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RESEARCH ARTICLE

Stock Assessment of Big Eye Scad (*Selar crumenophthalmus*, Bloch 1793) in Fisheries Management Area 10, Philippines

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ABSTRACT

The bigeye scad (*Selar crumenophthalmus*) is a major fishery resource in Fisheries Management Area (FMA) 10 and an important contributor to the Central Visayas fisheries sector. Despite its commercial and ecological importance, up-to-date studies on the stock status in this region remain limited. This study aimed to assess the species stock status based on growth, mortality, and CPUE indicators using the catch and effort and length-frequency data collected from the National Stock Assessment Program (NSAP) enumeration sites from 2020 to 2024. Results and information generated are intended to support science-based management and inform appropriate harvest control rules and other relevant measures. The estimated von Bertalanffy Growth Function (VBGF) includes an asymptotic length (L_∞) of 29.56 cm total length (TL) and a growth coefficient (k) of 1.0, indicating a fast-growing species. The analysis showed that bigeye scad exploitation has increased each year. Mortality estimates showed an average exploitation ratio (E) of 0.66 and fishing mortality (F) of 3.45, breaching the 0.5 and 2.0 thresholds, respectively, indicating high fishing mortality. CPUEs generally indicate declining trends for most major gears, and percentage catches of mature fish have breached the LRP for some dominant gears catching the species. Using the Length-Based Bayesian (LBB) approach, relative biomass at Maximum Sustainable Yield (B/B_{msy}) was estimated at 0.79, and current biomass at virgin biomass (B/B_0) was estimated at 0.3. Altogether, the estimated biological performance indicators are breaching the pre-determined limit reference values, which implies that management actions are needed to prevent further stock declines and promote stock recovery to sustainable levels. To this end, proactive management strategies such as a moratorium on gear licenses, minimum size limit regulations, and establishment of seasonal closures for specific gears or fishing grounds are potential recommendations.

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1. INTRODUCTION

Selar crumenophthalmus (Family Carangidae), commonly known as bigeye scad, is one of the commercially important fish species in the Philippines and particularly in Fisheries Management Area 10. Historically, this species accounted for roughly 3% of all marine landings and 6% of small pelagics (Dalzell and Ganaden 1987). *S. crumenophthalmus* is the dominant Carangidae species in Philippine fisheries, accounting for about 85% of total bigeye scad landings nationwide. In 2023, *S. crumenophthalmus* ranked seventh among the country's top-produced species, with an annual catch estimated at 120,204 metric tons (MT) and a value of PHP 14.37 billion (BFAR 2025). While the national ranking highlights the species' significance to Philippine fisheries, the FMA-level assessment recognizes spatial variability in stock condition and fishing pressure. Since fisheries management in the Philippines is implemented through Fisheries Management Areas, evaluating species status at the FMA level provides more appropriate information for developing and implementing area-specific management interventions.

S. crumenophthalmus is widely distributed across Philippine waters, with major fishing grounds in FMA 11 (Visayan Sea), FMA 10 (Camotes Sea), FMA 12 (Sibuyan Sea), FMA 8 (Leyte Gulf), and FMA 1 (Lagonoy Gulf). Within Fisheries Management Areas (FMAs), four (4) regions (V, VII, VIII, and IX) surrounding the Visayas area consistently record high catches of the species.

Despite its economic value and consistent presence in landings, scientific studies on its stock status and biological characteristics within this region remain limited. Elsewhere, Ingles and Pauly (1984) conducted size-based analyses of *S. crumenophthalmus* to estimate growth, mortality, and recruitment parameters using length-frequency data collected in Manila Bay. Dalzell and Penaflor (1989) also investigated the fisheries biology of big eye scad in the Philippines. More recent stock assessments of small pelagics, including *S. crumenophthalmus*, have been conducted in Lagonoy Gulf (Olaño et al. 2018), Camotes Sea (Belga et al. 2018), and Leyte Gulf (Francisco et al. 2018). Moreover, Uba (2020) reported on the reproductive biology of *S. crumenophthalmus* in the Northern Sulu Sea, and Gonzalez and Ribot (2023) reported on it in Romblon Passage. Collectively, these studies provide information on growth, mortality, exploitation, and reproductive characteristics of *S. crumenophthalmus* in selected Philippine fishing grounds. However, an integrated, recent assessment combining these indicators at the FMA 10 scale remains limited, particularly for the Central Visayas fishing grounds.

Although *S. crumenophthalmus* contributes significantly to the country's economy, its fisheries resources have been adversely affected by multiple threats, including overfishing, pollution, habitat degradation, and rapid population growth (Dalzell and Penaflor, 1989). Previous studies in the Camotes Sea and adjacent Visayan fishing grounds have documented increasing fishing pressure associated with intensive gear use and excessive fishing effort, resulting in elevated rates and evidence of growth overfishing among commercially important small pelagic species (Barut et al. 2004; Belga et al. 2018; Narido et al. 2016). In 2024, total production of *S. crumenophthalmus* was estimated at 27,788.37 MT, a 20% decline from previous years (PSA, 2024). Similarly, in Fisheries Management Area (FMA) 10, *S. crumenophthalmus* production showed a comparable decrease of 21% based on consolidated NSAP 7 data. Given this situation, FMA 10 depends on the best available scientific information to inform harvest policy decisions. However, limited data availability constrains the development of effective strategies, increasing the risk of overexploitation and unsustainable fishing practices. Therefore, a comprehensive stock assessment is crucial to establish appropriate harvest control rules and promote sustainable fisheries management.

This study assessed the stock status of *S. crumenophthalmus* to provide scientific information for FMA 10 as a basis for harvest policy formulation. Specifically, this study aimed to determine the following: (1) catch per unit effort (CPUE) and seasonality of the species; (2) growth and mortality parameters; (3) determine levels of fishing exploitation, such as exploitation ratio (E), fishing mortality ratio (F/M), and FROESE indicator (percentage of mature catches); and (4) determine proxy biomass estimate of the species. These pieces of information are intended to provide science-based policy recommendations for sustainable management and conservation of *S. crumenophthalmus* in FMA 10.

2. METHODOLOGY

2.1 Study Site

This study was conducted within Fisheries Management Area 10 (FMA 10), located in the Central Visayas and Eastern Visayas regions of the Philippines. The area covers about 1,526,500 hectares and includes the provinces of Biliran, Bohol, Cebu, Leyte, Masbate, Negros Oriental, Siquijor, Southern Leyte, and Zamboanga del Norte. FMA 10 encompasses several major fishing grounds, including the Camotes Sea, Cebu Strait, Biliran Strait, Ormoc Strait, Danajon Bank, and Maribojoc Bay.

