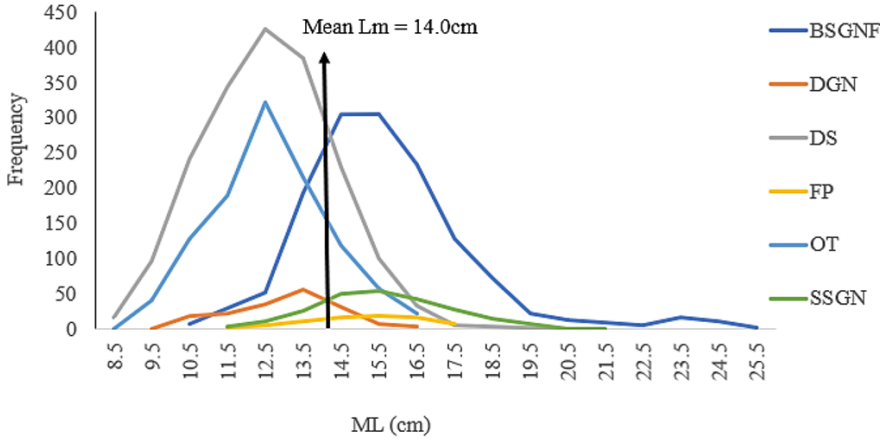



| *S. leptolepis* | BgN | Cast net | CT | DIN | EGN | FC | FS | FT | MCN | MHL | MWT | OT | PS | RLN | RN | RNFF | SN | SqP | TB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Immature | 25% | 29% | 15% | 42% | 31% | 50% | 91% | 52% | 85% | 81% | 19% | 16% | 25% | 46% | 33% | 66% | | 39% | 27% |
| Mature | 75% | 71% | 85% | 58% | 69% | 50% | 9% | 48% | 15% | 19% | 81% | 84% | 75% | 54% | 67% | 34% | 100% | 61% | 73% |



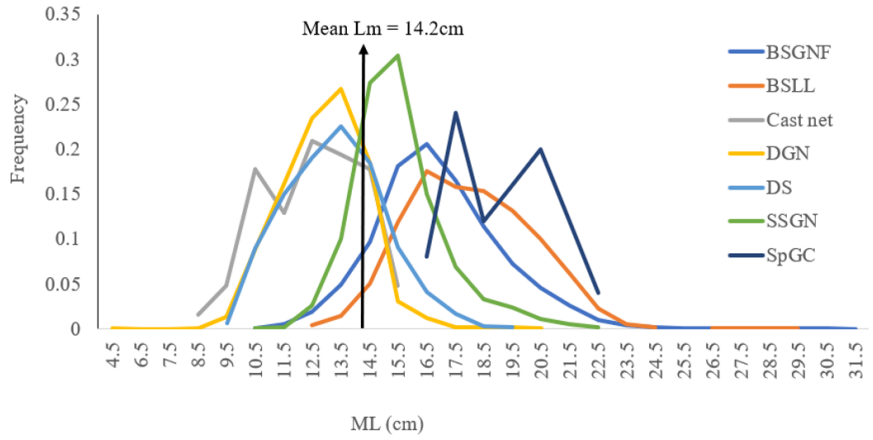

| *S. leptolepis* | BSGNF | DGN | DS | RNAC | ScN | SLN | SSGN |
|---|---|---|---|---|---|---|---|
| Immature | 11% | 40% | 26% | 42% | 10% | 83% | 9% |
| Mature | 89% | 60% | 74% | 58% | 90% | 17% | 91% |

Figure 12. Length distribution of *S. leptolepis* from different gear sources caught in FMA 11, 2015 to 2024.




| *U. asymmetricus* | BSGNF | DGN | DS | FP | OT | SSGN |
|---|---|---|---|---|---|---|
| Immature | 20% | 76% | 80% | 24% | 82% | 17% |
| Mature | 80% | 24% | 20% | 76% | 18% | 83% |

Figure 13. Length distribution for *U. assymentricus* from different gear sources caught in FMA 11, covering 2015 to 2024.




| *U. moluccensis* | BSGNF | BSLL | Cast net | DGN | DS | SSGN | SpGC |
|---|---|---|---|---|---|---|---|
| Immature | 7% | 2% | 77% | 77% | 66% | 13% | |
| Mature | 93% | 98% | 23% | 23% | 34% | 87% | 100% |

Figure 14. Length distribution of *U. moluccensis* from different gear sources caught in FMA 11, covering 2015 to 2024.

