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Species composition and seasonal dynamics of tongkol fishes (Thunnini Tribe) landed at TPI Kranji, Lamongan, Indonesia

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Abstract. *Saputri RRL, Paricahya AF. 2026. Species composition and seasonal dynamics of tongkol fishes (Thunnini Tribe) landed at TPI Kranji, Lamongan, Indonesia. Indo Pac J Ocean Life 10 (1): o100103. https://doi.org/10.13057/oceanlife/o100103.* Tongkol fisheries potential in East Java, Indonesia, including at TPI Kranji, Lamongan, is highly dependent on the policies and management of the area. Identification of tongkol species, tongkol-associated species, data on fishing grounds, annual catch, and fishing season are necessary for policy making and sustainable management. This study was conducted from April 2022 to July 2024, with catch data collection and participatory mapping methods. Identification of tongkol at TPI Kranji leads to three species: *Auxis thazard*, *Euthynnus affinis*, and *Thunnus tonggol*. The tongkol fishing ground during the fishing season ranged around 20 to 40 miles from the landing base. When not during the tongkol fishing season, fishers catch more tongkol-associated species dominated by *Hilsa keele* at distances around 10 to 20 miles from the landing base. Tongkol-associated species identified 38 species from 13 families. The annual catch of tongkol fluctuated annually, but the trend of *A. thazard* catch declined. The increase in catch of *T. tonggol* since 2013 could potentially decline if not appropriately managed, considering that *T. tonggol* dominates the catch of tongkol commodity at TPI Kranji up to 77.11%, followed by *E. affinis* with 18.98% and *A. thazard* with 3.91%. The average annual catch of tongkol commodity at TPI Kranji from 2013 to 2023 is 1,641.13 tons per year. TPI Kranji has to avoid additional fishing effort in the peak fishing season due to the decreasing stock trends.

Keywords: Indopacific, monsoon cycle, multispecies fishery, neritic tuna, participatory mapping

Abbreviations: FMA 712: Fisheries Management Area 712, TPI Kranji: Kranji Fish Auction Place

INTRODUCTION

The fishermen in Kranji Fish Auction Place (called TPI Kranji in Indonesia), Lamongan, East Java, have several main catches, such as tongkol fishes. The catches at TPI Kranji can reach 3,997.6 tons per year, dominated by tongkol, reaching up to 54.4% for a single species (Elasari et al. 2022), and be the great potential to Java Sea or Fisheries Management Area (FMA) 712. Tongkol at TPI Kranji is caught using purse seine by their pelagic and schooling character. Tongkol in Indonesia refers to multispecies pelagic fishes from the Thunnini Tribe. Multispecies fishery stocks with vulnerabilities to overexploitation have historically been complicated to manage, it is possible that minor species recorded in multispecies commodities, are more fatally exploited than other species in the commodity (Starr et al. 2016). The identification of tongkol catch at TPI Kranji using specific terminology which was different from the national terminology of tongkol, namely tongkol lisong (*Auxis rochei* (Risso, 1810)), tongkol krai/balaki (*Auxis thazard* (Lacepède, 1800)), tongkol komo (*Euthynnus affinis* (Cantor, 1849)), and tongkol abu-abu (*Thunnus tonggol* (Bleeker, 1851)). Globally, *A. rochei* is known as bullet tuna a.k.a. BLT, *A. thazard* as frigate tuna a.k.a. FRI, *E. affinis* as kawa-kawa a.k.a. eastern little tuna a.k.a. KAW, and *T. tonggol* as longtail tuna a.k.a. LOT (Yuniarta and Satrioajie 2023).

