Preliminary analysis on the abundance indices of neritic tuna species from Indonesian fleets in the north-eastern Indian Ocean 2012-2021

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Abstract

Indonesia is one of the world's largest tuna producers, with approximately 300,000 tons/year (equal to £35 billion in value in 2018) harvested from its archipelagic waters, Economic Exclusive Zone (EEZ), and high seas. About a quarter of the catch belongs to the neritic tuna group, e.g., eastern little tuna. Neritic tuna is caught mainly by artisanal fisheries, associated with fish aggregating devices (FADs), and consumed and traded among coastal communities. However, given its importance, the available data, such as reported catches and effort, are insufficient for stock assessment models. Therefore, this study aims to give some preliminary historical trends of abundance indices of neritic tuna species from Indonesian fleets, with an attempt to separate based on association of the fleets with FADs. Key asssumptions include that sets conducted in waters deeper than 3,000 m were not influenced by the presence of FADs, while above were classified as FADs-associated fisheries. Catch-per-unit-of-effort (CPUE) in free-schooling fisheries for neritic tuna varied less over time than CPUE associated with FADs. While CPUE associated with Fish Aggregating Devices (FADs) showed significant variability. Further refinement and a comprehensive approach are necessary to establish robust abundance indices for regional assessments beyond purse seine fisheries.

Introduction

Indonesia is recognized as a prominent global producer of tuna, accounting for up to 15% of the worldwide tuna catch in 2009 (Miyake et al. 2010; Sunoko and Huang 2014). In 2010, the export volume of tropical, temperate, and neritic tuna from Indonesia reached approximately 125,000 tons, with Japan being the primary destination (Chodrijah, Hidayat, and Noegroho 2016). Notably, among the different tuna species, the Indonesian fleet accounted for about one-third (~170,000 tons) of the total neritic tuna catch in the Indian Ocean, with approximately 40,000 tons attributed to eastern little tuna (IOTC-WPTT21 2019). Despite the significance of these tuna species for local industries and household consumption, there is limited knowledge regarding their current dynamics and stock status, particularly at a regional level (Wijopriono and Rachmawati 2015).

Uncertainty in catch and effort data, particularly from small and medium-scale tuna fisheries, poses a significant challenge to fish stock assessment at a regional scale, including Indonesia (Yuniarta et al. 2017). This issue has become a bottleneck in fisheries management within the country. The government's annual historical data has often been criticized by various stakeholders (Duggan and Kochen 2016; IOTC-WPDCS14 2018) due to its inconsistency and uncertainty. Interestingly, the problem is not caused by the absence of data but rather by the opposite situation. Many organizations, including NGOs, have been collecting similar data, driven by a lack of trust in the existing data's validity. However, most of these alternative data sources have not been considered when estimating the national catch statistic. While some of these data sources could potentially be valuable for determining fish abundance from time series of catch and effort, further investigation is required, particularly when dealing with species like the neritic tuna group (Novianto et al. 2019).

Fish aggregating devices (FADs) are floating objects utilized by fishermen to attract and capture pelagic fish, including tunas, thereby increasing their fishing yield (Moreno et al. 2016). FADs come in two types: drifting FADs, primarily utilized by European fleets in the western region of the Indian Ocean, and anchored FADs, which are equipped with attractors (such as coconut leaves) and secured to the sea floor. Coastal countries in the eastern part of the Indian Ocean, notably Indonesia, extensively employ anchored FADs. Most of the surface fisheries are conducted around FADs, for which selectivity bias means that catch per unit of effort (CPUE) is not proportional to abundance (Bannerot and Austin 1983). To overcome these limitations and obtain a better understanding of neritic tuna abundance, we separated the CPUE by its association with FADs. We assume that sets conducted in waters deeper than 3000 m were not influenced by FADs, while those in waters shallower than 3000 m were FAD-associated. The concept is supported by previous studies, which indicated that deep-sea anchored FADs are typically placed at depths ranging from 1,000 to 2,500 meters (Priatna, Nugroho, and Mahiswara 2017; Widodo et al. 2020), as it is economically unviable to place them in deeper water.