A total of 26 landing sites were identified for monitoring catch landings across 26 coastal municipalities within the five fishing grounds of FMA 10 (Figure 1). Eleven sites were monitored in the Camotes Sea, specifically in the coastal municipalities of Bogo City, Tabogon, Borbon, Carmen, Danao City, Compostela, San Francisco, and Ormoc Bay. Seven sites were monitored in the Cebu Strait, covering the coastal municipalities of Tagbilaran City, Dauis, Loon, Dumaguete City, Dalaguete, and Argao. Eight sampling sites were monitored in the Danajon Bank, particularly in the coastal municipalities of Tubigon, Getafe, Talibon, Bien Unido, Ubay, and Hilongos.

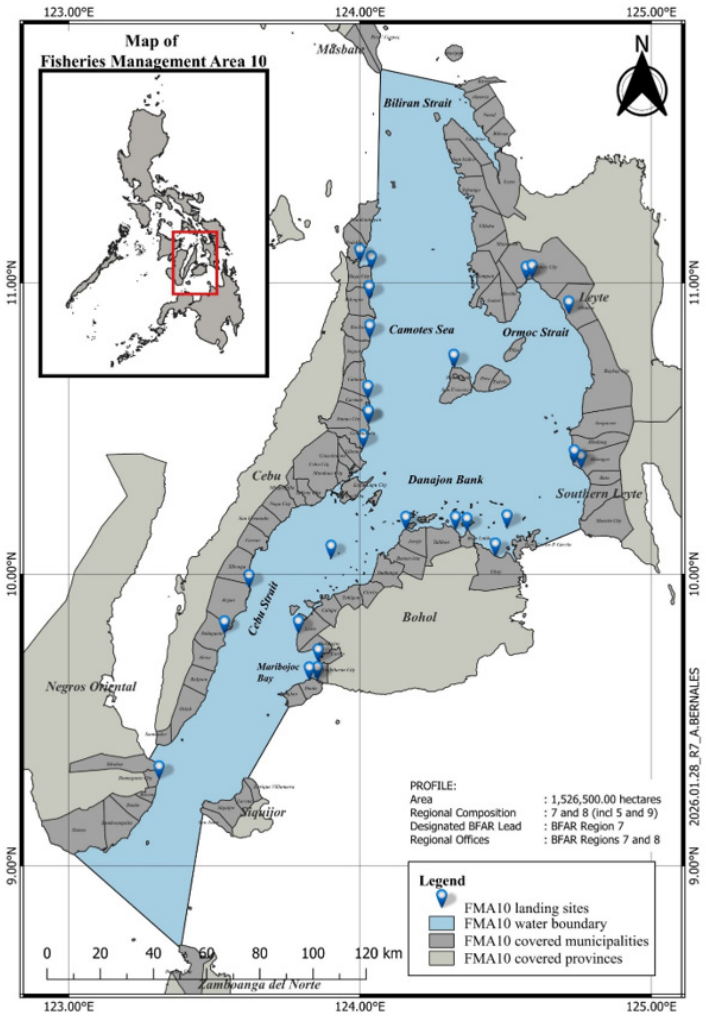


Figure 1. Map of Fisheries Management Area 10 and the locations of the landing sites

2.2 Data collection and sampling

Data for the stock assessment analysis were collected from 2020 to 2024. The National Stock Assessment Program (NSAP) standard data-collection protocol was followed, as described by Santos et al. (2017). Prior to deployment, field enumerators received technical training from the National Fisheries Research and Development Institute (NFRDI). These enumerators monitored catch landings at their designated landing sites.

The sampling protocol involved monitoring catch landings for two consecutive days, followed by a one-day interval, resulting in an average of 21 sampling days per month. Data were recorded using standardized data collection forms to document information including fishing ground, landing center, sampling date, vessel name, vessel sector (municipal or commercial), fishing effort (e.g., number of fishing days or hours, hauls, hooks, number of fishers), total catch per vessel (kg), species composition (identified to scientific name), sample catch weight (kg), length-frequency measurements (total length, TL) of sampled species, and geospatial grid map data.

Species identification of fish and invertebrates was conducted using published identification guides such as NSAP training modules developed by NFRDI, other species ID reference materials (Masuda et al. 1984; Randall et al. 1997; Rau and Rau 1980), and online databases including FishBase (Froese and Pauly 2000) and Sealife Base (Palomares and Pauly 2025).

2.3 Data processing and analysis

2.3.1 Catch per unit effort (CPUE) and seasonality

Fishing gears used in catching *S. crumenophthalmus* were identified and categorized into municipal and commercial sectors based on vessel gross tonnage (GT), where municipal fishing vessels had a gross tonnage of three (3) GT or less, while commercial fishing vessels had a gross tonnage greater than three (3) GT (RA 8550, as amended by RA 10654). Catch data were recorded in kilograms (kg), while fishing effort was measured as the number of fishing days for each gear type.

The CPUE for each gear type was calculated by dividing the total catch by the total number of fishing days. Annual mean CPUE was estimated by summing the monthly catches and dividing by the total number of fishing days within the year. CPUE was expressed in kilograms per day (kg/day) and served as an index of relative fishing efficiency and resource abundance across gear types and years. Fishing effort was expressed in fishing days due to limitations in detailed trip-level effort data; however, it is acknowledged that variation in trip duration, fishing power, and operational practices may still influence CPUE estimates. Despite these limitations, CPUE trends were used in conjunction with length-based indicators and mortality estimates to provide a more robust inference of relative stock status over time.

To characterize temporal patterns in the fishery, monthly mean catch was calculated by averaging catches for the same calendar month across all years. Seasonal trends were then examined based on monthly fluctuations in catches, enabling the identification of peak and lean fishing periods. These seasonal patterns provided additional context for interpreting variations in catch rates and describing the seasonality of *S. crumenophthalmus.*

2.3.2 Estimation of growth and mortality parameters

The analysis of growth and mortality parameters was based on length-frequency data from purse seine catches collected at monitored landing sites, as this gear contributed to most samples and provided the most representative stock size distribution. Sampled length frequencies were expanded using the raising factor (RF), which was calculated as:

$$RF = \frac{Total\ Weight\ of\ species}{Total\ Weight\ sampled}\ x\ Total\ Number\ of\ Fish\ Sampled$$

where the Total Weight of Species refers to the total landed weight (kg) of *S. crumenophthalmus* recorded for each sampled landing, Total Weight Sampled is the weight (kg) of the subsample from which individual fish lengths were measured, and the Total Number of Fish Sampled is the number of *S. crumenophthalmus* individuals measured in the subsample. The raised length-frequency data were stratified by landing site, month, and fishing gear, then aggregated into monthly length-frequency distributions. These monthly length-frequency data were subsequently processed using the FAO-ICLARM Stock Assessment Tool II (FiSAT II) (Gayanilo et al. 2005) to estimate growth and mortality parameters.