The Thunnini Tribe is a member of the Scombridae family, this family is an essential fisheries commodity in the world wide. Scombridae members annual catch rates increasing steadily since the 1950s. Overall, Scombridae species contribute up to 15% of the annual catch of marine fish commodities, although tongkol is excluded from the seven main species of the tuna market (Juan-Jordá et al. 2013). The Thunnini Tribe in Indonesia is better known as Tuna, Cakalang, and Tongkol (TCT), that increased its export value by 2.73% from 2017-2021. The TCT commodities contributing 14.30% up to 16.47% for the total export volume of Indonesian (Pulungan et al. 2022; Kementrian Kelautan dan Perikanan 2023). Furthermore, small pelagic fishery avarage production is about 40.7% in Java Sea (Purwanto et al. 2014), and tongkol commodities in FMA 712 are estimated about up to 61% of capture fisheries products. Tongkol commodities in Java Sea have been declared as fully and overexploited as in Indo-Pacific generally that approaching overfishing category (Al Malik et al. 2020). Tongkol fishes in Java Sea was exploited more than the levels of Maximum Economic Yield (MEY) and Maximum Sustainable Yield (MSY), impacted to the disrupted of fish stocks sustainability (Bintoro et al. 2022). Previous research at TPI Kranji related to superior commodities showed that *T. tonggol* catches reached 1,536.8

tons per year, while *E. affinis* reached 273 tons per year (Dewi et al. 2021). The analysis of fishing grounds, catch composition, annual production, and fishing season can help in efforts to optimize sustainable fisheries, especially for tongkol commodities landed at TPI Kranji, Lamongan.

Caught analysis on tongkol landed at TPI Kranji in this study, may be combined with oceanographic data to understand the fisheries species community in this area more holistically. Analysis of fishing grounds, annual production, fishing season and diversity analysis can be the basis for tracing fish life patterns and status to management urgency. Those data are closely related to oceanographic parameters. The combination of oceanographic data and fishing season data can be utilized for the effectiveness and efficiency of fishing efforts based on fishing grounds (Nurani et al. 2022). Study on the relationship between catches and oceanographic parameters at TPI Kranji has been conducted recently (Elasari et al. 2022). However, the study is still limited, especially during the fishing season, but fishing season of tongkol fishes, especially for *E. affinis* is strongly correlated to several parameters as Sea Surface Temperature (SST) and chlorophyll-*a* (Syamsuddin et al. 2018).

This study aims to understanding the patterns and trends of tongkol commodities with those associated species, that caught by purse seine at TPI Kranji. This study focused to the caught data that collected from 2013 up to 2023. Analysis of multispecies catch of tongkol needs to be narrowed down to species level, including species of fish associated with tongkol community at TPI Kranji. Holistic catch composition data can be the basis for sustainable fisheries management, considering that catches of unwanted or non-targeted species threaten nature conservation and are the most significant source of unclear fisheries assessment (Cerbule et al. 2022). The results of this study can be the basis of sustainable tongkol fisheries management, both locally, nationally, and globally, furthermore can be combined with oceanographic parameters in the future.

MATERIALS AND METHODS

The study was conducted from April 2022 to July 2024 at TPI Kranji, Lamongan. TPI Kranji located in Lamongan, East Java, Indonesia, specifically at 6°52'32.1“ S, and 112°23'05.9” E (Figure 1). During that period, field data collection and sample collection were conducted from purse seine catches at TPI Kranji, then samples to identify were documented in fresh condition. Samples collected ranged from one to five individuals of each species, and then identification was carried out using literature studies (Carpenter and Niem 1999, 2001; Nelson et al. 2016; Yuniarta and Satrioajie 2023) then accompanied by additional field observations when needed. Species identification was narrowed down based on 16 distinguishing characteristics from literature of *A. thazard*, *A. rochei*, *E. affinis*, and *T. tonggol*. Rapid observations were made in general by random sampling method, on external characters such as interpelvic flap, belly mark, corselet, dorsal fin rays, dorsal interspace, dorsal marks, scales, dorsal and anal fin height, finlets, and fork length. Observations that required dissection were only made on samples collected for confirmation, particularly on gill rakers. Other characters, such as liver shape and presence of swim bladder, were specific to the genus *Thunnus* (South, 1845), as they are interspecies features in the genus *Thunnus*, not intergenus in Thunnini (Carpenter and Niem 1999). The identification was then matched to its application in the field during the recording process (Yuniarta and Satrioajie 2023). Validation was then continued with observation of data collection from February to April 2022, and showed high similarity between field data and retribution data at TPI Kranji. However, records of *A. rochei* in the North Sea of Java Island is lack and need to be reassessed.