The objective of this study was to investigate the feasibility of developing an index of abundance using fisheries-dependent data, specifically logbook information, while also exploring the potential to differentiate fishing activities based on their association with Fish Aggregating Devices (FADs).

Materials and Methods

Data Source

The primary data for this study were obtained from the Integrated Logbook Information System (SILOPI), specifically from Fisheries Management Areas (FMA) 571, 572, and 573, covering the period from January 2012 to December 2021. The purse seine method served as the primary fishing gear employed to capture neritic tuna species. Consequently, this study places its emphasis on four prevailing species that are frequently encountered in association with this gear, and are recognized for their substantial economic importance. These species are *Euthynnus affinis* (Eastern little tuna, KAW), *Thunnus tonggol* (Longtail tuna, LOT), *Auxis rochei* (Bullet tuna, BLT), and *Auxis thazard* (Frigate tuna, FRI). The data was provided by the Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries. The logbook data provides a comprehensive record of commercial fishing activity, encompassing vessel information, trip identity, set number, time and location of each set, as well as species-specific estimates of the total catch. To ensure the reliability of the analysis, the data underwent a cleaning and filtering process prior to analysis. This step was crucial to deal with possible reporting errors that are commonly found in logbook data (Sampson 2011; Mendo et al. 2022). The data cleaning process involved the following steps:

1. Fishing sets must be conducted between the departure and arrival dates.
2. Filtering out trips that contained sets below 20°S, assuming that was the farthest fishing ground for Indonesian purse seine based on VMS (Vessel Monitoring System) data (MMAF 2022)

By conducting these data cleaning and validation procedures, the study aimed to enhance the quality and accuracy of the analyzed data.

Data Analysis

Catch per unit of effort (CPUE) refers to the average catch of neritic tuna species per set, assuming a daily set frequency. To differentiate between different catch types (FADs associated and free schooling), a defined threshold of sea floor elevation (3,000 meters depth) was established by intersecting logbook data with the General Bathymetric Chart of the Oceans (GEBCO) using tidyverse 2.0.0 (Wickham et al. 2019), sp 1.6-0 (Pebesma and Bivand 2005), raster 3.6-20 (Hijmans 2023) and maps 3.4.1 (Becker, Minka, and Deckmyn. 2022) under the R version 4.2.3 (R Core Team 2023). The GEBCO_2023 GRID is a continuous, global terrain model for both ocean and land, providing a spatial resolution of 15 arc seconds. It available for download at https://www.gebco.net.

Coefficient of variance (CV) of the abundance estimation throughout the time series was defined as:

$$CV = \frac{sd(CPUE)}{mean(CPUE)}$$

Results

In this study, we utilized a dataset comprising 257,988 sets of purse seine gear data collected from January 2012 to December 2021. After the data cleaning process, approximately 15% of the data was excluded. Among the remaining sets, around 69,356 (26.88%) were conducted in waters shallower than 3,000 m, indicating their association with Fish Aggregating Devices (FADs), while the remaining 149,919 sets (73.12%) were performed in waters deeper than 3,000 m. The representation of known fishing grounds is depicted in Figure 1, illustrating the distribution of sets ranging from 10°N to 20°S and 75°E to 135°E. Notably, fishing activities have expanded towards the north-central Indian Ocean, particularly within the last five years.