### 3.2 Growth and mortalities

Table 4 shows the growth and mortality parameters for the major species caught in FMA 11, with the corresponding range of literature values. As reflected in the table, the mean values are averaged over four (4) years, reflecting the average lifespan of small pelagic and demersal species. Results of mean values for $L_\infty$ for CY 2015 to 2018 and 2019 to 2023 were compared to the recent 2024 data and with the literature. Species with increasing $L_\infty$ and higher literature values include those with increasing or stable $L_\infty$ and larger than those reported in previous studies, including *S. crumenophthalmus, R. brachysoma, R. kanagurta, S. lemuru, S. tumbil, U. asymmetricus,* and *U. moluccensis*. Species with decreasing $L_\infty$ values below historical records include *A. mate* (36.81 cm in 2024), with a mean $L_\infty$ from 2015 to 2023 of 39.94 cm and a literature $L_\infty$ range of 38.34 cm. *S. leptolepis* shows the same result, with CY 2024 $L_\infty$ at 20.52 cm, a mean L from 2015 to 2023 at 22.50 cm, and an L range from the literature at 21.95 cm. *S. gibbosa* also had the same indication, with CY 2024 $L_\infty$ at 19.46 cm, a mean $L_\infty$ from the years 2015 to 2023 at 21.49 cm, and an $L_\infty$ range from the literature at 20.54 cm. These are the species caught by different types of fishing gear, both

Table 4. Growth and mortality indicators of the major fish species in FMA 11 from CY 2015 to 2024.

| Species | Years | mean L∞ (cm) | mean k year$^{-1}$ | mean M | mean F | Mean E |
|---|---|---|---|---|---|---|
| *A. mate* | Literature | 33.34 | 0.90 | 3.52 | 5.07 | 0.59 |
| | 2015-2018 | 36.81 | 1.12 | 1.81 | 3.49 | 0.65 |
| | 2019-2023 | 39.94 | 1.17 | 1.83 | 2.75 | 0.57 |
| | 2024 | 35.15 | 1.04 | 1.75 | 3.40 | 0.66 |
| *S. crumenophthalmus* | Literature | 36.50 | 0.89 | 1.57 | 1.34 | 0.46 |
| | 2015-2018 | 31.48 | 1.17 | 1.95 | 4.84 | 0.70 |
| | 2019-2023 | 31.80 | 1.07 | 1.83 | 5.03 | 0.73 |
| | 2024 | 35.40 | 1.03 | 1.74 | 4.58 | 0.72 |
| *S. leptolepis* | Literature | 21.95 | 1.13 | 3.20 | 6.77 | 0.68 |
| | 2015-2018 | 22.31 | 1.00 | 1.94 | 3.93 | 0.67 |
| | 2019-2023 | 22.07 | 1.06 | 2.02 | 3.80 | 0.64 |
| | 2024 | 20.52 | 1.03 | 2.03 | 4.35 | 0.68 |
| *R. brachysoma* | Literature | 25.00 | 1.60 | 2.56 | 6.93 | 0.73 |
| | 2015-2018 | 31.18 | 1.09 | 1.86 | 6.09 | 0.75 |
| | 2019-2023 | 27.77 | 1.11 | 1.96 | 4.34 | 0.68 |
| | 2024 | 34.92 | 1.04 | 1.76 | 7.19 | 0.80 |
| *R. kanagurta* | Literature | 33.44 | 1.17 | 3.71 | 5.80 | 0.61 |
| | 2015-2018 | 36.76 | 1.32 | 2.02 | 6.02 | 0.75 |
| | 2019-2023 | 36.10 | 1.30 | 2.01 | 4.13 | 0.67 |
| | 2024 | 39.40 | 1.08 | 1.74 | 4.68 | 0.73 |
| *S. gibbosa* | Literature | 20.54 | 1.06 | 2.64 | 3.96 | 0.60 |
| | 2015-2018 | 22.80 | 0.98 | 1.90 | 6.24 | 0.77 |
| | 2019-2023 | 21.49 | 1.05 | 2.02 | 5.74 | 0.74 |
| | 2024 | 19.46 | 1.04 | 2.07 | 2.77 | 0.57 |
| *S. lemuru* | Literature | 23.00 | 1.10 | 2.05 | 5.21 | 0.72 |
| | 2015-2018 | 22.65 | 1.16 | 2.13 | 5.62 | 0.73 |
| | 2019-2023 | 22.16 | 1.17 | 2.15 | 5.75 | 0.72 |
| | 2024 | 22.16 | 1.10 | 2.07 | 7.89 | 0.79 |
| *S. taenioptera* | Literature | 28.10 | 0.89 | 1.97 | 2.53 | 0.56 |
| | 2015-2018 | 30.73 | 1.20 | 2.00 | 3.90 | 0.66 |
| | 2019-2023 | 27.70 | 1.13 | 1.98 | 6.14 | 0.75 |
| | 2024 | 24.20 | 1.08 | 1.99 | 4.18 | 0.68 |
| *S. tumbil* | Literature | 41.00 | 0.70 | 1.30 | 0.92 | 0.42 |
| | 2015-2018 | 46.40 | 1.07 | 1.65 | 4.88 | 0.74 |
| | 2019-2023 | 54.27 | 1.03 | 1.54 | 4.61 | 0.74 |
| | 2024 | 56.60 | 1.00 | 1.50 | 4.54 | 0.75 |
| *U. asymmetricus* | Literature | - | - | 0.31 | 0.80 | 0.72 |
| | 2015-2018 | 22.34 | 1.20 | 2.19 | 4.87 | 0.69 |
| | 2019-2023 | 22.68 | 0.89 | 1.79 | 3.74 | 0.68 |
| | 2024 | - | | | | |
| *U. moluccensis* | Literature | 22.50 | 1.10 | 2.06 | 1.96 | 0.49 |
| | 2015-2018 | 21.94 | 0.89 | 1.80 | 2.80 | 0.59 |
| | 2019-2023 | 24.39 | 1.10 | 2.01 | 1.70 | 0.46 |
| | 2024 | 25.68 | 1.03 | 1.90 | 2.98 | 0.61 |

