



Characteristics of tuna fisheries in the Indian Ocean, especially in Quota Based Fishing in the Zone 04 (IFMA 572 and 573)

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ABSTRACT

Indonesia is one of the world's leading tuna-producing countries. Under the Quota Based Fishing (Penangkapan Ikan Terukur/PIT), its Exclusive Economic Zone (ZEEI) in the Indian Ocean is designated as zone 04 of PIT. This research aims to analyzing the characteristics of tuna fisheries in the zone 04 (Indonesian Fisheries Management Area/IFMA 572 and 573), including tuna production by fishing gear and by port landing, species composition by gear, Landing per Unit Efforts (LPUE) by gear and by tuna species. The most dominant fishing gear for tuna is lines (hand lines, troll lines, kite lines, and rod handlines). Purse seines and longlines also caught a lot of tuna, but their percentages were still lower. The dominant tuna species caught was yellowfin tuna, which came from all types of fishing gear. The average LPUE in 2024 for gillnets was 28.6 kg/days, lines 56 kg/days, purse seine 161 kg/days, longline 58.5 kg/days, and pole and line 268 kg/trip/day. The abundance of ALB was highest in July, but the trend has been increasing since March and began to decline in last year. Pole and line and purse seine were the most productive fishing gear for catching tuna. The abundance of YFT varied greatly with high abundance in March, July, and October. The abundance of BET was high in February, July, and September. SBT is highly abundant in March, April, and July, with some months being empty. Bena Public Port is recorded as the port with the highest production within Zone 04.

Introduction

The Government of Indonesia has implemented a Quota Based Fishing (Penangkapan Ikan Terukur, PIT) in marine waters to regulate fishing activities in a controlled and balanced manner (Nurlaela, 2023; Trenggono, 2023). This policy is enforced within PIT zones and involves establishing fishing quotas designed to ensure the sustainability of fishery resources and promote equitable national economic development. Fishing quotas are determined based on the potential of fish resources and allowable catch limits for specific fish species, as recommended by the National Commission on Fish Stock Assessment. Quotas are established through three methodologies: (1) for species with defined Maximum Sustainable Yield (MSY) and Allowable Catch (Jumlah

Tangkapan yang Diperbolehkan/JTB), as determined by the National Commission on Fish Resource Assessment (KomnasKajiskan); (2) for species lacking MSY and JTB definitions; and (3) for migratory species, such as tuna, regulated under Regional Fisheries Management Organizations (RFMOs). The PIT system divides fishing areas into six zones, encompassing Indonesian Fisheries Management Areas (WPPNRI) and open waters. Tuna, as a highly migratory species, inhabits both Exclusive Economic Zones (EEZ) and open ocean regions (Firdaus, 2019). Tuna stocks are managed by RFMOs to achieve Maximum Sustainable Yields (Napitupulu *et al.*, 2022). In the Indian Ocean, tuna stock management is coordinated by the Indian Ocean Tuna Commission (IOTC), which oversees

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various tuna species, and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), which specifically manages *Thunnus maccoyii* (southern bluefin tuna).

As one of the world's largest tuna producers, Indonesia possesses substantial tuna fishery potential in the Indian Ocean. National production data reveal significant tuna catches (excluding skipjack tuna) in Zones 02, 03, 04, 05, and 06. Under the PIT framework, the EEZ waters of the Indian Ocean are categorized within Zone 04, which exhibits ideal environmental conditions—such as temperature, salinity, and food availability—favoring tuna species (Jatmiko *et al.*, 2020; Sambah *et al.*, 2017). Indonesia's tuna fisheries contribute significantly to the national and global economy (Agustina *et al.*, 2019; Nikijuluw, 2017). Tuna products meet domestic demand and support international trade, particularly in markets such as Japan, the United States, and Europe (Buana *et al.*, 2018; Firdaus, 2019). The expanding tuna industry creates numerous employment opportunities in fishing and processing sectors, making it a cornerstone of local and national economic development (Nursya'ban, 2024).

The increasing demand for tuna commodities, both domestically and globally, alongside high market prices, has led to intensified exploitation of tuna resources. Economic incentives driven by high market prices have contributed to overfishing (Firdaus, 2019). Given tuna's migratory nature across national administrative boundaries, cooperative stock management is essential. RFMOs, such as IOTC and CCSBT, coordinate tuna stock management in the Indian Ocean through agreements among member countries. As an RFMO member, Indonesia must ensure sustainable tuna fisheries management and adherence to regional agreements to maintain resource sustainability. Efforts to control tuna fishing through sustainable governance frameworks continue to evolve in Indonesia. The PIT policy, specifically applied to tuna fisheries governed by RFMOs, provides a benchmark for implementing measured fishing policies across other fishery resources. However, challenges remain, particularly during the initial phases of PIT implementation.

Key challenges include inaccurate catch reporting and the prevalence of Illegal, Unreported, and Unregulated (IUU) fishing (Belhabib and Billon, 2022; Kurota *et al.*, 2010). Data inaccuracies lead to several issues: (1) discrepancies in vessel numbers, fishing efforts, and tuna production after policy implementation; (2) unreliable recommendations for Tuna Fishery Management Plans (RPP); (3)

difficulties in evaluating quota utilization set by RFMOs, potentially resulting in non-compliance, resource sustainability risks, and fines imposed by IOTC and CCSBT; and (4) a lack of recent scientific literature on tuna fisheries, limiting access to updated information for sustainable management (Bradford *et al.*, 2016). Sustainable tuna fisheries management necessitates a holistic approach to maintain population levels and minimize environmental impacts (Akbar *et al.*, 2020). Strengthened regulations, inter-agency coordination, and accurate data collection systems are critical to fostering trust among RFMOs and supporting sustainable tuna resource governance (Akbar *et al.*, 2020; Bradford *et al.*, 2016; Hartaty and Arnenda, 2019). This research aims to analyzing the characteristics of tuna fisheries, including tuna production, tuna production by fishing gear and by port landing, species composition by gear, Landing per Unit Efforts (LPUE) by gear and by tuna species., particularly within PIT in the Zone 04. Accurate baseline data from Zone 04 are crucial for optimizing tuna quota management and mitigating over-exploitation risks. Developing a systematic data collection approach can enhance monitoring of fishing quotas within Indonesia's fishery management areas (Ramdhani *et al.*, 2022). This study aspires to provide scientific support for tuna quota governance in Zone 04, aligning with national and international efforts toward sustainable fisheries management.