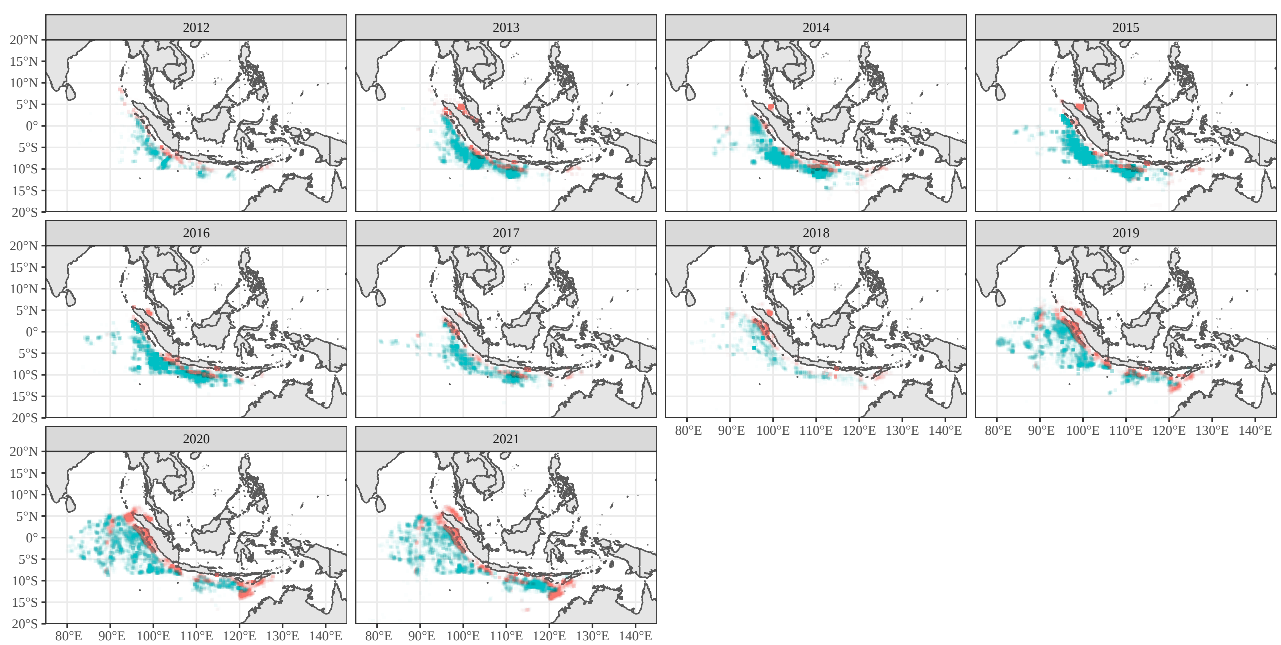

Figure 1. The spatial distribution of purse seine activities, represented by the number of sets, was examined for the period from January 2012 to December 2021. Sets performed in waters with depths exceeding 3,000 m were indicated by points in dark blue, while sets conducted in waters with depths less than or equal to 3,000 m were represented by points in dark red.

The annual data representation is depicted in Figure 2. Initially, the number of landings sampled, i.e., logbook records was relatively low, with just over 1,000 records. However, over the following three years, there was a consistent increase before experiencing a decline to below 4,000 records in 2017. The subsequent year saw a significant surge in data, potentially attributable to intensive dissemination efforts by the ministry. Nonetheless, it gradually decreased to approximately match the recorded value in 2014, which was little over 4,500 records.