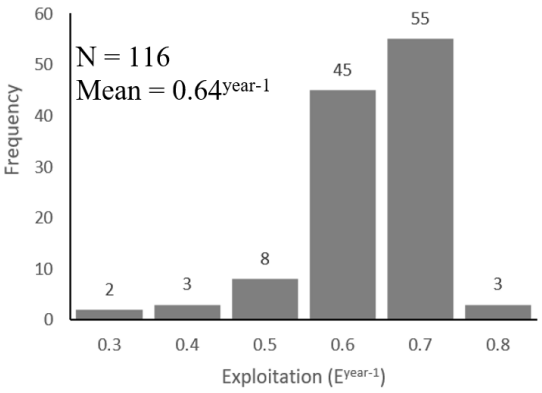



Figure 15. Results on the distribution of exploitation (E) values of major fish species monitored for FMA 11 covering the period of CY 2015 to 2024.

commercial and municipal, with *A. mate* caught by 14 gear types, *S. gibbosa* and *S. taenioptera* caught by 24 gear types, and S. leptolepis caught by 26 gear types, as listed in Table 2.

Given the wide variety of fishing gear catching multiple species, Figure 15 shows the distribution of the exploitation (E) ratio for the 10-year and 11-species data sets analyzed for the major fish species of FMA 11. As the figure suggests, most E ratios exceed the 0.5 year$^{-1}$ threshold, with 45% at 0.6 year$^{-1}$ and 55% at 0.7 year$^{-1}$. Noting further that breaching the TRP of 0.5 year$^{-1}$ accounted for 89% of the data sets, and only 11% are within the TRP level.

Table 5. List of fishing gears identified during the boat and gear inventory conducted in the years 2011, 2018, and 2024 for FMA 11.