2.3.2.1 E-ratio

Exploitation rate (E) was estimated from the derived mortality parameters using the relationship E=F/Z, where F is fishing mortality, and Z is total mortality. The exploitation rate represents the proportion of total mortality attributable to fishing. Reference points were used to evaluate stock status, where E=0.5 is commonly considered an approximate threshold for optimal exploitation, assuming fishing mortality equals natural mortality (F = M) (Gulland 1970). Values of E<0.5 and E>0.5 were used as indicative benchmarks for under-exploitation and potential overexploitation, respectively (Ingles and Pauly, 1984).

2.3.2.2 Fishing mortality ratio

The fishing mortality ratio (F/M) was calculated as the ratio of fishing mortality (F) to natural mortality (M) to evaluate the relative intensity of fishing pressure on the stock. An F/M ratio greater than 1 indicates fishing mortality exceeds natural mortality (Gulland 1971).

2.3.3 Froese sustainability indicators

The annual proportion of mature *S. crumenophthalmus* in the catch was estimated using the Froese Sustainability Indicator Tool (Froese, 2004). Stock condition was evaluated using the three simple fisheries indicators derived from length frequency data. The first indicator is the percentage of mature fish in the catch (target: 90–100%), which follows the "let them spawn" principle by allowing fish to reach sexual maturity before being harvested. The second is the percentage of fish within the optimum length (*Lopt*) (target: 100%), following the "let them grow" principle by allowing fish to reach maturity and reproduce at least once. Optimum length (Lopt) is the length at which harvesting the fewest individuals yields maximum biomass. The optimum harvest range is defined as Lopt ±10%, corresponding to 10% below to 10% above Lopt. The third indicator is the percentage of mega-spawners (0–10% target), following the "let them live" principle; Mega-spawners are individuals at least 10% larger than Lopt and are considered particularly important to reproduction because larger females generally produce more numerous and higher quality eggs (Froese 2004; Apel at al. 2013).

For the assessment in Fisheries Management Area (FMA) 10, the Limit Reference Point (LRP) for the proportion of mature catches was set at ≤ 50%. The length at first maturity (Lm =17.08 cm), used to classify fish as mature or immature, was obtained from an unpublished NSAP 7 reproductive biology study in FMA 10.

2.3.4. Biomass estimation

The stock status of the *S. crumenophthalmus* was assessed using the Length-Based Bayesian (LBB) method (Froese et al. 2018), a length-based stock assessment approach designed for data-limited fisheries where only representative length-frequency (LF) data are available. The method applies Bayesian inference to estimate key population and fishery parameters from the observed length distributions under the assumption of equilibrium conditions.

Length-frequency data were obtained from fish sampled at NSAP landing sites, where the total length (TL) of each individual was measured to the nearest 0.1 cm. Monthly length-frequency data were pooled over the study period to produce representative length distributions for analysis. The datasets were screened to remove erroneous records and ensure adequate sample representation.

The LBB analysis was performed using the LBB package in R. The model estimated the asymptotic length (L_∞), the ratios of natural mortality to growth (M/K), fishing mortality to growth (F/K), and total mortality to growth (Z/K), as well as the length at first capture (Lc). From these estimates, the model calculated the relative biomass of the exploited stock (B/B_0) and the biomass relative to the level producing maximum sustainable yield (B/B_{MSY}), which were used to evaluate stock condition. Model fit was assessed by comparing the predicted and observed length-frequency distributions.

Stock status was interpreted using estimated B/B_{MSY} values following Froese et al. (2018), where values >1.2 indicate a healthy or underexploited stock, 0.8–1.2 a fully exploited stock, 0.5–0.8 an overfished stock, and <0.5 a severely overfished stock. Fishing pressure was further evaluated using the F/M ratio, with values greater than one indicating fishing mortality exceeding natural mortality and suggesting excessive exploitation.

3. RESULTS

3.1 Fishing gears

Both municipal and commercial fishing sectors catch *S. crumenophthalmus* using various fishing gears. The commercial sector accounts for about 85% of landings, caught primarily with purse seine and ring net. The municipal sector contributes the remaining 15% mainly via surface set gillnet, municipal ring net, and multiple hook and line.

3.2 Catch composition

Table 1 presents the species composition across dominant fishing gears targeting *S. crumenophthalmus*. Across all fishing gears, *S. crumenophthalmus* (bigeye scad) was the most abundant species, in terms of total catch and relative abundance over the five years. Species of the genus *Decapterus* (*D. tabl, D. macrosoma*, and *D. kurroides)* and *Auxis (A. rochei and A. thazard)* comprised a substantial portion of the catch. Other species, such as *Sardinella lemuru, Mene maculata,* and other tuna species, contributed smaller yet consistent shares of the total catch.

By gear, *S. crumenophthalmus* accounted for about 37% of the catch in purse seine and 22% in ring net. In municipal fishing gears, *S. crumenophthalmus* accounted for 79% of the catch in surface set gillnet,

Table 1. Common fishing gears catching *S. crumenophthalmus* from CY 2020–2024 in FMA 10, categorized by sector, gear type, gear count, landed catch, and relative abundance.

Fishing Gear	Gear Code	Local Name	Count of gears	Monitored Landed Catch (MT)	Relative Abundance (%)
Commercial (C.)				***3,226.31***	***85***
Purse Seine	PS	Likom	39	2,569.91	79.65
Ring Net	RN	Kobkob	43	650.86	20.17
Bagnet	BgN	Tapay-tapay	10	5.54	0.17
Municipal (M)				***570.17***	***15***
Surface Set Gillnet	SSGN	Pukot	362	274.88	48.21
Ring Net	RN	Kobkob	14	180.60	31.68
Multiple Hook and Line	MHL	Pasol	482	59.53	10.44
Bottom Set Gillnet	BSGN	Panulod	156	21.08	3.70
Encircling Gillnet	EGN	Panglikos	6	13.22	2.32
Drift Gillnet	DGN	Paanod	128	12.21	2.14
Fish jig	FJ	Saranggat	47	5.01	0.88
Multiple Troll Line	MTL	Bahanbahan	40	1.99	0.35
Single Handline	SHL	Pasol	84	1.27	0.22
Troll Line	TL	Bahanbahan	12	0.12	0.02
Drive-in-Net	DIN	Pukot	8	0.10	0.02
Bagnet	BgN	Tapay-tapay	2	0.08	0.01
Squid Jigger	SqJ	Panukos	15	0.07	0.01
Beach seine	BS	Baling	1	0.01	0.00
Total				**3,796.48**	**100**

29% in municipal ring nets, and 30% in multiple hook and line.