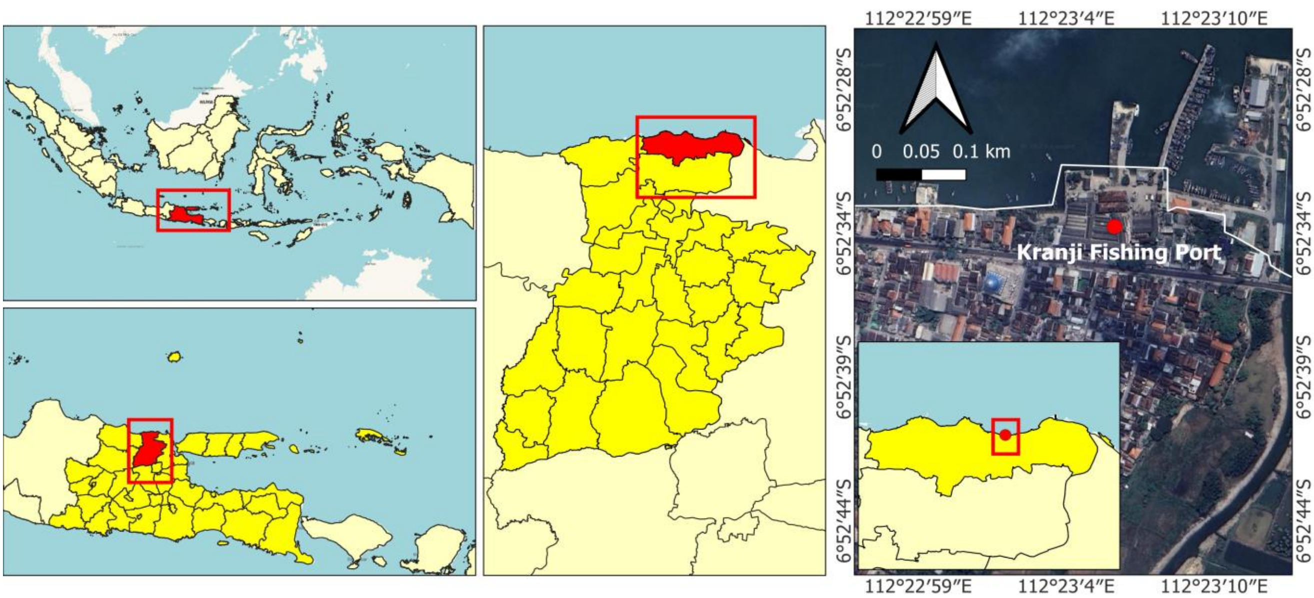

Figure 1. The study was conducted in TPI Kranji, Lamongan, East Java, Indonesia. The fishing ground is from Lamongan to Bawean Island around the Java Sea or FMA 712

Identification of tongkol, in general, can follow the identification key as follows:

1. a. Scales covering the entire body, including the part outside the corselet; no pattern on the dorsal part → *T. tonggol*
   b. Scales are only in the form of a corselet, the body is naked outside the corselet; has patterns on the dorsal part → 2
2. a. Distance between dorsal fins are incredibly close to each other; the flap between the two ventral fins is small and forked (two flaps); sometimes has one to six black dots in the body between the pectoral and ventral fins → *E. affinis*
   b. The distance between the dorsal fins is vast apart, equal to the length of the first dorsal fin base; the flap between both ventral fins is large and not forked (single flap); the abdomen is always plain with no pattern such as dots or lines → genus *Auxis* → 3
3. a. Upper naked body part extending forward to align with pectoral fin tip; thin corselet extension, about 1-5 scales below the origin of the second dorsal fin → *A. thazard*
   b. Upper naked body not reaching alignment with the tip of pectoral fin; thick corselet extension, about 10-15 scales below the origin of the second dorsal fin → *A. rochei*

Whereas incomplete, the three tongkol species found in the TPI Kranji, Lamongan catch have at least 16 important characters in their identification (Table 1, Figure 2).