| Sector | Gear type | Gear code | Local name | 2011 | 2018 | 2024 |
|---|---|---|---|---|---|---|
| Commercial | Danish seine | DS | *Hulbot, zipper* | 198 | 87 | 33 |
| | Mid-water trawl | MWT | *Palupad* | 56 | 40 | 20 |
| | Otter trawl | OT | *Trawl* | 220 | 110 | 169 |
| | Purse seine | PS | *Purse seiner* | 24 | 58 | 27 |
| | Round haul seine | RHS | *Palukso* | 81 | 22 | 83 |
| | Ring net-compressor | RNAC | *Sinsuro* | 59 | 45 | 53 |
| | Ring net – fish finder | RNFF | *Arong* | | 71 | 57 |
| | Squid trawl | SqT | *Trawl-panglukos* | | 62 | 74 |
| | Trawl boat | TB | - | | 3 | 3 |
| **TOTAL** | | | | **638** | **498** | **519** |
| Municipal | Bagnet | BgN | *Basnig* | 169 | 194 | 111 |
| | Barrier net | BrN | *Pabhas* | 25 | 495 | |
| | Beach seine | BS | *Sahid* | | 645 | 233 |
| | Bottomset gillnet-crab | BSGNF | *Pukot pangasag* | 670 | 7,111 | 5,109 |
| | Bottomset gillnet-fish | BSGNC | *Pukot* | 5,798 | 6,907 | 5,406 |
| | Bottomset longline | BSLL | *Labay* | 1,952 | 2,344 | 769 |
| | Crab lift net | CLN | *Bintol* | 100 | 693 | |
| | Crab pot | CP | *Panggal, timing* | 1,474 | 1,650 | 840 |
| | Crab trap | CT | *Bubo pangasag* | 63 | 2,655 | 1,947 |
| | Drift gillnet | DGN | *Palubog, patuloy* | 2.422 | 4,605 | 1,970 |
| | Drift gillnet-modified | DGNm | *Pakaroy* | | 9 | |
| | Drive-in-net | DIN | *Panamba* | 573 | 724 | 478 |
| | Drift longline | DLL | *Labay, kitang* | | 12 | |
| | Danish seine | DS | *Hulbot* | 237 | 310 | 293 |
| | Encircling gillnet | EGN | *Likos, likopan* | 538 | 743 | 383 |
| | Fish corral | FC | *Taba, punot* | 816 | 1,507 | 611 |
| | Filter net | FN | *Saluran* | 346 | 1,129 | 537 |
| | Fish pot | FP | *Bubo* | 1,646 | 59 | 294 |
| | Fish trap | FT | *Bubo* | 96 | 2,150 | 800 |
| | Hook & line | HL | *Lagulo* | 4,147 | 10,258 | 5,163 |
| | Hook & line-modified | HLM1 | *Buslog, tindakaw* | | 23 | |
| | Cast net – motorized | Cast net | *Siklob* | | | 231 |
| | Multiple hook & line | MLH | *Into-into* | 1,785 | 3,372 | 2,655 |
| | Motorized push net | MPN | *Hudhud/sudsud* | 16 | 232 | 10 |
| | Otter trawl | OT | *Trawl* | 558 | 2,054 | 1,037 |
| | Push net | PN | *Hud-hud* | 327 | 105 | 200 |
| | Round haul seine | RHS | *Palukso* | 73 | 53 | 52 |
| | Raft lift net | RLN | *Floater* | 23 | | 158 |
| | Ring net-fish finder | RNFF | *Arong* | 41 | | 29 |
| | Scoop net | ScN | *Sikpaw* | 289 | 36 | 95 |
| | Shrimp trawl | ST | *Trawl-pasayan* | | 316 | 45 |
| | Stationary lift net | SLN | *Tangkal-tangkal* | 97 | 293 | 167 |
| | Speargun -compressor | SpGC | *Panalom* | 3,354 | 696 | 2,727 |
| | Squid jig | SqJ | *Panglokos* | 6,256 | 6,313 | 1,867 |
| | Squid pot | SqP | *Bubo panglokos* | 1,307 | 1,599 | 332 |
| | Squid trap | SqT | *Bubo panglokos* | 21 | 31 | |
| | Surface set gillnet | SSGN | *Paanod* | 56 | 14 | 577 |
| | Troll line | TL | *Labay* | 349 | | 71 |
| **TOTAL** | | | | **35,624** | **59,337** | **35,207** |

### 3.3 Fishing effort inventory

Table 5 shows the total inventory of fishing gear operating in FMA 11 in 2011, 2018, and 2024. The census identified nine commercial fishing gear types and 36 municipal gear types. For the commercial gears in the census done in 2011, otter trawl had the most with 220 units, and the least was purse seine with 24 units. In 2018 and 2024, otter trawl still had the most units, while a modified Danish seine called trawl had the fewest, at 3 units in the 2018 and 2024 censuses.

For the municipal gears, squid jiggers accounted for 6,256 units of the 35,624 total units in the 2011 census. In 2018, hook and line had the highest number at 10,200 units of the 59,337 total units. In 2024, bottomset gillnet for fish had the most, with 5,406 units of the total 35,207 units. Combining the specific types of gears into the general classification shown in Figure 16, hook and line types