Materials and Methods

Location and time of research

The research will be conducted at the primary tuna landing sites within the Measured Fishing Zone 04 (Zona 04 of PIT), specifically at the Palabuhanratu National Fishing Port (PPN), Cilacap Oceanic Fishing Port (PPS), Benoa General Port (PU), and Tenau Fishing Port. These locations serve as the main landing points for four tuna species: Bigeye Tuna (BET), Yellowfin Tuna (YFT), Albacore (ALB), and Southern Bluefin Tuna (SBT), which are harvested by Indonesian vessels operating in Zone 04. The research will be carried out in 2024.

Data Collection Procedure

The data collected in this study focuses on national tropical tuna production from 2005 to 2023, the production of four tuna species (BET, YFT, ALB, SBT) based on fishing fleets in 2023, the production of these species in measured fishing zones in 2023, and their production at the fishing ports within the research locations for 2023 and 2024. Data collection involved field observations at

landing sites, including Palabuhanratu, Cilacap, Benoa, and Tenau ports, to record tuna statistics. Additionally, secondary data from relevant institutions were obtained to complement the primary data collected.

Tuna is a major species group in terms of global catches. In 2015, catches of these seven species reached 4.8 million tonnes, i.e. 5% of the world marine fish catch. Thus, every second, nearly 152 kilos of tuna are caught, while the skipjack alone is the third most fished species in the world. Tuna are present in all the world's oceans, with the Western Pacific representing the largest fishing area (ISSF, 2017).

The bigeye tuna stock is determined to be overfished and subject to overfishing. The skipjack tuna stock is determined to be not overfished and not subject to overfishing. The yellowfin tuna stock is determined to be not overfished and not subject to overfishing (IOTC-WPTT, 2024).

Data analysis

The data were analyzed descriptively to provide a comprehensive understanding of tuna resources and fishing activities in Zone 04. Descriptive statistics summarize key information such as national tropical tuna production from 2005 to 2023, tuna production by fishing fleet, production of four tuna species by fishing fleet, production of four tuna species in measurable fishing zones, and production of four tuna species at the fisheries ports in the study locations. This study aims to offer a thorough depiction of the current status of tuna resources and provide critical insights for improving future tuna fisheries management.

Landing Per Unit Effort (LPUE)

Landing Per Unit Effort (LPUE) is used to determine the relative abundance of fish resources for purposes of fish stock studies. LPUE calculates the catch actually caught and sold at the port through reporting. LPUE can be used in various ways, depending on the available data and based on different assumptions. The LPUE value in this study was calculated per fishing gear and per tuna species caught. In general, the LPUE calculation can be formulated as follows:

$$LPUE = \frac{\text{Landing}}{\text{trips}}$$

where:

LPUE : Landing Per Unit Effort

landing : total catch landed at the port by each vessel

trips : number of trips

Results

National Production of Tropical Tuna

Tuna species, including Bigeye Tuna (*Thunnus obesus*), Yellowfin Tuna (*Thunnus albacares*), Albacore (*Thunnus alalunga*), and Southern Bluefin Tuna (*Thunnus maccoyii*), play a crucial role in marine ecosystems and fisheries sectors within the Western and Central Pacific Ocean (WCPO) and the Indian Ocean. According to the Indian Ocean Tuna Commission (IOTC, 2024), assessments of key tuna stocks in the Indian Ocean indicate that Bigeye Tuna (BET, *Thunnus obesus*) and Yellowfin Tuna (YFT, *Thunnus albacares*) are in an overfished state (biomass) and experiencing overfishing (fishing mortality). In contrast, Albacore Tuna (ALB, *Thunnus alalunga*) is neither overfished (biomass) nor subject to overfishing (fishing mortality).

Furthermore, the International Union for Conservation of Nature (IUCN, 2024) classifies BET as a Vulnerable species, while YFT and ALB are listed as species of concern. Data from the Commission for the Conservation of Southern Bluefin Tuna (CCSBT, 2023) reveal that Southern Bluefin Tuna (SBT, *Thunnus maccoyii*) is overfished, and IUCN (2024) categorizes SBT as an Endangered species. Conservation and effective management of these tuna stocks are imperative, considering their ecological roles and economic value. Assessments of stock performance in designated fishing zones, such as Zone 04, are essential to support sustainable management (Vaiholo and Kininmonth, 2023).

Regional Fisheries Management Organizations (RFMOs) play a vital role in implementing tuna conservation measures. The interconnectedness of tuna stocks across regions underscores the need for stricter transboundary management approaches, given the extensive migratory behavior of tuna species (Arrizabalaga et al., 2015). However, issues such as Illegal, Unreported, and Unregulated (IUU) fishing and high exploitation rates, particularly for Yellowfin Tuna, raise concerns regarding stock sustainability, prompting recommendations for quota restrictions and temporal closures. Climate change further compounds these challenges, impacting tuna distribution and population dynamics by altering migratory and reproductive patterns. Environmental factors, such as temperature and salinity, significantly influence the distribution of tuna species, as these species tend to prefer cooler water habitats that support their prey, such as small fish and squid (Vaiholo and Kininmonth, 2023).