3.3 Catch per Unit Effort (CPUE)

Catch per unit effort (CPUE) varies among fishing gears and across years from 2020 to 2024 (Figure 2A-E). CPUE values for purse seine fisheries ranged from 400 to 1,057 kg day^{-1} and increased from 2020 to 2023. In 2024, mean CPUE declined sharply from 1,057 kg day^{-1} to 436 kg day^{-1}. Ring net fisheries exhibited a similar temporal pattern but at lower levels, with CPUE ranging from 230 to 597 kg day^{-1} and a decreasing trend observed from 2022 to 2024. Among municipal fishing gears, surface gill nets recorded the highest CPUEs, ranging from 11 to 13 kg day^{-1}, with fluctuations observed between 2020 and 2023 and a slight increase in 2024. Municipal ring nets showed CPUE values comparable to those of commercial ring nets, while multiple hook-and-line gears consistently exhibited the lowest CPUEs, ranging from 2 to 7 kg day^{-1}.

3.4 Catch seasonality

Figure 3 presents monthly catch seasonality of *S. crumenophthalmus* in FMA 10 over the study period. The data showed distinct seasonal fluctuations in landings, with volumes ranging from 1,718.65 MT to 3,593.86 MT per month. Catch volumes were highest in the second through fourth quarters, particularly from May to November.

3.5 Length distribution

Distribution of mean lengths of *S. crumenophthalmus* caught between 2020 and 2024 in FMA 10 is presented in Figure 4 A-E. Species size ranged from 8.5 cm to 29.5 cm with minimal variations observed across all gears. Mean lengths across all gears reached the size of maturity (17.08 cm) except for Surface Set Gill Net and Multiple Hook and Line.

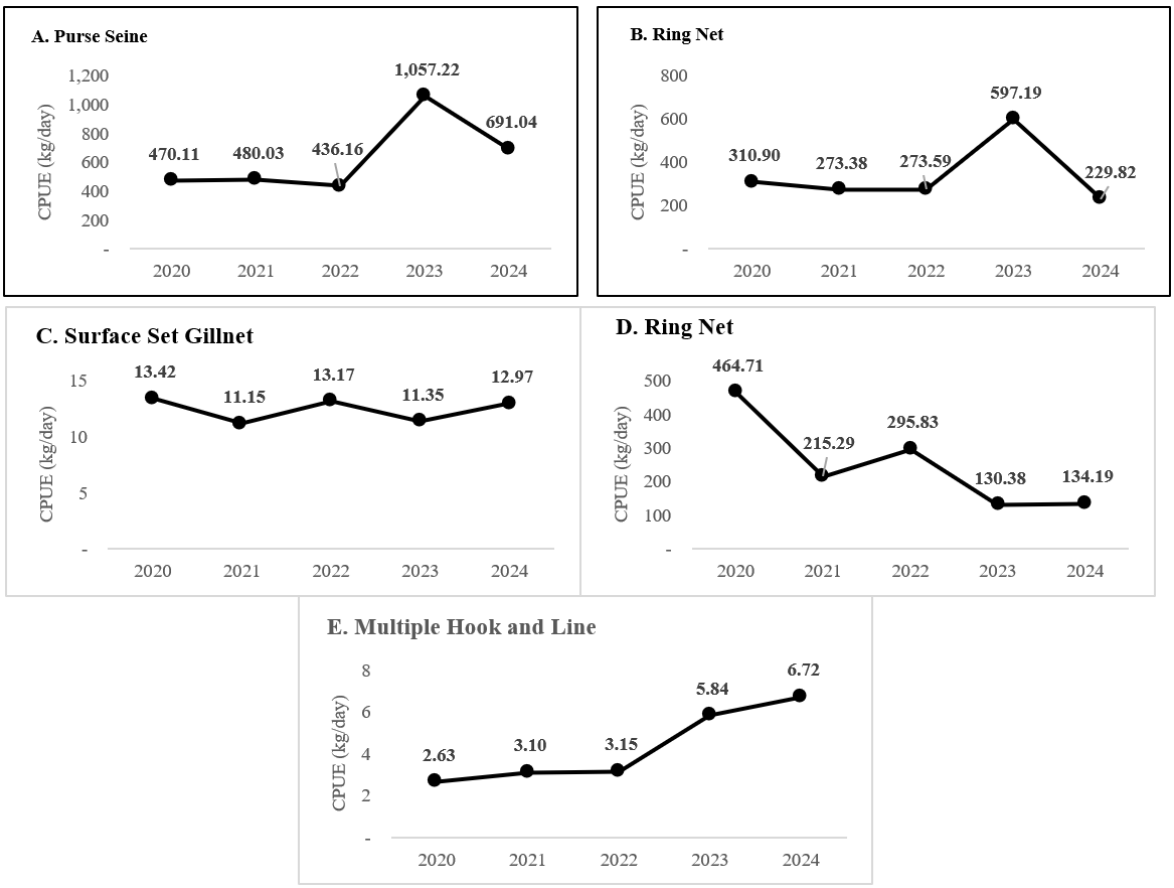


Figure 2 A-E. Annual trend of mean CPUE (kg/day) of *S. crumenophthalmus* from CY 2020–2024 in FMA 10.

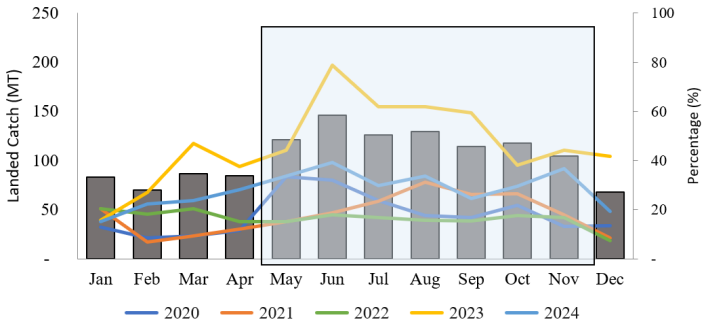


Figure 3. Monthly catch seasonality of *S. crumemophthalmus* for CY 2020–2024 in FMA 10.