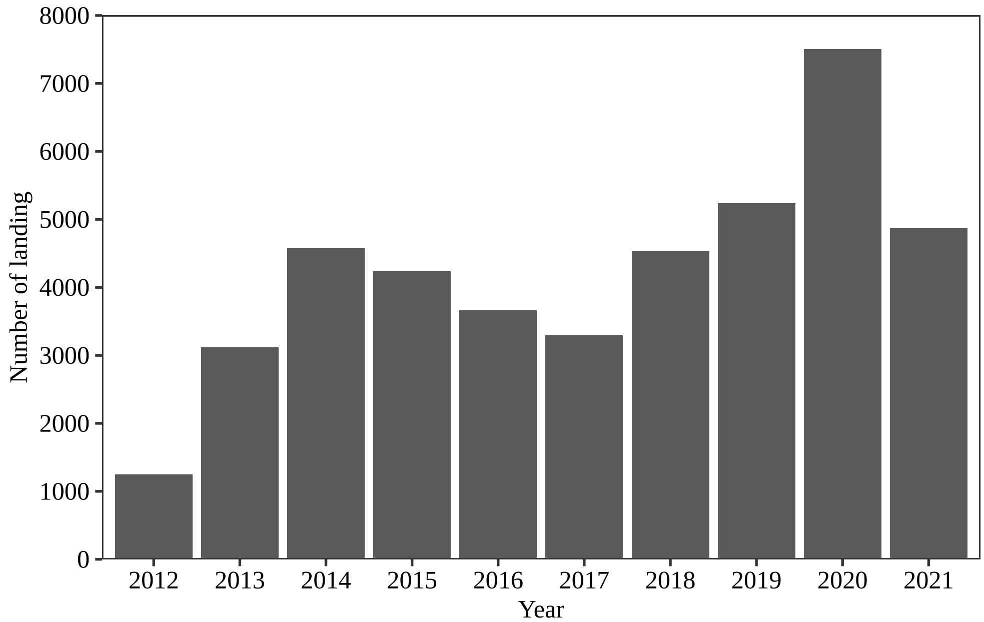

Figure 2. Logbook data representation (number of landing) from January 2012 to December 2021.

The historical CPUE based on fishing type is shown in Figure 3. Overall, the CPUE derived from free-schooling fishing exhibited a relatively low variability, possibly due to the prevalence of industrial-type purse seiners. However, the CPUE trend associated with Fish Aggregating Devices (FADs) showed substantial variability, as evidenced by exceptionally high catches in certain years.

Except for a large spike in 2017, the abundance of bullet tuna exhibited minor discrepancies between FADs associated and free schooling. A similar trend was observed for frigate tuna, despite a considerable catch in 2018. The challenge in distinguishing between these two species could impact the overall estimation of abundance, as they are often caught together and grouped as a single entity for sale. While there was a noticeable surge in 2014, the CPUE series of longtail tuna also displayed minimal differences between the two types, although the purse seine catch for this species has relatively increased in the past five years. Conversely, the abundance of eastern little tuna presented more promising outcomes, even though the series remained relatively stable throughout the observation period, apart from a significant rise in 2018.

This preliminary study demonstrates the capability of logbook data to provide abundance indices for neritic tuna fisheries. Nevertheless, further refinement is necessary, particularly in addressing data noise. For regional purposes, a comprehensive approach involving joint CPUE analysis may be required to establish robust abundance indices using approved methodologies, transcending the limitations of purse seine fisheries alone.