Tropical tuna production is an integral component of Indonesia's fisheries sector, contributing substantially to the national economy

and the sustainability of marine resources. Key tropical tuna species, including Yellowfin Tuna (*Thunnus albacares*), Bigeye Tuna (*Thunnus obesus*), and Skipjack Tuna (*Katsuwonus pelamis*), have become

Data indicate that tropical tuna production has increased over recent years, driven by various management policies, evolving environmental

flagship commodities, supporting exports while highlighting the importance of prudent management to preserve marine ecosystems.

conditions, and growing global market demand. Figure 1 illustrates the statistical trends of national tropical tuna production from 2005 to 2023.

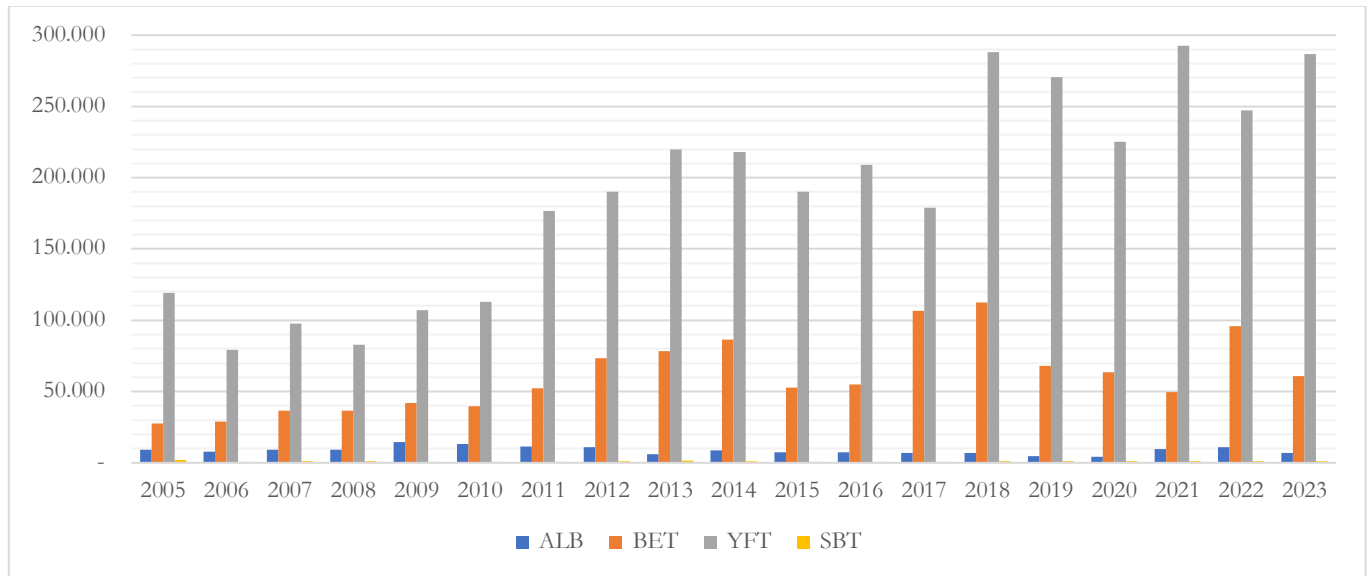


Figure 1. National Tropical Tuna Production Data for the Years 2005–2023

Figure 1 illustrates the fluctuating yet increasing trend in tropical tuna fisheries data. Tuna production in Indonesia exhibits variability due to multiple factors, including climate change, fishing gear, and fisheries management policies. This observation aligns with the findings of (Khoerunnisa et al., 2021), which highlighted that management policies influence production levels and the frequency of fish landings from tuna longline fleets. The use of Fish Aggregating Devices (FADs) has been shown to enhance catch rates but poses risks of overfishing, particularly of juvenile fish (Hargiyatno et al., 2021). Similarly, FADs have contributed to increased catch rates but require careful regulation to prevent ecosystem degradation. These findings underscore

the importance of sustainable management to balance production needs with resource conservation.

Tuna Production by Fishing Gear

There are many fishing gears used to catch tuna in Zone 4 of the Indian Ocean, but after grouping them, they are categorized into gillnets, lines, purse seines, pole and line, and longlines. The most dominant fishing gear for tuna is lines, which include hand lines, troll lines, kite lines, and rod handlines. Purse seines and longlines also catch a significant amount of tuna, but their percentage is still lower than that of lines (Figure 2).

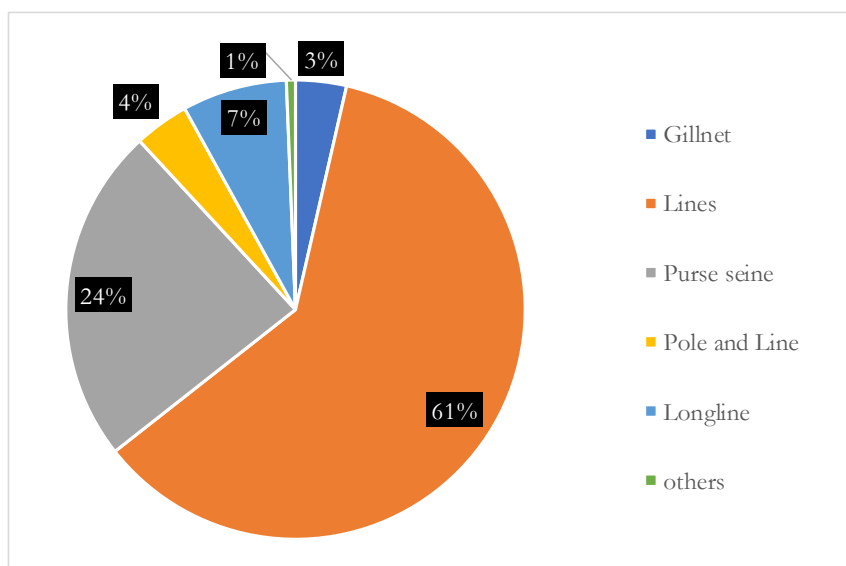


Figure 2. Tuna Production by Fishing Gear in 2023 (Kg), Lines (hand line, troll line, kite line, rod handline)