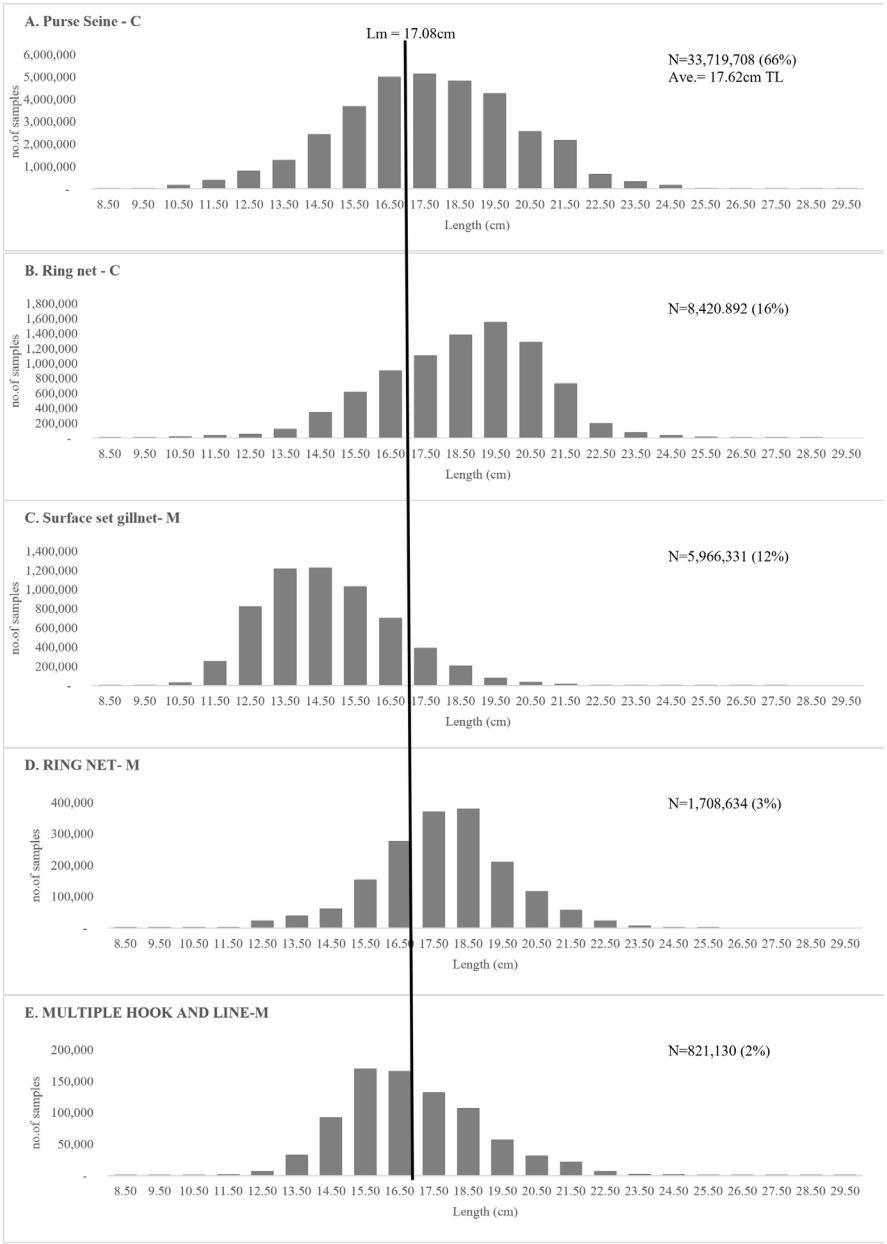


Figure 4. A-E. Length frequency distribution and average size (Total Length-TL) of *S. crumenophthalmus* by gear type monitored from CY 2020 to 2024 in FMA 10.

3.6 Growth and mortality parameters

Population parameters were estimated based on the growth curve (Figure 5) constructed from length-frequency data from purse seine catches. The asymptotic length (L_∞) is the maximum length the fish population can attain if it lives indefinitely, while the growth coefficient (K) expresses the rate at which the length at infinity is approached (Isaac 1990).

Using the FISAT II, the asymptotic Length (L_∞) of *S. crumenophthalmus* was estimated at 29.56 cm, while the growth coefficient (K) was estimated at 1.0 yr^{-1} with a performance index of 0.9974.

The estimated mortality parameters from the length-converted catch curve (Figure 6) showed a higher fishing mortality than natural mortality F/M >1. Further, the computed exploitation ratio (E) was 0.66 yr^{-1}, above the sustainable threshold of 0.5.

The probability of capture of *S. crumenophthalmus*, or the mean length at first capture (L50), was 16.56 cm and was generated from the catch curve of the same data set, as shown in Figure 7.

The recruitment pattern of *S. crumenophthalmus* was unimodal, peaking in June and July (Figure 8).

3.7 Proportion of mature catch

Among the five major fishing gears evaluated (Figure 10), only the small-scale gears such as Surface set gillnet (SSGN) and Multiple hook and line (MHL) exceeded this threshold, with SSGN recording mature catch proportions of 12% and MHL of 43% on average across the sampling years.

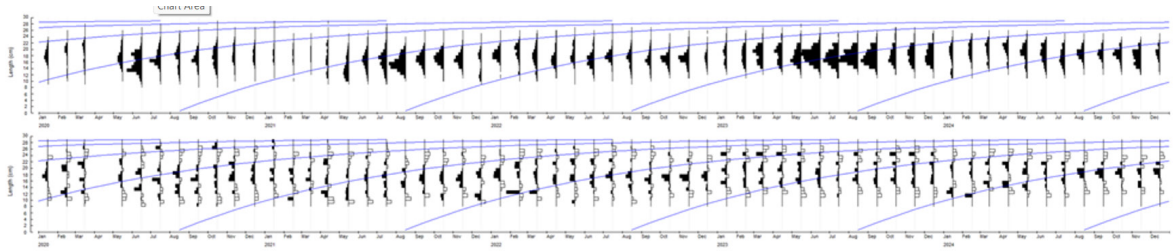


Figure 5. Length frequency and fitted growth curves of *S. crumenophthalmus* restructured by ELEFAN 1 in FMA10.