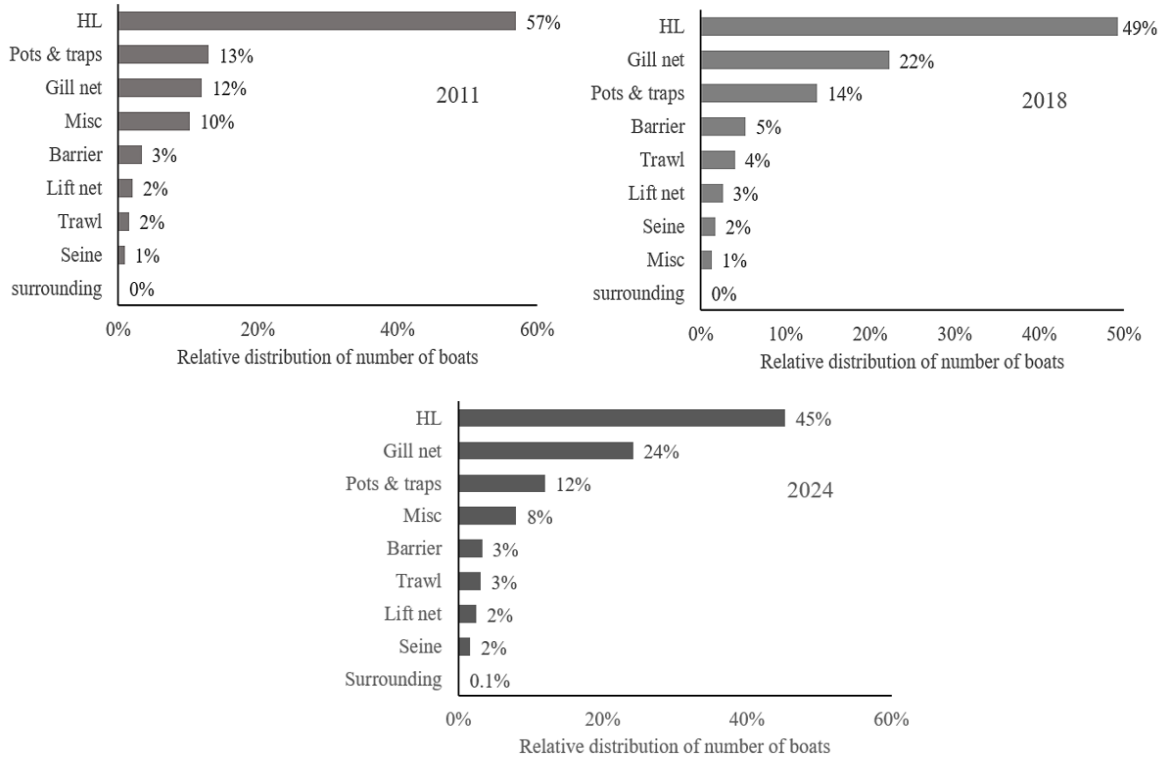



Figure 16. Relative distribution of fishing gear classification operating in FMA 11 in the conduct boat gear census in years 2011, 2018, and 2024

are commonly used, having 57%, 49%, and 45% in the respective years of the census. To account for the gear types using fine-meshed nets in all or at the bottom of the gear, such as trawls, seines, traps, lift nets, barrier nets, and surrounding nets, specifically *Sinsuro*, they were accounted for at 3,484 units in year 2011, 7,156 units in year 2018, and 3,829 units in year 2024.

### 3.4 Fishing area

As discussed in Section 3.1, the size distribution shows that multiple fishing gear types catch major fish species of FMA 11 at various sizes. Figure 17 shows the area of operation among major fishing gears in the Visayan Sea, with the T-zone indicating commercial waters and the outside indicating municipal waters. As Fig. 17a shows, almost all operations occur within municipal waters, where trawl and ring net variations operate mostly in Northern Iloilo Province. Commercial Danish seine operations are seen mostly in the municipal waters of Balud, Masbate. Figure 17b shows the operation of major municipal fishing gear; gillnet gear and its variations are spread across Northern Iloilo Province

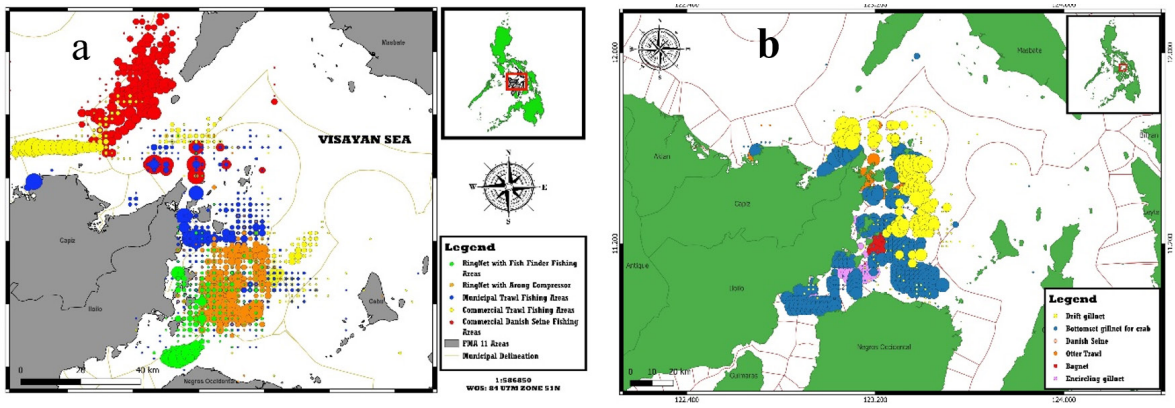



Figure 17. Map plots of fishing areas of major commercial (a) and municipal (b) gears operating in FMA 11, specifically in the Visayan Sea, for the year 2024.

and Pilar, Capiz. Municipal-scale Danish seine is observed in the municipal waters of Ajuy and Banate, Iloilo. Municipal otter trawls frequently operate in Carles, Estancia, and Roxas City, Capiz.