Composition Tuna Species by Fishing Gear

The composition of tuna species based on fishing gear is presented in Figure 3. The figure shows that the overall catch of yellowfin tuna is the most dominant species across all fishing gears. Bigeye tuna catches are highly dominant in gillnet fishing gear and moderately dominant in lines, purse seine, and longline fishing gear, with a small percentage being caught on pole and line. Southern bluefin tuna is most dominantly caught on longline, with a small percentage being caught on gillnet. Albacore is also caught more often on longline compared to other fishing gears.

Information on tuna species composition is crucial for understanding the dominant tuna species caught by each gear, fishing patterns, gear selectivity, and for general tuna fisheries management. Each gear has different selectivity and operating methods. Species composition also reflects the influence of gear use in determining catch targets and significantly influences the number and types of tuna caught. Each tuna gear has different selectivity and is operated at different water depths. Regular monitoring of species composition is essential to detect changes in composition, abundance, and other factors, such as fishing grounds. Changes resulting from gear use and environmental changes over time will impact the condition of tuna stocks.

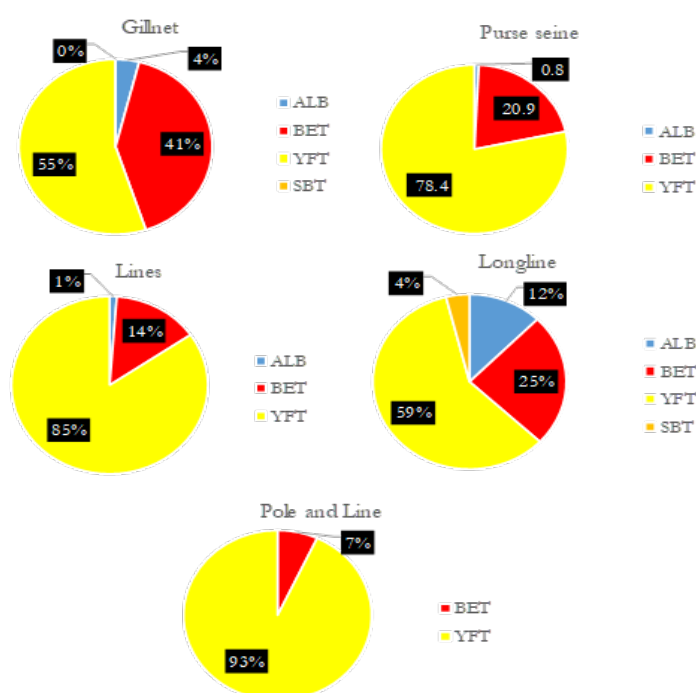


Figure 3. Composition tuna species by fishing gear

Landing per Unit efforts (LPUE)

The average LPUE in 2024 for gillnets was 28.6 kg/day, lines 56 kg/day, purse seine 161 kg/day, longline 58.5 kg/day, and pole and line 268 kg/day. The 2013 gillnet LPUE had a higher average value compared to 2024. The 2023 LPUE trend showed an increase in value from June to October, with the highest values in September and October. Meanwhile, in 2024 the highest values were in June and August. Both 2023 and 2024 saw a decrease in LPUE values at the beginning of each year. For lines, the highest abundance in 2023 occurred in July, while in 2024 it occurred in February. The average catch abundance was higher in 2023 than in 2024 for lines. In purse seine fishing, the abundance trend began to increase in early 2023 and peaked in April, while it peaked in June 2024. The average abundance in 2023 was still higher than in 2024, despite the fact that the number of trips in 2024 was greater than in 2023. This could indicate a decrease in the abundance of fish caught by purse seine fishing in 2024.

Longline fishing showed the highest abundance at the beginning of the year, both in 2023 and 2024. The average LPUE for longline fishing in 2024 experienced a very high increase compared to 2023, including a significant increase in the number of boat trips in 2024. The increase in trips in 2024 did not

cause a decrease in the production value of fish caught by longline fishing, this indicates that longline fishing gear is still safe and does not cause a decrease in fish abundance. The highest LPUE for pole and line fishing in 2023, namely in January and May, while in 2024 only in January. The average trip for pole and line fishing decreased from 2023 to 2024 and there was a slight increase in catch from 2023 to 2024. The number of pole and line trips decreased is suspected because the number of pole and line vessels operating is decreasing due to the problem of difficulty in obtaining live bait for fishing operations. The LPUE value of fishing gear that catches tuna is presented in Figure 4.

LPUE ALB was highest in July, but the trend has been increasing since March, and by the end of the year, abundance began to decline drastically. YFT abundance varied significantly each month, with peaks in March, July, and October. BET abundance also fluctuated significantly, with peaks in February, July, and September. SBT abundance was highest in March, April, and July, with several months being empty. This is suspected because SBT is not landed every month or, if landed, the percentage value is relatively small compared to other tuna species. Tuna abundance in zone 04 is presented in Figure 5.