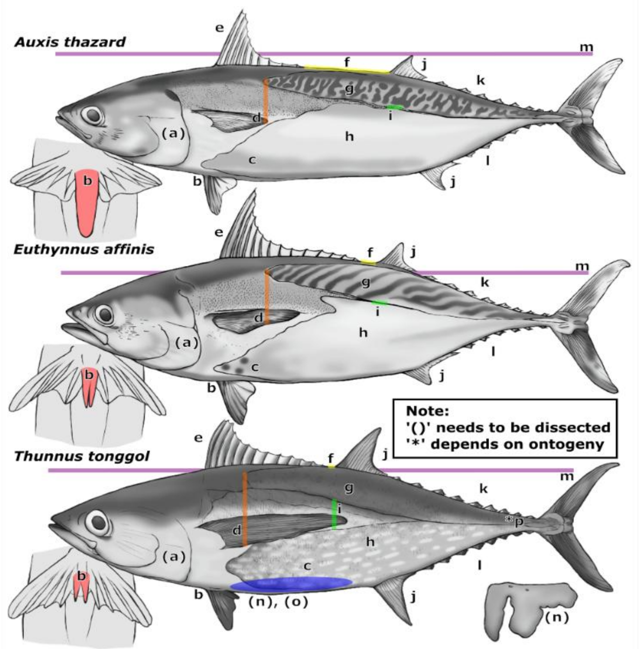

Figure 2. Illustration of tongkol species identification keys at TPI Kranji, Lamongan, East Java, Indonesia, consisting of three species, namely *Auxis thazard*, *Euthynnus affinis*, and *Thunnus tonggol.* The codes in the figure were matched with the codes in Table 1

Table 1. Identification keys of tongkol species at TPI Kranji, Lamongan, East Java, Indonesia, consisting of three species, namely *Auxis thazard*, *Euthynnus affinis* and *Thunnus tonggol*. The codes can be matched with Figure 1

Code	Characters	*Auxis thazard*	*Euthynnus affinis*	*Thunnus tonggol*
a	Gill rakers at first gill arch	36-42	29-34	19-27
b	Flap of interpelvic process	Single large flap	Two small flaps	Two small flaps
c	Belly mark	Absent	Sometimes has 1-6 dark spots between pectoral and ventral fin	Sometimes has horizontal elongate-oval white
d	Dorsal post-corselet to pectoral fin overlap	Reaching the tips of fins	Reaching almost to the middle of fins	Reaching forward over the middle of fins
e	First dorsal fin rays	X-XII	XI-XIV	XIII
f	Both dorsal interspace	Very long, at least equal to first dorsal fin base	Extremely short	Extremely short
g	Dorsal marks at post-corselet area	Slanted to horizontal 15 or more blunt-tip narrow dark wavy lines	Slanted to horizontal, stripped narrow, dark wavy lines, usually has several conical lines	Absent
h	Scales after corselet	Absent	Absent	Body covered with very small scales
i	Posterior of corselet aligned to second dorsal fin origin	Narrow, not more than 5 scales wide	Extremely narrow	Still wide
j	Second dorsal and anal high	Short	Short	Longer than other tongkol, usually equal to first dorsal fin high
k	Dorsal finlets	8	8-10	9
l	Anal finlets	7	6-8	8
m	Maximum fork length	50 cm	100 cm	130 cm
n	Specific liver characteristic	Not evaluated	Not evaluated	Not striated on the ventral surface
o	Swimbladder	Not evaluated	Not evaluated	Absent or rudimentary
p	Extremaly long caudal peduncle by ontogeny	Not evaluated	Not evaluated	In adults only, when larger than 60 cm in fork length

Monthly and annual production data for eleven years (2013 to 2023) were obtained from retribution data of TPI Kranji, then adjusted with identification results and data analysis. Data collection for fishing ground analysis was conducted using the participatory mapping method. Catch data is analyzed using the average percentage method based on the time using several time series analysis formulas (Spiegel and Stephens 2008; Zhao and Shen 2016). The formulas used in this study is as follows:

Monthly average production per year

$$Y = \frac{1}{m} x \sum_{i=1}^{m} Yi$$

Percentage of monthly production divided to the monthly average per year

$$Yp = \frac{Ym}{Y} x\ 100\%$$

Fishing Seasonal Index (FSI)

$$FSI = \frac{1}{t} (\sum\nolimits_{y=i}^{t} TYp)$$

Where, Y: Monthly average of production per year, m: Month (12), Yi: Total production of the first month, Yp: Percentage of monthly production with the monthly average of each year, Ym: Monthly production (Kg), FSI: Fishing Season Index, t: Number of years, Typ: Total percentage of monthly production