Plotting all the area operations of the major commercial and municipal fishing gears of FMA 11 in the Visayan Sea, as shown in Figure 18, in a year, almost the same areas are being operated by both commercial and municipal fishing gears, which leads to a single species being caught by multiple fishing gear types for both sectors.

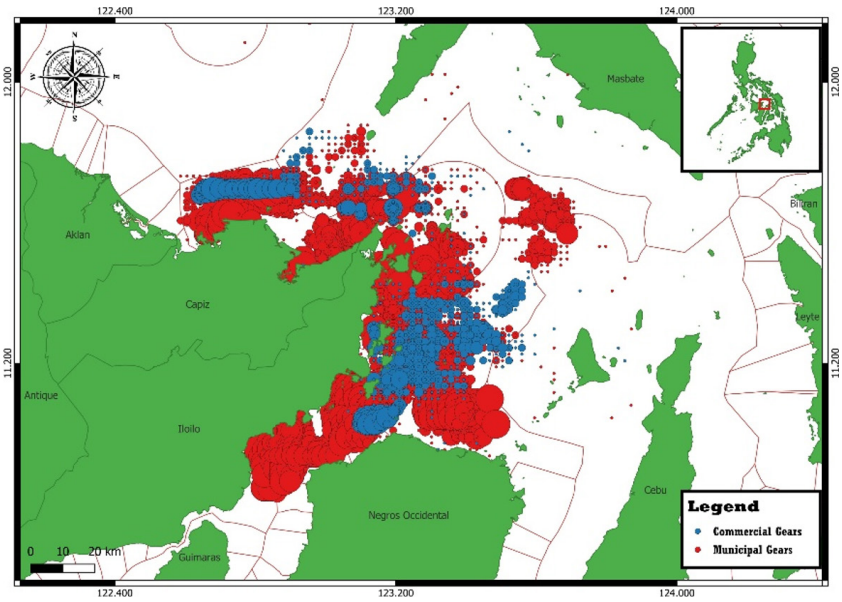



Figure 18. Map plots of fishing area overlaps of major commercial (a) and municipal (b) gears operating in FMA 11, specifically in the Visayan Sea, for the year 2024.

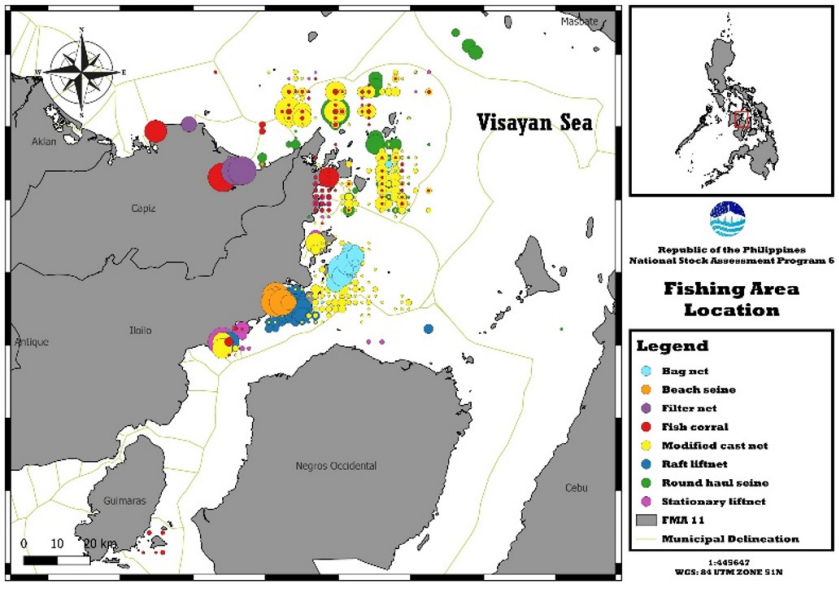



Figure 19. Map plots of fishing areas with gears using fine-meshed nets during operation in FMA 11, specifically in the Visayan Sea, for the year 2024.

Consistent with this effect, Figure 19 shows the locations of fishing gears using fine-meshed nets in either the bundt or body of the gear. Bag net, beach seine, filter net, fish corral, raft lift net, and stationary lift net operations occur in nearshore areas, while round haul seine and modified cast net operations occur offshore, targeting sardines. Referring back to Figure 17a, otter trawl, ring net, or "sinsuro," and ring net with fish finders using fine-meshed nets operate in nearshore areas targeting sardines and anchovies, with high by-catch of other species. As mentioned earlier in this section, most commercial gear operates within the 15-kilometer municipal waters, causing multi-species catches and a wider range of sizes caught.