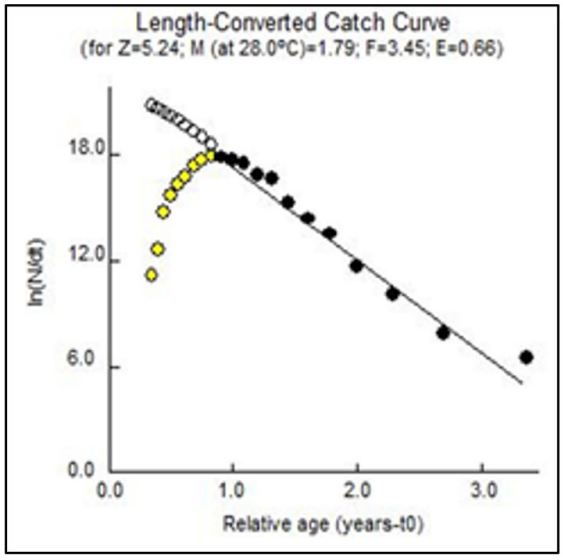


Figure 6. Length-converted catch curve analysis of *Selar crumenophthalmus* CY 2020–2024 in FMA10.

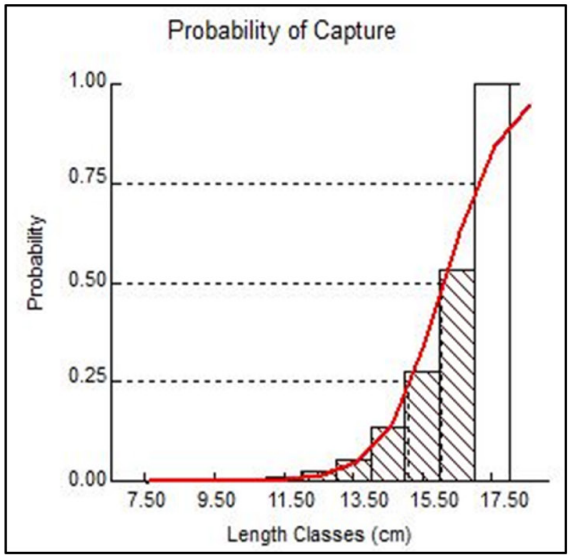


Figure 7. Probability of capture of *Selar crumenophthalmus* CY 2020–2024 in FMA10.

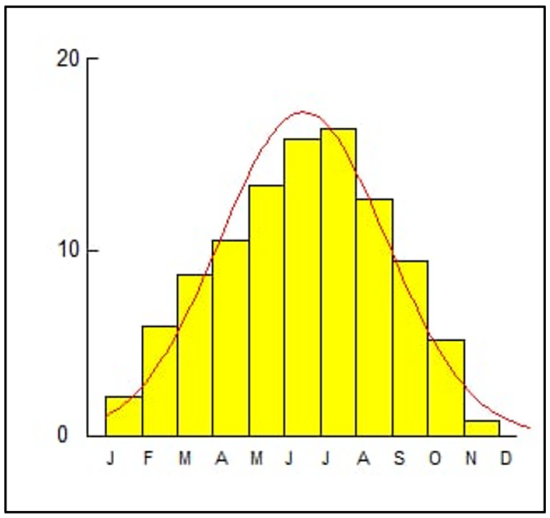


Figure 8. Recruitment pattern observed for *Selar crumenophthalmus* from CY 2020–2024 in FMA10.

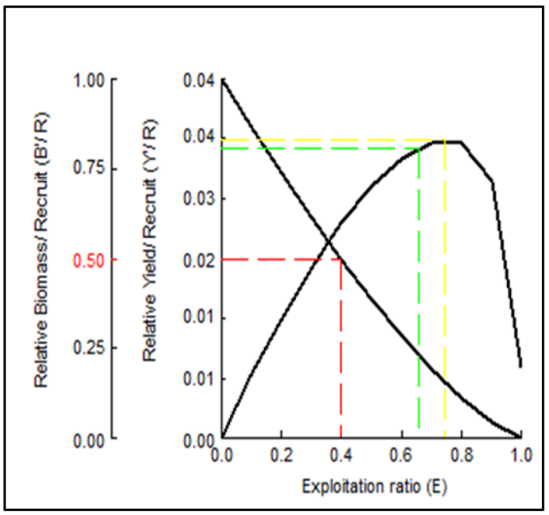
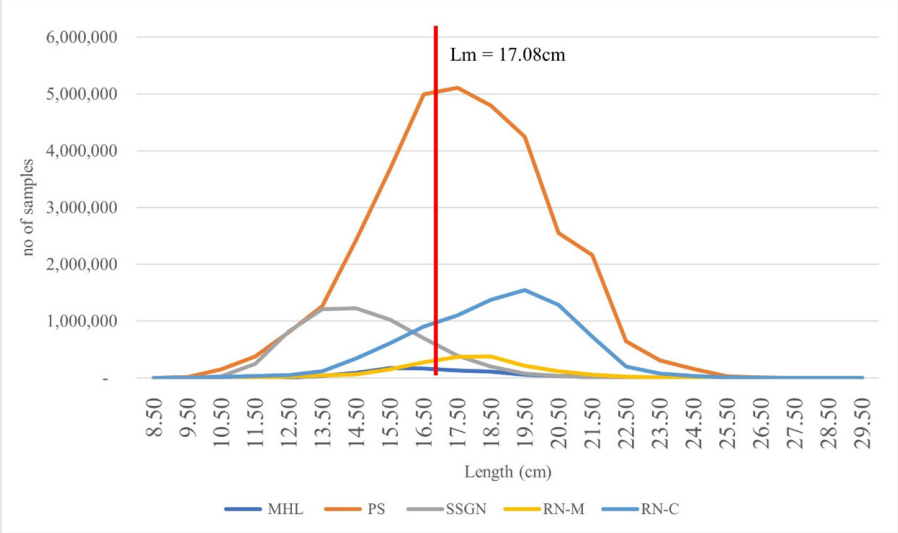


Figure 9. Relative yield per recruit exploitation rate(E) of *Selar crumenophthalmus* CY 2020–2024



Indicator	PS	RN-C	SSGN	RN-M	MHL
Immature	41%	25%	88%	32%	57%
Mature	59%	75%	12%	68%	43%

Figure 10. Percentage mature and immature of the dominant geartype catching *S. crumenophthalmus* for CY 2020–2024 in FMA10.

3. 8 Biomass

Length frequency data were used to estimate the proxy biomass of *S. crumenophthalmus* using the Length Based Bayesian (LBB) method. Results indicated that the current biomass relative to the virgin biomass (B/B_0) was 0.3, corresponding to an estimated 70% depletion from the original stock and falling below the sustainability threshold of 0.5. Additionally, the relative biomass at maximum sustainable yield (B/B_{MSY}) was 0.79, which is below the sustainability benchmark of 1.