During the data collection in field, the individuals of tongkol commodities was observed. The data in this study then conducted the diversity analyses as the abundance (Sa), diversity index (H') and dominance index (C). Value ranges in H' and C analyses may follow the categorization used in several previous studies. A value of H' < 1 is interpreted as low diversity, and H' > 3 is interpreted as high diversity. The value between those categories is categorized as moderate diversity. The value of C ranges from 0 to 1. When the value of C is between 0 and 0.5, it is categorized as low dominancy. Meanwhile, if the C value ranges from 0.75 to 1, it is categorized as high dominancy. The value between those categories is categorized as moderate dominancy (Sihombing et al. 2017; Ulfah et al. 2019). The formulas that used in this study as follows:

Abundance

$$Sa = \frac{ni}{N} \times 100\%$$

Diversity Index

$$H' = \sum \frac{ni}{N} \ln \frac{ni}{N}$$

Dominance Index

$$C = \sum \left[\frac{ni}{N}\right]^2$$

Where: Sa: Composition percentage or abundance, ni: Number of individuals of a species, N: Total individuals of all species, H': Shannon-Weiner Index, C: Dominance Index

RESULTS AND DISCUSSION

Tongkol and tongkol-associated species identification

The purse seine catches landed at TPI Kranji consisted of at least 38 species of fish from various families, and 7 species from the Scombridae family were recorded, three belonging to the Thunnini Tribe known as tongkol. The identification result of tongkol wilus leads to *A. thazard*, tongkol lorek to *E. affinis* and tongkol walang to *T. tonggol*. Identification in the data collection process at Kranji TPI for Thunnini, according to the identification key used based on the literature. So far, *A. rochei* has not been caught at TPI Kranji, and there is also no known local name for *A. rochei* in this area, but it is possible that if *A. rochei* is caught, it will be known as tongkol wilus. All four tongkol species are recorded in the North Sea of Java Island, including *A. rochei* (Hidayat et al. 2021). Misidentification of tongkol commodities is not only done by the general public but also by researchers, potentially leading to misconceptions in the community. In general, members of the genus *Thunnus* are referred to as tuna in Indonesia, except for *T. tonggol*, which is referred to as tongkol, most likely because *T. tonggol* is the only member of *Thunnus* that is classified as a pelagic-neritic tuna species. The uncommon terms of *T. albacares* (Bonnaterre, 1788)*,* called tongkol (Chalid et al. 2019), are likely misidentified. Although *T. tonggol* and *T. albacares* are grouped in the same subgenus, which is *Neothunnus* (Fraser-Brunner 1950), but *T. albacares* is a pelagic-oceanic tuna species (Carpenter and Niem 1999). Misidentification of tongkol in the genus *Auxis* also occurred, possibly because there is two species of tongkol were included in the genus *Auxis*. The difference between *A. rochei* and *A. thazard* was recorded to be assumed as sexual dimorphism of *A. rochei* species in a study in Mamuju, North Sulawesi, Indonesia (Nur et al. 2023). Furthermore, many articles do not identify tongkol of the genus *Euthynnus* to the species level, so they are written it as *Euthynnus* sp. (Syah et al. 2020; Pramesthy et al. 2022), but the statement that tongkol of the genus *Euthynnus* have more than one species is also not well proven. The claim of three species of tongkol from the genus *Euthynnus* as abon or peng-peng (*E. affinis*), glondong (*Euthynnus alleteratus* (Rafinesque, 1810)), and rengi (*Euthynnus lineatus* (Kishinouye, 1920)) in Indonesia (Lelono and Bintoro 2019), is not supported by clear identification. Moreover, previous studies indicate that the distribution of *E. alleteratus* is only in the Atlantic to the Mediterranean Sea (Saber et al. 2018). The distribution of *E. lineatus* is limited to the Eastern Pacific (Marrast and Béarez 2019), and neither of them has been recorded to extend their distribution into the Indopacific, including Indonesia, with *E. affinis* that distributed well here. The community must use robust identification literatures in the field, and this article can serve as the guide basis.