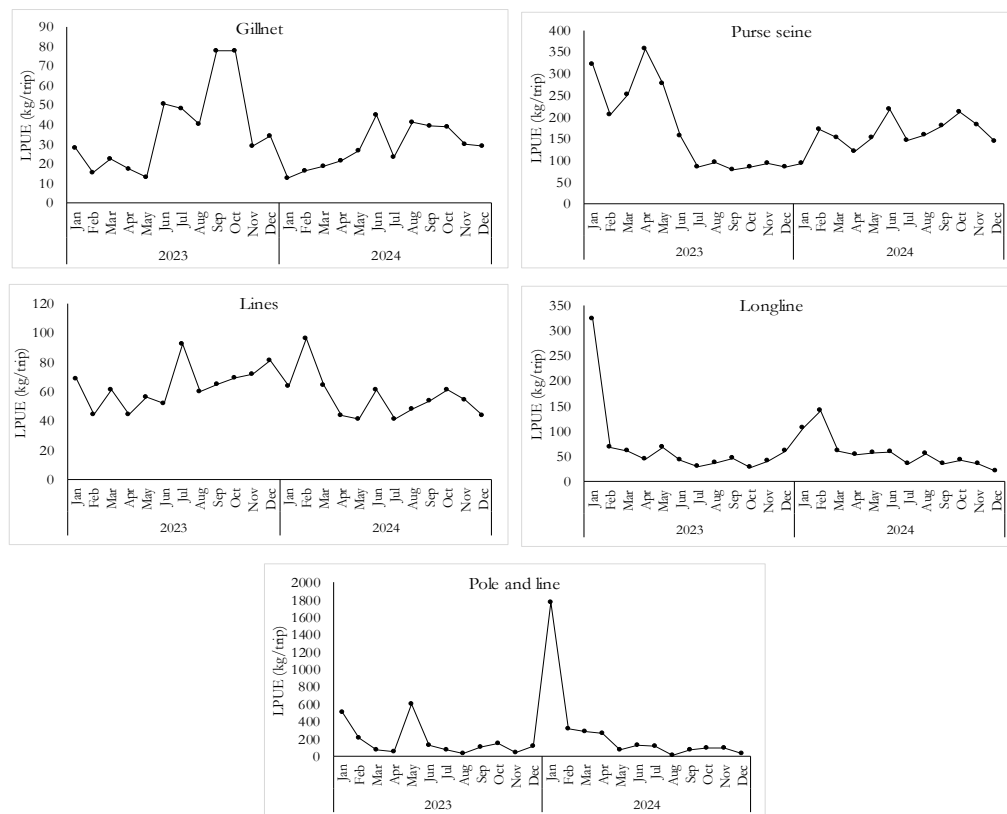


Figure 4. LPUE by Fishing Gear (Data source: Fishery Port Information Center, 2023-2024)

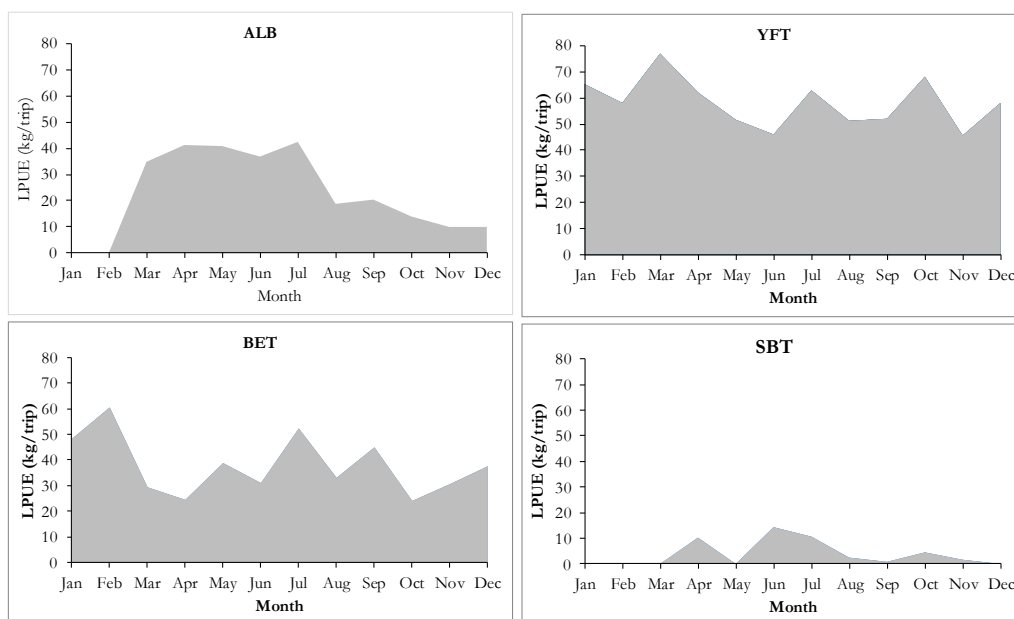


Figure 5. Average Monthly LPUE for Tuna in 2023-2024 in Zone 04

Tuna Production Based on Measured Fishing Zones (PIT) in 2023

The four major tuna species in Indonesia—bigeye tuna (*Thunnus obesus*), yellowfin tuna (*Thunnus albacares*), albacore (*Thunnus alalunga*), and southern bluefin tuna (*Thunnus maccoyii*)—are key components of marine ecosystems and critical to the fisheries industry, particularly in the Western and Central Pacific Ocean as well as the Indian Ocean. Figure 2

illustrates the production data for these four tuna species in Indonesia during 2023, categorized by PIT zones. This data highlights the production distribution of each tuna species across various zones, providing insights into the stock distribution of tuna throughout Indonesia's fishing areas. National tuna production figures are calculated based on fish landing locations. The 2023 national fisheries statistics data serve as the reference for the information presented in Figure 6.