### 3.5 Trophic systems modeling and simulation

Using results from Bacalso et al. (2023), simulation scenarios were developed to assess the effects of different approaches. This includes a Business as Usual (BAU) scenario, wherein all existing practices are continued despite the existing policy in place; another approach involves the banning of gears with fine-meshed nets, specifically a total ban for RNAC/Sinsuro, a ban on fish corral (FC), a ban on both RNAC and FC, a ban on lift nets (SLN, BgN, RLN), and a ban on FC and lift nets. The last simulation involves a combined prohibition of all fine-mesh net gears and Illegal, Unreported, and Unregulated (IUU) gears such as trawl, DS, and RN. Also, based on the fishing boats and gear census, the gear uses fine-mesh nets in the bottom area of the net.

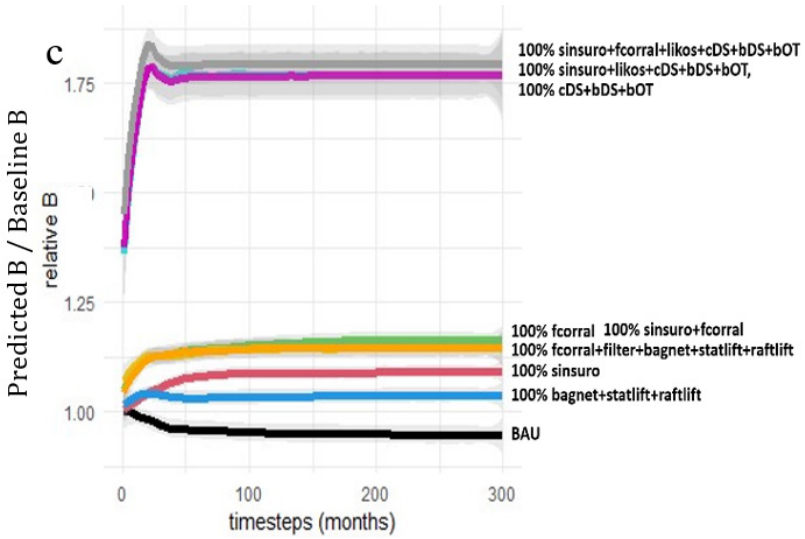



Figure 20. Ecopath with Ecosim scenario simulation for the prediction of biomass of sardines (a), mackerel (b), and demersal (c) species caught in FMA 11, specifically in the Visayan Sea, covering the years 2015 to 2024.

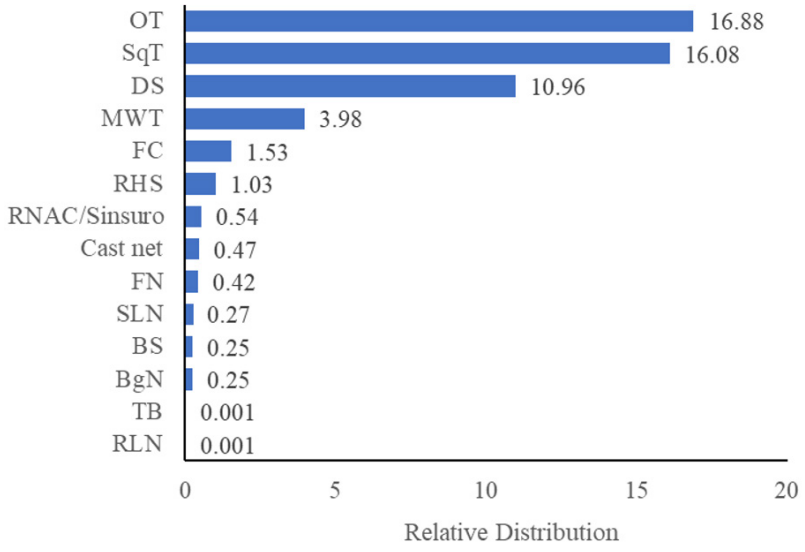



Figure 21. Relative distribution of fish catch of the various fine-meshed and IUU gears identified and operating in FMA 11, simulated using the 2024 NSAP data.

Figure 20 shows the results of different scenario simulations by Bacalso et al. (2023) for representative fish groups, such as sardines, mackerel, and demersal fish stocks. As the figures suggest, banning operations with fine-meshed nets and IUU gear together shows high efficiency in recovering fish biomass. A standalone ban on a single gear type, or a combination of fine-meshed and IUU gears, shows minimal progress toward fish biomass recovery.

Based on the modeling results, Figure 21 accounts for fine-meshed and IUU gears. As reflected in the fishing gear inventory, 50 gear types were identified: 11 for the commercial sector and 39 for the IUU sector. Of these, IUU gears accounted for 5 types, with a 47.90% relative distribution to catch. Fine-mesh gears accounted for 9 types, with a 4.76% relative distribution. Based on the simulation, banning both IUU and fine-mesh gears will contribute 52.66% of catches for FMA 11.