Table 2. Species composition of purse seine landed at Kranji TPI, Lamongan, East Java, Indonesia

Species	**Local name**	**National name**	**Global name**
Class Actinopterygii			
Order Scombriformes			
Family Scombridae			
Auxis thazard (Lacepède, 1800)	Tongkol wilus	*Tongkol krai*	Frigate tuna
Euthynnus affinis (Cantor, 1849)	Tongkol lorek	*Tongkol komo*	Kawakawa
Thunnus tonggol (Bleeker, 1851)	Tongkol walang	*Tongkol abu-abu*	Longtail tuna
Rastrelliger brachysoma (Bleeker, 1851)	Kembung	*Kembung perempuan*	Short mackerel
Rastrelliger kanagurta (Cuvier, 1816)	Kembung	*Kembung lelaki*	Indian mackerel
Scomberomorus commerson (Lacepède, 1800)	Tengiri	*Tenggiri melayu*	Narrow-barred mackerel
Scomberomorus guttatus (Bloch & Schneider, 1801)	Icang-icang	*Tenggiri papan*	Indo-pacific king mackerel
Family Stromateidae			
Pampus argenteus (Euphrasen, 1788)	Loang	*Bawal putih*	Silver pomfret
Pampus chinensis (Euphrasen, 1788)	Loang	*Bawal putih*	Chinese silver pomfret
Family Trichiuridae			
Trichiurus auriga (Klunzinger, 1884)	Layur	*Layur*	Pearly hairtail
Trichiurus lepturus (Linnaeus, 1758)	Layur	*Layur*	Largehead hairtail
Order Beloniformes			
Family Belonidae			
Strongylura incisa (Valenciennes, 1846)	Oler	*Julung-julung karang*	Reef needlefish
Strongylura leiura (Bleeker, 1850)	Bono	*Todak belang*	Banded needlefish
Subseries Carangaria/misc (Unclear Order)			
Family Sphyraenidae			
Sphyraena barracuda (Edwards, 1771)	Kitir	*Barakuda*	Barracuda
Sphyraena putnamae (Jordan & Seale, 1905)	Kucul	*Barakuda*	Sawtooth barracuda
Family Polynemidae			
Eleutheronema tetradactylum (Shaw, 1804)	Laosan	*Senangin*	Fourfinger threadfin
Eleutheronema rhadinum (Jordan & Evermann, 1902)	Laosan	*Senangin*	East Asia fourfinger threadfin
Eleutheronema tridactylum (Bleeker, 1849)	Laosan Pisang	*Senangin*	Trifinger threadfin
Family Menidae			
Mene maculata (Bloch & Schneider, 1801)	Bagong	*Semar*	Moonfish
Order Carangiformes			
Family Carangidae			
Caranx ignobilis (Forsskål, 1775)	Putihan	*Kuwe gerong*	Giant trevally
Craterognathus plagiotaenia	Mlowo ireng	-	Barcheek trevally
Decapterus macarellus (Cuvier, 1833)	Layang	*Layang biru*	Blue scad
Elagatis bipinnulata (Quoy & Gaimard, 1825)	Sunglir	*Sunglir*	Rainbow runner fish
Megalaspis cordyla (Linnaeus, 1758)	Monggo	*Tetengkek*	Torpedo scad
Parastromateus niger (Bloch, 1795)	Dorang	*Bawal hitam*	Black pomfret
Scomberoides commersonnianus (Lacepède, 1801)	Talang	*Cangilang*	Talang queenfish
Scomberoides tol (Cuvier, 1832)	Baes	*Daun bambu*	Needlescaled queenfish
Selar crumenophthalmus (Bloch, 1793)	Golok	*Selar*	Bigeye scad
Caranx papuensis (Alleyne & W. J. Macleay, 1877)	Mlowo lilin	-	Bludger
Family Coryphaenidae			
Coryphaena hippurus (Linnaeus, 1758)	Mladang	*Lemadang*	Dolphin fish
Order Clupeiformes			
Family Chirocentridae			
Chirocentrus dorab (Forsskål, 1775)	Mlido	*Parang*	Wolf-herring
Family Dorosomatidae			
Escualosa thoracata (Valenciennes, 1847)	Krosak	*Terasak*	White sardine
Sardinella brachysoma (Bleeker, 1852)	Juwi	*Serisih*	Indian herring
Sardinella gibbosa (Bleeker, 1849)	Juwi	*Tembang pipih*	Goldstripe sardinella
Hilsa kelee (Cuvier, 1829)	Belo	*Hilsa*	Fivespot herring
Order Istiophoriformes			
Family Istiophoridae			
Istiompax indica (Cuvier, 1832)	Umbuk	*Setuhuk hitam*	Black marlin
Istiophorus platypterus (Shaw, 1792)	Umbuk layar	*Layaran Indo-Pasifik*	Indo-Pacific sailfish
Order Siluriformes			
Family Ariidae			
Hexanematichthys sagor (Hamilton, 1822)	Dukang	*Kedukang*	Sagor catfish