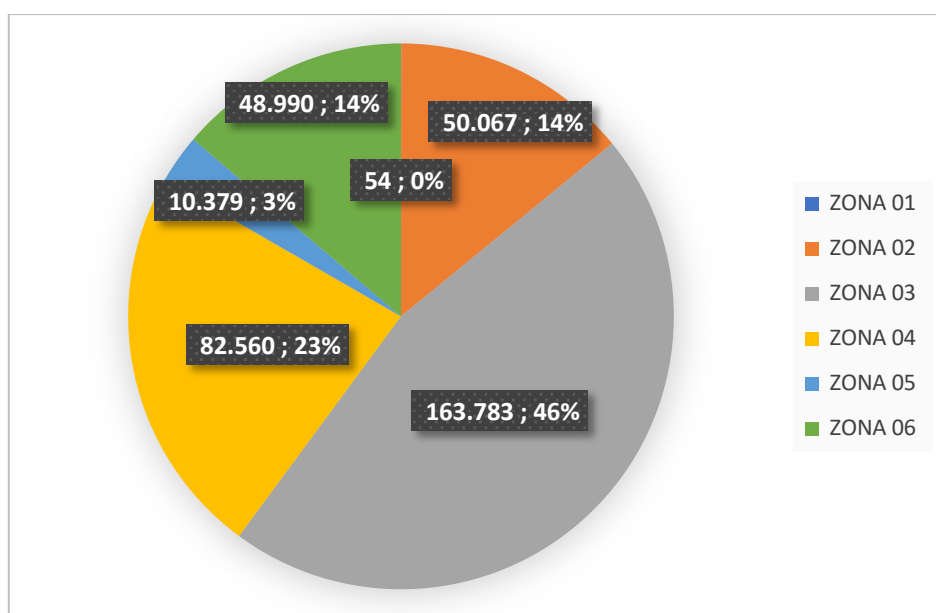


Figure 6. Production of Four Major Tuna Species in Indonesia, 2023

Based on the 2023 production data obtained from fish landing sites and national capture fisheries statistics, significant variations in production volume

are observed across different PIT Zones. Zone 03 is recorded as the region with the highest production volume, contributing 46% to the national total. This

reflects intense fishing activities and abundant tuna resources in this area. Zone 04 is the second-largest contributor, accounting for 23% of total production. Zones 02 and 06 each contribute 14%, indicating relatively significant fishing activities, albeit lower compared to Zones 03 and 04. Zone 05 shows a considerably smaller contribution, only 3%, possibly due to limited resources or reduced fishing activity. Zone 01 reports minimal production, with only 54 tons. This uneven distribution of production illustrates disparities in tuna stock potential, exploitation levels, and fisheries management across zones. A region-based management approach could be a viable solution to ensure the sustainability of ecosystems and economic balance in Indonesia's tuna fisheries sector.

Tuna Production in PPS Cilacap, PPN Palabuhanratu, PU Benoa, and PP Tenau

The production of four key tuna species at four strategic fishing ports within Zone 04—namely Pelabuhan Perikanan Samudera (PPS) Cilacap, Pelabuhan Perikanan Nasional (PPN) Palabuhanratu, Pelabuhan Umum (PU) Benoa, and Pelabuhan Perikanan Tenau—serves as a critical indicator for mapping tuna distribution in Indonesia (Table 1). These ports function as major landing hubs supporting the national tuna fishing industry. Table 2 presents the production volume of the four tuna species from these ports in 2023. This data underscores the significance of these ports in national tuna fisheries and provides insights into the

The production data of the four main tuna species across four strategic ports within Zone 04 in 2023 provide critical insights into the distribution of catch yields in this region. The Benoa General Port (PU Benoa) recorded the highest production volume, totaling 7,758 tons. The largest contribution was Port (PPS Cilacap) ranked second with a total production of 7,354 tons. The largest share came from Bigeye Tuna (BET) at 2,778 tons and Yellowfin Tuna (YFT) at 4,285 tons, while Albacore (ALB) contributed 290 tons, and Southern Bluefin Tuna (SBT) was recorded at 1 ton. This port highlights a focus on Bigeye and Yellowfin Tuna, which dominate the landings.

The Palabuhanratu National Fisheries Port (PPN Palabuhanratu) recorded a smaller production volume than the two aforementioned ports, at 1,712 tons. The production was dominated by Yellowfin Tuna (YFT) at 1,200 tons, followed by Bigeye Tuna

distribution and regional dynamics of tuna production in Indonesia.

Table 1. Tuna Production at the Research Site in 2023

BASE PORT	TYPES OF TUNA	VOLUME (TON)
PU. Benoa	ALB	1,932
	BET	1,485
	SBT	1,007
	YFT	3,333
Sub Total		7,758
PPS. Cilacap	ALB	290
	BET	2,778
	SBT	1
	YFT	4,285
Sub Total		7,354
PPN. Palabuhanratu	ALB	215
	BET	297
	YFT	1,200
Sub Total		1,712
PP. Tenau Kupang	ALB	3
	BET	114
	YFT	110
Sub Total		227
Grand Total		17,051

from Yellowfin Tuna (YFT) at 3,333 tons, followed by Albacore (ALB) at 1,932 tons, Bigeye Tuna (BET) at 1,485 tons, and Southern Bluefin Tuna (SBT) at 1,007 tons. This high volume underscores PU Benoa's pivotal role as the primary tuna landing center in Zone 04. The Cilacap Oceanic Fisheries (BET) at 297 tons, and Albacore (ALB) at 215 tons. No data were recorded for Southern Bluefin Tuna at this port. The lower production volume indicates relatively limited tuna fishing activities at PPN Palabuhanratu compared to other ports in this zone. The Tenau Fisheries Port registered the lowest production volume at 227 tons, dominated by Bigeye Tuna (BET) at 114 tons, followed by Yellowfin Tuna (YFT) at 110 tons, while Albacore (ALB) accounted for only 3 tons. This port operates at a smaller capacity for tuna landings, making its role more localized compared to other ports.

These data demonstrate that each port exhibits specialization and focus on specific tuna species, reflecting the marine resource potential in their respective areas. The dominant production volumes at PU Benoa and PPS Cilacap highlight the significance of these two ports in supporting the national tuna fisheries industry, while PPN

Palabuhanratu and Tenau Fisheries Port function as auxiliary ports, complementing the distribution of tuna catch in Zone 04. This information forms a foundation for more strategic fisheries management planning, tailored to the potential and capacities of each port.