## 4. DISCUSSION

Catching immature-sized fish of different types and a lower percentage of mature-sized catches reflects recruitment overfishing (Froese 2004). This suggests that specific gear may target certain sizes, even as it affects other species caught as bycatch. It is also worth noting that overlaps in fishing-gear catches reflect either the selective or non-selective design of the gear, resulting in high bycatch incidence.

Relative to the growth and mortality of the major fish species, a dominance of E ratios at 0.6 year$^{-1}$ to 0.7 year$^{-1}$, breaching the threshold of E<0.5 year$^{-1}$ is indicative of a growth overfishing state of the stocks (Ingles and Pauly 1984). These findings, coupled with recruitment overfishing, show that immediate management interventions must be designed and implemented to ensure sustainability.

The findings above only show the status but could not recommend how and whom to start the regulation process with. As such, the effort inventory would help identify who will be regulated. The diversity of fishing gear in FMA 11 and the increase in gear typology from traditional to recent modifications imply the ingenuity of Filipino fishers. However, this ingenuity reflects their desire to increase daily catches, as traditional gear is less efficient due to high competition from different gear types. Gear types also reflect the sizes caught. Gears using fine meshes and

others considered IUU are now taken into account, along with their impacts on size. As reflected in sizes caught, multiple gear types catch common small pelagics like *S. gibbosa* (caught by 24 gear types) and *S. leptolepis* (caught by 26 gear types). In contrast, the common demersal species *S. taenioptera* is also caught by 24 gear types. This shows the overlap of fishing gear deployed across FMA 11.

The fishing area map plots confirm this scenario. Results show that the wide variety of gear and the 30 thousand to almost 60 thousand gear units operating in the area indicate resource-use conflict. The results also show that even commercial fishing gear, whether in fleets or single boats, operates in municipal waters, intensifying overfishing. Fishing overlaps occur not only across different municipal gear types but also across sectors, as commercial vessels operating in fleets are far more efficient than municipal gear.

The simulation study shows that removing fine-meshed and IUU gears is important for management intervention. These gears contribute to the severe overfishing of major fish stocks in FMA 11 and account for around 53% of the overfishing contribution. By correlating results from size distribution, mortalities, and exploitation, and by increasing fishing effort and fishing-area overlaps, the simulation confirms and pinpoints which stocks should be regulated or banned as part of management decisions and interventions.

## 5. RECOMMENDATION

FMA 11 is in a decadal state of overfishing, with immature-fish catches as the lead indicator, supported by other reference points. To maintain the health of the fishing ground, fine-meshed net gear and commercial fishing fleet operations should be banned and/or regulated in municipal waters that serve as spawning and breeding grounds for the fishery resource. It is also important to regulate fishing in municipal waters to allow fish stocks to grow and reproduce. Existing policies and laws related to illegal, unregulated, and unreported fishing (IUUF) must be strengthened and strictly implemented. If the ratio of mature-sized catches of the major species is below 80%, effort reduction of at least 40% should be implemented through a five-year staggered scheme to regulate the fishing capacity of FMA 11.

## ACKNOWLEDGMENT

The authors sincerely thank the National Fisheries Research and Development Institute (NFRDI) for funding and technical support for the National Stock Assessment Program 6 (NSAP). The authors also thank the Bureau of Fisheries and Aquatic Resources RFO V, VI, and VII for their continued collaboration and support for NSAP in their respective regions. The authors also acknowledge the United States Agency for International Development-FishRight (USAID-FishRight) and the University of Rhode Island (URI) for their financial and technical support. Heartfelt appreciation is especially given to the NSAP project leaders, data analysts and encoders, and field enumerators for their unwavering diligence and dedication to successful collection and management of fisheries data.

## SUPPLEMENTARY MATERIAL

Link to the electronic supplementary material. Supplementary file.

## AUTHOR CONTRIBUTIONS

**Mesa SV**: Conceptualization, assessment, validation, review, data analysis, preparation of draft, editing of manuscript. **Bartolome RA**: Data collection and analysis, preparation of draft, editing of manuscript. **Dela Cruz DM**: Data collection and analysis, preparation of draft, editing of manuscript.

## CONFLICTS OF INTEREST

To the best of the authors' knowledge, there are no conflicts of interest related to the conduct of this study.

## ETHICS STATEMENT

Fisherfolk voluntarily provided data such as catch and effort, along with boat and gear inventories, and NSAP-hired field enumerators systematically collected them. This ensured comprehensive stock assessments through consistent, community-engaged sampling methods.

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