4. DISCUSSION

Selar crumenophthalmus is the dominant species landed in Fisheries Management Area (FMA) 10, encompassing major fishing grounds such as the Camotes Sea, Ormoc Bay, Danajon Bank, and Cebu Strait in Regions 7 and 8. The fishery largely depends

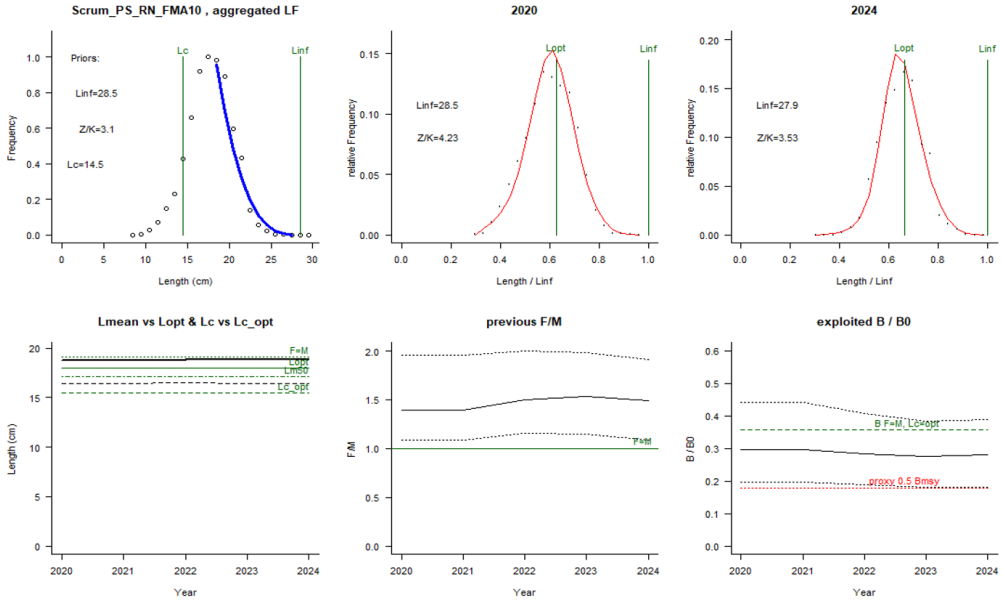


Figure 11. LBB plot for *S. crumenophthalmus* CY 2020–2024 in FMA 10.

Table 2. Percentage share of top five species by gear type monitored from CY 2020–2024 in FMA 10.

Gear type	Species	Common Name	Catch (MT)	RA (%)
A. Commercial				
Purse seine	*Selar crumenophthalmus*	Bigeye scad	2,569.91	37.66
	Decapterus tabl	Roughear scad	1,195.11	17.51
	Decapterus macrosoma	Shortfin scad	947.18	13.88
	Decapterus kurroides	Redtail scad	366.30	5.37
	Sardinella lemuru	Bali sardinella	282.85	4.14
	Others (51 spp.)		1,463.47	21.44
	Total		***6,824.82***	
Ring Net	*Selar crumenophthalmus*	Bigeye scad	650.86	22.47
	Decapterus tabl	Roughear scad	319.51	11.03
	Auxis rochei	Bullet tuna	256.47	8.86
	Rastrelliger faughni	Island mackerel	251.23	8.67
	Decapterus macrosoma	Shortfin scad	243.17	8.40
	Others (73 spp.)		1,175.10	40.57
	Total		***2,896.36***	
B. Municipal				
Surface set gillnet	*Selar crumenophthalmus*	Bigeye scad	274.88	79.31
	Sardinella fimbriata	Fringescale sardinella	31.21	9.00
	Sardinella lemuru	Bali sardinella	9.47	2.73
	Auxis thazard	Frigate tuna	6.56	1.89
	Sardinella gibbosa	Goldstripe sardinella	5.96	1.72
	Others (86 spp.)		18.53	5.35
	Total		***346.61***	
Ring net	*Selar crumenophthalmus*	Bigeye scad	180.60	29.53
	Auxis rochei	Bullet tuna	118.26	19.34
	Decapterus macrosoma	Shortfin scad	41.62	6.81
	Herklotsichthys quadrimaculatus	Bluestripe herring	31.35	5.13
	Cubiceps whiteleggii	Shadow driftfish	28.48	4.66
	Others (42 spp)		211.19	34.54
	Total		***611.51***	
Multiple hook and line	*Selar crumenophthalmus*	Bigeye scad	59.53	30.28
	Euthynnus affinis	Kawa-kawa	43.29	22.02
	Katsuwonus pelamis	Skipjack tuna	16.64	8.46
	Auxis rochei	Bullet tuna	11.83	6.02
	Auxis thazard	Frigate tuna	9.74	4.95
	Others (226 spp)		55.58	28.27
	Total		***196.60***	

Table 3. Growth and mortality parameters of *S. crumenophthalmus* in FMA 10 and comparative parameters in other fishing grounds.

Area	Linf	K	F	M	E	Lm50	Year	Reference
FMA 10	29.56	1.00	3.45	1.79	0.66	17.08	2020–2024	This study
Camotes Sea	30.03	0.89	2.96	1.64	0.68		2003–2012	Belga et al. 2018
Hinatuan Passage	27.5	1.3	2.64	2.17	0.55	-	2013	Baclayo et al. 2016
Visayan Sea	31.6	1.8	4.92	2.59	0.65	21.1	1987–1988	Dalzell and Penaflor 1989
Moro Gulf	27	2	6.13	2.9	0.67	13.8	1987–1988	Dalzell and Penaflor 1989
Camotes Sea	31.2	1.77	7.44	2.58	0.74	13.2	1987–1988	Dalzell and Penaflor 1989
Northern Sulu Sea	29	2.05	3.2	2.89	0.52	21.2	1987–1988	Dalzell and Penaflor 1989

on commercial fishing gears, with ring nets and purse seines contributing about 85% of the total catch, while municipal gears, including multiple hook-and-line, surface set gill nets, and municipal ring nets, account for the remaining 15%. These gears also target other economically important small pelagic species, particularly *Decapterus* spp. (*D. macrosoma, D. tabl,* and *D. kurroides*) and *Auxis* spp. (*A. rochei* and *A. thazard*), indicating that *S. crumenophthalmus* is exploited as part of a multispecies small pelagic fishery. In recent years, technological improvements, including the adoption of power blocks, have increased the operational efficiency of ring nets, leading some vessels to be reclassified as purse seines. Power blocks, hydraulic net haulers, fish-finding equipment, and other mechanization collectively increased fishing power and operational efficiency (Dinglasan, 1970). Such advancements may have enhanced harvesting efficiency and contributed to the high proportion of catches obtained by these commercial gears.