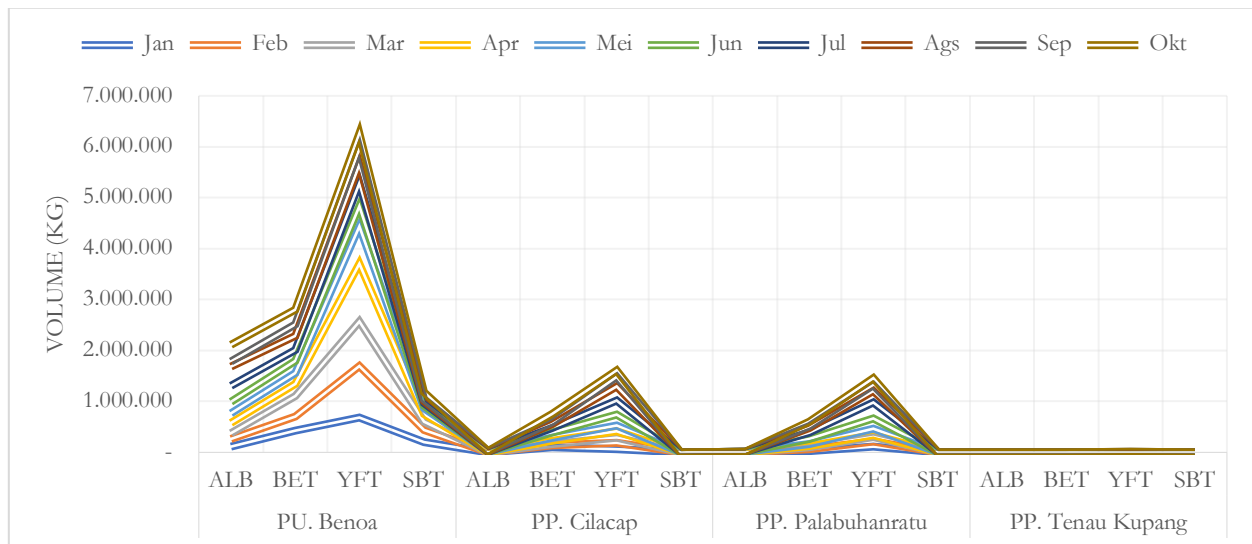


Figure 7. Monthly Tuna Production at Research Locations in 2024

The data presented in Figure 7 illustrates the landing patterns of tuna at four major fishing ports in Zone 04 during the period from January to October 2024. The highest production was recorded at Benoa Public Port (PU Benoa), dominated by Yellowfin Tuna (YFT). Production volume peaked mid-year, particularly in May and June, exceeding 6,000,000 kg. This suggests that the tuna fishing season in this region reaches its highest intensity during these months, likely influenced by tuna migration patterns and favorable oceanic conditions. The Cilacap Oceanic Fishing Port (PPS Cilacap) also exhibited significant production patterns, primarily focusing on Bigeye Tuna (BET) and Yellowfin Tuna (YFT). Peak production occurred in the same months, although the volumes were lower compared to PU Benoa. This pattern indicates synchronization of the fishing season between the two ports, given their shared oceanographic characteristics.

The Palabuhanratu Nusantara Fishing Port (PPN Palabuhanratu) recorded lower production volumes than the previous two ports. The primary focus of production in this port was Yellowfin Tuna, with peak production observed from May to July. Bigeye Tuna production was relatively minor, while Southern Bluefin Tuna was nearly absent in the records for this port. The Tenau Fishing Port reported the lowest production volumes among the four ports, with significantly smaller quantities for all

tuna species. The highest contributions were from Bigeye Tuna and Yellowfin Tuna, but their volumes were not comparable to the other ports. The production patterns across the four ports reflect a peak tuna fishing season occurring mid-year, particularly in May and June. These findings can serve as a basis for planning the distribution of landings and managing tuna stock at each port to ensure the sustainability of Indonesia's tuna fisheries industry.

Discussion

The data from Indonesia's Central Bureau of Statistics demonstrates a growth trend in Indonesian tuna exports, despite a decline observed between 2012 and 2018. Yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) remain the primary export commodities, driven by high demand in Japan and the European Union. However, challenges such as overfishing and illegal fishing threaten the sustainability of production (McCluney et al., 2019). Global market dynamics also influence production, with fluctuating tuna prices driven by demand and competition, particularly from countries like Thailand and the Philippines. Export tariff policies in destination countries further affect the competitiveness of Indonesian tuna. Figure 1 illustrates that bigeye tuna (BET), a species with high economic value, tends to exhibit increased

production when stringent management policies are implemented to mitigate overfishing. Conversely, yellowfin tuna (YFT) experiences high international demand, contributing to increased catch volumes in Indonesia. Albacore tuna (ALB) shows a more fluctuating production pattern, often as bycatch. Improved management is necessary to ensure the sustainability of its population (Hartaty and Arnenda, 2019; Kusdiantoro et al., 2019). Meanwhile, southern bluefin tuna (SBT) faces severe overfishing threats, but potential recovery is evident with proper management implementation (Nikijuluw, 2017; Rahmawati et al., 2017). The economic impact of tuna production is significant for local fishermen and coastal economies. Tuna fisheries create employment opportunities, enhance incomes for coastal communities (Kusdiantoro et al., 2019), and offer substantial export potential to support local economies. Challenges such as illegal fishing necessitate strict policies and collaborative efforts to ensure resource sustainability.