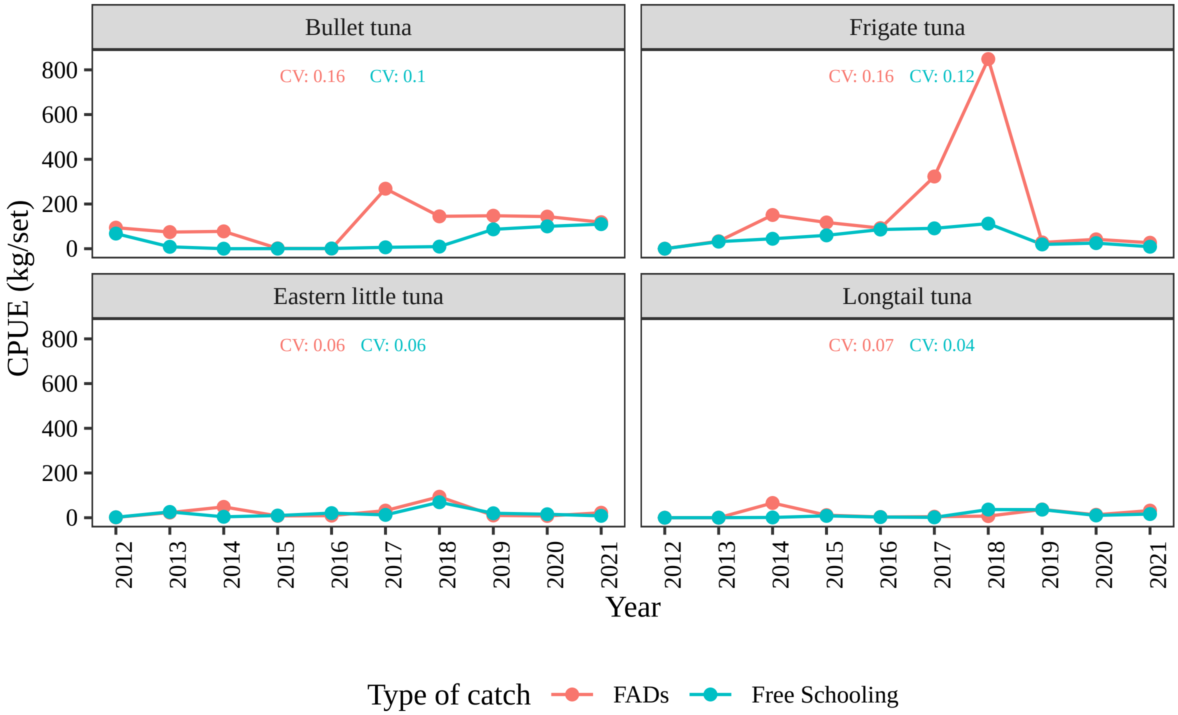

Figure 3. Catch per unit of effort (CPUE) series of some neritic tuna species derived from logbook data from January 2012 to December 2021. FADs refers to sets conducted from depths shallower than 3,000 m, whereas Free schooling refers to sets conducted deeper than 3,000 m. The coefficient of variation (CV) for each species and each type of catch is indicated on the panels.

References

Bannerot, Scott P., and C. Bruce Austin. 1983. "Using Frequency Distributions of Catch Per Unit Effort to Measure Fish-Stock Abundance." *Transactions of the American Fisheries Society* 112 (5): 608–17. https://doi.org/10.1577/1548-8659(1983)112%3C608:UFDOCP%3E2.0.CO;2.

Becker, Original S code by Richard A., Allan R. Wilks. R version by Ray Brownrigg. Enhancements by Thomas P Minka, and Alex Deckmyn. 2022. "Maps: Draw Geographical Maps." https://CRAN.R-project.org/package=maps.

Chodrijah, Umi, Thomas Hidayat, and Tegoeh Noegroho. 2016. "Estimasi Parameter Populasi Ikan Tongkol Komo (*Euthynnus Affinis*) Di Perairan Laut Jawa." *BAWAL* 5 (3): 167–74. https://doi.org/http://dx.doi.org/10.15578/bawal.5.3.2013.167-174.

Duggan, Deirdre E., and Momo Kochen. 2016. "Small in Scale but Big in Potential: Opportunities and Challenges for Fisheries Certification of Indonesian Small-Scale Tuna Fisheries." *Marine Policy* 67: 30–39.

Hijmans, Robert J. 2023. "Raster: Geographic Data Analysis and Modeling." https://CRAN.R-project.org/package=raster.

IOTC-WPDCS14. 2018. "Report of the 14th Session of the IOTC Working Party on Data Collection and Statistics." Working Party Report. Mahé, Seychelles: Indian Ocean Tuna Commission (IOTC).

IOTC-WPTT21. 2019. "Report of the 21st Session of the IOTC Working Party on Tropical Tunas." Working Party Report IOTC– 2019– WPTT21– R[E]. San Sebastian, Spain: Indian Ocean tuna Commission (IOTC).

Mendo, T., J. Mendo, J. M. Ransijn, I. Gomez, P. Gil-Kodaka, J. Fernández, R. Delgado, et al. 2022. "Assessing Discards in an Illegal Small-Scale Fishery Using Fisher-Led Reporting." *Reviews in Fish Biology and Fisheries*

32 (3): 963–74. https://doi.org/10.1007/s11160-022-09708-9.

Miyake, Makoto Peter, Patrice Guillotreau, Chin-Hwa Sun, and Gakushi Ishimura. 2010. *Recent Developments in the Tuna Industry: Stocks, Fisheries, Management, Processing, Trade and Markets*. FAO Fisheries and Aquaculture Technical Paper, No. 543. Rome: FAO (Food and Agriculture Organization).