In 2023, the catch per unit effort (CPUE) for both major commercial gears increased markedly, reaching approximately twice the values recorded in the previous year. This report is consistent with the production trend generated from Philippine Statistics Authority annual data on bigeye scad. In addition, commercial fishing vessel landings in 2023 were consistently present daily compared to other years, which may have been influenced by the below-average frequency of tropical cyclones in the Philippines in 2023 (PAGASA 2024). Consistently, total catch-landing records of *S. crumenophthalmus* were also higher in 2023 based on NSAP 7 data. For municipal gears, surface set gill net showed relatively stable CPUE values; multiple hook and line showed an increasing trend over time; however, ring net-municipal showed a significant decreasing pattern due to inconsistent landings, which was observed only at one landing site in 2020–2022. Additional monitoring sites in Napo and Loon in 2023-2024 later contributed to the stabilization of observed CPUE for ring net-municipal.

Catch trends are typically driven by seasonality (Belga et al. 2018). Similar to Belga et al. (2018) in Camotes Sea, catches of *S. crumenophthalmus* in FMA 10 increased from May, peaked in June, and declined from November to December. This seasonality can be attributed to the recruitment pulse exhibited by the species, which also peaks in June. Recruitment pulses represent periods when a large number of young fish survive early life stages and enter the exploitable population. As these recruits grow to sizes vulnerable to fishing gears, they often produce seasonal increases in catch and catch per unit effort (CPUE), provided that fishing effort remains relatively constant.

The length composition of *S. crumenophthalmus* caught by purse seine in FMA 10 ranged from 8.50 to 28.50 cm, indicating generally larger individuals compared to those reported from the ring net fishery in the Camotes Sea, where sizes varied from 6 to 23cm (Belga et al. 2018).

The estimated exploitation rate (E) in this study is comparable to values reported for the Camotes Sea, which exceed the 0.5 threshold, indicating exploitation beyond the optimum level (Belga et al. 2018). Fishing mortality also surpasses natural mortality, signaling high fishing pressure. These findings suggest that *S. crumenophthalmus* stocks in the Philippines have been heavily exploited since the mid-1970s (Dalzell and Ganaden 1987).

Among the five major gears catching *S. crumenophthalmus,* the mean lengths of catches obtained from SSGN and MHL are smaller than the length at first maturity. The proportion of mature individuals in these catches exceeds the 50% threshold, suggesting that these gears contribute to recruitment overfishing. Additionally, the mean length at first capture (Lc50) is slightly lower than the length at first maturity (Lm), further indicating recruitment overfishing.

The probability of capture of *S. crumenophthalmus*, or mean length at first capture (L50), generated in this study is generally lower than that reported in previous studies in the Camotes Sea by Jabat and Dalzell (1988) and Belga et al. (2018), which is a major fishing ground of FMA 10.

The observed recruitment pattern is unimodal, differing from ringnet catches in the Camotes Sea, but matches the unimodal recruitment of *S. crumenophthalmus* documented from trawl fisheries in the Visayan Sea (Dalzell and Penaflor, 1989) and in West Bengal, India (Panda et al. 2016)

Biomass estimates such as current biomass relative to virgin biomass (B/B_0) and relative biomass at maximum sustainable yield (B/B_{MSY}) both indicate that the threshold has been breached, suggesting the stock has been overfished.

5. CONCLUSION AND RECOMMENDATIONS

The stock assessment of *S. crumenophthalmus* in Fisheries Management Area (FMA) 10, based on multiple performance indicators, consistently indicates that this key small pelagic species is experiencing overexploitation. Although a variety of fishing gears contribute to total landings, five dominant gears (ring net, purse seine, surface set gillnet, multiple hook and line, and municipal ring net) account for most of the catch. This level of exploitation is associated with a biomass estimate below sustainable thresholds and may indicate recruitment overfishing in certain gear types, such as SSL and MHL, with estimated length at capture (Lc) less than length at first maturity. In the context of the three priority management measures for FMA 10, namely, (1) strengthening enforcement against illegal, unreported, and unregulated fishing, (2) maintaining a moratorium on the issuance of fishing vessel and gear licenses, and (3) expanding and protecting critical habitats covering at least 30% of the area by 2030, the present findings provide evidence supporting the implementation of targeted fisheries management actions. To mitigate excessive fishing pressure, continuing the moratorium on issuing fishing vessel and gear licenses may help reduce fishing effort, particularly for commercial gears such as purse seines and ring nets, which collectively account for approximately 85% of total landings. To address recruitment overfishing, we recommend implementing minimum catch or landing size limits, especially for catches from surface set gillnets and multiple hook-and-line fisheries, whose mean catch lengths fall below the estimated length at first maturity (17.08 cm). In addition, establishing seasonal fishing closures for specific gears or fishing grounds, particularly during the peak recruitment period of June to July, is also recommended. These measures should be supported and refined through reproductive biology studies, including spawning seasonality, gonadosomatic index, fecundity, and spawning potential ratio. Collectively, these results provide essential baseline information for managing *S. crumenophthalmus* and offer valuable insights applicable to the broader scope of small pelagic species in FMA 10, which share overlapping habitats and similar vulnerabilities to fishing pressure. These integrated and proactive management approaches are therefore necessary to ensure the long-term sustainability and resilience of these stocks.

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CONFLICTS OF INTEREST

The authors have no conflict of interest to declare. All co-authors have seen and agreed with the contents of the manuscript, and there is no financial interest to report. We certify that the submission is an original work and is not under review at any other publication.

AUTHORS CONTRIBUTIONS

Garcia JH: Conceptualization, assessment, validation, draft preparation, review and editing of manuscript. **Bernales AM:** Data collection, analysis, data visualization, and draft preparation. **Paran JS**: Data collection, analysis. **Fajardo MJ**: Data collection, analysis, and draft preparation. **Ruinata MN**: Conceptualization, review and editing of manuscript. **Acosta RP**: Draft preparation and editing.

ETHICS STATEMENT

Enumerators collect data such as catch and effort through voluntary interviews with fisherfolk during sampling, using a standardized protocol.

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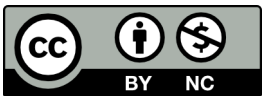

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