Lines is the dominant groups of fishing gear for tuna fishing and the most dominant from lines group is handline. Handline gear is simple and environmentally friendly, allowing fishermen to target various tuna species, including bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*). Its advantages include reduced bycatch and higher sustainability compared to other methods like purse seine. Studies show that handline fishing achieves higher catch yields relative to other gear types. Handline fishing contributes to marine ecosystem balance by minimizing adverse impacts on fish populations and habitats. This method is particularly popular among small-scale fishermen due to its low environmental footprint and high selectivity, which reduces overfishing risks and bycatch. However, effective handline fishing relies on fishermen's skills and environmental conditions, including seasonality and fishing locations. Despite its advantages, monitoring and management are essential to ensure the sustainability of tuna resources.

Tuna fisheries in the Indian Ocean are among the most productive globally, contributing significantly to food security and the economy of many coastal and island nations. The Indian Ocean Tuna Commission (IOTC) monitors and manages the exploitation of tuna and tuna-like species in the region. Tuna production varies substantially by fishing gear, with different gears targeting different species and sizes of tuna. The primary gears used are purse seines, longlines, gillnets, pole-and-line, handlines, and trolling lines. Purse seine fisheries are the dominant method in the Indian Ocean,

particularly for skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*). These large-scale, industrial operations involve encircling schools of tuna using large nets. Purse seining accounts for the largest share of tuna catches, contributing about 45–50% of the total tuna production in the Indian Ocean (IOTC, 2023). Tuna production in the Indian Ocean is diverse in gear use, with purse seine and gillnets dominating in volume. However, sustainability concerns differ across gear types. While pole-and-line and handline methods are considered eco-friendly, gillnets and longlines raise issues around bycatch and ecosystem impacts. Continued efforts from the IOTC and national fisheries authorities are necessary to ensure sustainable exploitation of tuna stocks and to promote responsible gear use. This is different from the dominant fishing gear used to catch tuna in zone 04, namely the lines group fishing gear in the waters of West Sumatra and South Java.

The composition of tuna catch in the Indian Ocean varies significantly by fishing gear. Purse seines dominate skipjack production, gillnets are the main source of yellowfin, while longlines are essential for deep-water species like bigeye and albacore. The use of selective gears like pole-and-line and handlines offers sustainable alternatives, especially for coastal and island nations. Tuna fisheries in the Indian Ocean are highly diverse, not only in terms of gear types but also in the species composition of the catch. Each gear type tends to target specific tuna species based on the fishing depth, method, and scale of the operation. These species are caught in varying proportions depending on the fishing gear used.

Purse Seine dominant species are skipjack tuna: 60–70%, yellowfin tuna: 25–30%, bigeye tuna: 5–10% (IOTC, 2023). Handline and troll Lines have the dominant species: yellowfin tuna: 60–70%, skipjack tuna: 20–30% (FAO, 2010). Longline have dominant species: bigeye tuna: 45–55%, yellowfin tuna: 30–35%, albacore tuna: ~10–15% (IOTC, 2022). This study found that yellowfin tuna was predominantly caught in almost all fishing gear. It can be concluded that yellowfin tuna are highly vulnerable to fishing pressure, as they are caught in almost all gear types and are highly dominant. Catching of juvenile yellowfin tuna around fish aggregating devices (FADs) should be reduced or regulated to allow them to develop into adults.

Peaks of LPUE purse seine during inter-monsoon seasons (March–May and September–November). Higher LPUE observed during free-school sets compared to FAD-associated sets. Influenced by sea surface temperature (SST) and prey aggregation. The highest of monthly abundance for

skipjack and yellowfin in March–June and September–November, especially in equatorial and Western Indian Ocean zones (IOTC, 2023). Longline catch dominated by bigeye tuna, yellowfin and albacore. LPUE for bigeye is higher in deep oceanic waters during April–July (south) and October–December (equatorial). Monthly Abundance of bigeye and albacore migrate with deep current systems, with higher abundance during the southwest monsoon due to oceanic productivity (IOTC, 2022). Tuna fishing seasons align with oceanographic conditions, such as sea surface temperature (SST) and chlorophyll-a concentration, which influence tuna productivity by supporting phytoplankton growth, a primary food source (Bahri et al., 2017; Pratama et al., 2022).

High LPUE of gillnet observed in March–May and October–November, coinciding with coastal upwelling and productivity. Monthly abundance of yellowfin migrate nearshore in productive seasons, increasing catch rates during pre- and post-monsoon periods (Anderson, 2014). Pole and line have seasonally high LPUE during calm seas and optimal bait availability, especially in March–June and September–November. Monthly abundance of skipjack school abundance correlates with surface temperature and productivity, especially in Maldives and Indonesia (Adam, 2010). Peaks LPUE of handline and troll line during January–April and August–October, when large yellowfin aggregate near islands, reefs, and seamounts (FAO, 2010).

Data on Indonesia's tuna fisheries, particularly in Zone 04, underscores the importance of evidence-based management to support sustainable fishing practices. A quota-based management system is essential to prevent overfishing while ensuring equitable and long-term resource utilization. By leveraging comprehensive data on fishing fleets, landing locations, and catch volumes, Indonesia can effectively balance exploitation and conservation to sustain its tuna fisheries and economic stability.

Conclusion

Based on the research findings, it can be concluded that Zone 04 PIT contributes 23% of the national tuna production. Benoa Public Port is recorded as the port with the highest production within Zone 04. The most dominant fishing gear for tuna is lines, which include hand lines, troll lines, kite lines, and rod handlines. The composition of tuna catches from all fishing gear is dominated by yellowfin tuna. Pole and line and purse seine has the highest productivity compared to other fishing gear. ALB abundance was highest in July, YFT abundance

in March, July, and October, BET abundance in February, July, September and SBT abundance was highest in March, April, and July. Yellowfin tuna is the most commonly landed tuna species at Benoa Public Port and other ports, with peak production in May–June.

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