MMAF. 2022. "Indonesia National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2022." National Report IOTC-2022-SC25-NR09_Rev1. Victoria, Seychelles: Indian Ocean Tuna Commission (IOTC). https://iotc.org/sites/default/files/documents/2022/11/IOTC-2022-SC25-NR09_Rev1E_Indonesia.pdf.

Moreno, G., L. Dagorn, M. Capello, J. Lopez, J. Filmalter, F. Forget, I. Sancristobal, and K. Holland. 2016. "Fish Aggregating Devices (FADs) as Scientific Platforms." *Fisheries Research*, The use of fishing vessels as scientific platforms, 178 (June): 122–29. https://doi.org/10.1016/j.fishres.2015.09.021.

Novianto, Dian, Ilham, Chandara Nainggolan, Syarif Syamsuddin, Arief Efendi, Sugianto Halim, Yaser Krisnafi, et al. 2019. "Developing an Abundance Index of Skipjack Tuna (Katsuwonus Pelamis) from a Coastal Drifting Gillnet Fishery in the Southern Waters of Indonesia." *Fishes* 4 (1): 1–11. https://doi.org/10.3390/fishes4010010.

Pebesma, Edzer J., and Roger S. Bivand. 2005. "Classes and Methods for Spatial Data in {r}" 5. https://CRAN.R-project.org/doc/Rnews/.

Priatna, Asep, Duto Nugroho, and Mahiswara Mahiswara. 2017. "Keberadaan Ikan Pelagis Rumpon Laut Dalam Pada Musim Timur Di Perairan Samudera Hindia Sebelah Selatan Teluk Pelabuhan Ratu Dengan Metode Hidroakustik." *Jurnal Penelitian Perikanan Indonesia* 16 (2): 83–91. https://doi.org/http://dx.doi.org/10.15578/jppi.16.2.2010.83-91.

R Core Team. 2023. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.

Sampson, David B. 2011. "The Accuracy of Self-Reported Fisheries Data: Oregon Trawl Logbook Fishing Locations and Retained Catches." *Fisheries Research* 112 (1-2): 59–76. https://doi.org/10.1016/j.fishres.2011.08.012.

Sunoko, Rahmadi, and Hsiang-Wen Huang. 2014. "Indonesia Tuna Fisheries Development and Future Strategy." *Marine Policy* 43 (January): 174–83. https://doi.org/10.1016/j.marpol.2013.05.011.

Wickham, Hadley, Mara Averick, Jennifer Bryan, Winston Chang, Lucy D'Agostino McGowan, Romain François, Garrett Grolemund, et al. 2019. "Welcome to the {Tidyverse}" 4: 1686. https://doi.org/10.21105/joss.01686.

Widodo, Agustinus Anung, Lilis Sadiyah, Mahiswara Mahiswara, Craig Proctor, and Scott Cooper. 2020. "Investigation on Tuna Fisheries Associated with Fish Aggregating Devices (FADs) in Indonesia FMA 572 and 573." *Indonesian Fisheries Research Journal* 26 (2): 83–96. https://doi.org/http://dx.doi.org/10.15578/ifrj.26.2.2020.83-96.

Wijopriono, Wijopriono, and Puput Fitri Rachmawati. 2015. "Perikanan Tongkol Dan Daya Dukungnya Terhadap Penyediaan Bahan Baku Industri Pengolahan Di Palabuhanratu." *Jurnal Penelitian Perikanan Indonesia* 21 (1): 17–24. https://doi.org/http://dx.doi.org/10.15578/jppi.21.1.2015.17-24.

Yuniarta, Shinta, Paul AM van Zwieten, Rolf A. Groeneveld, Sugeng Hari Wisudo, and E. C. Van Ierland. 2017. "Uncertainty in Catch and Effort Data of Small-and Medium-Scale Tuna Fisheries in Indonesia: Sources, Operational Causes and Magnitude." *Fisheries Research* 193: 173–83. https://doi.org/http://dx.doi.org/10.1016/j.fishres.2017.04.009.