Tongkol at TPI Kranji associated with at least 35 other species from the purse seine catch (Table 2). The most dominant species of tongkol caught in TPI Kranji was *T. tongkol*, followed by *E. affinis*. The least dominant species was *A. thazard* (Figure 3). Tongkol-associated species, especially purse seine caught that landed at TPI Kranji, comprise at least six orders with 13 different families. Three families, namely Sphyraenidae, Polynemidae, and Menidae, have unclear order groupings, thus using the higher-level grouping, namely the subseries Carangaria. The grouping of Sphyraenidae as a member of Istiophoriformes (Nelson et al. 2016) was not used because it was not supported by molecular data (Betancur et al. 2013). Furthermore, some intragenous species are referred to by a single local name, such as *Sardinella brachysoma* (Bleeker, 1852) and *Sardinella gibbosa* (Bleeker, 1849), called juwi fish. Catch records of these species at TPI Kranji follow their local names. In addition to fish commodities from the vertebrate subphylum, purse seines at TPI Kranji also catch squid (family Loliginidae), but further identification is needed to confirm specifically at the species level.

Fishing ground mapping

The results of participatory mapping for purse seine use at TPI Kranji, Lamongan, have been adjusted with the results of catch composition identification (Figure 4). Data shows 282 fishing points from 282 respondents from April to June 2022, all within FMA 712. Based on the interview results, the limitation of fishing point coverage is due to the size of the vessel and limited supplies such as ice blocks and fuel. The distance of fishing points during the tongkol season (generally from October to April) ranges from 20 to 40 miles, while during the small fish season (not tongkol season, generally from May to September) ranges from 10 to 20 miles. A mixed species group in the map is a combination of various species in juvenile stadia, dominated by members of the order Clupeiformes. The general catch at TPI Kranji is dominated by belo fish (*Hilsa keele* (Cuvier, 1829)) with a percentage as high as 38.46%, followed by *T. tonggol* with a percentage of 30.49%, while *E. affinis* with 10.67% and *A. thazard* with 2.60%.

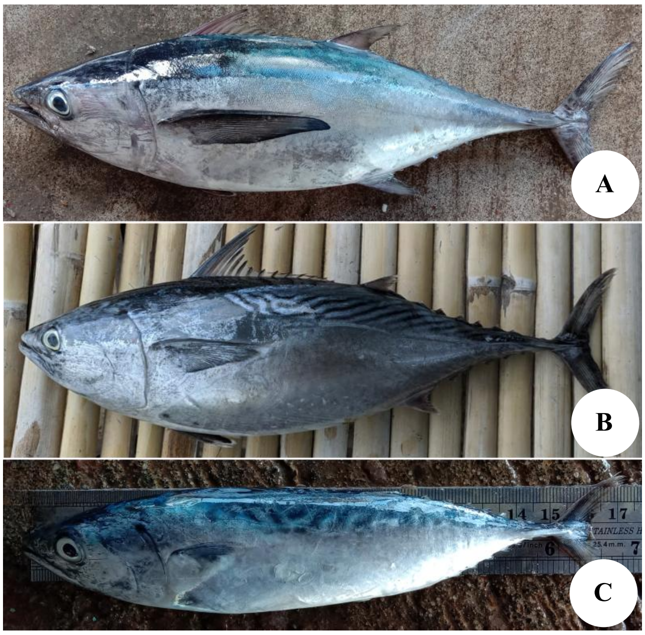

Figure 3. Tongkol specimens from the most dominant (top) to the least dominant (below) that commonly landed at TPI Kranji, Lamongan, East Java, Indonesia. There are three specimens of tongkol, namely A. *Thunnus tonggol*, B. *Euthynnus affinis*, C. *Auxis thazard*

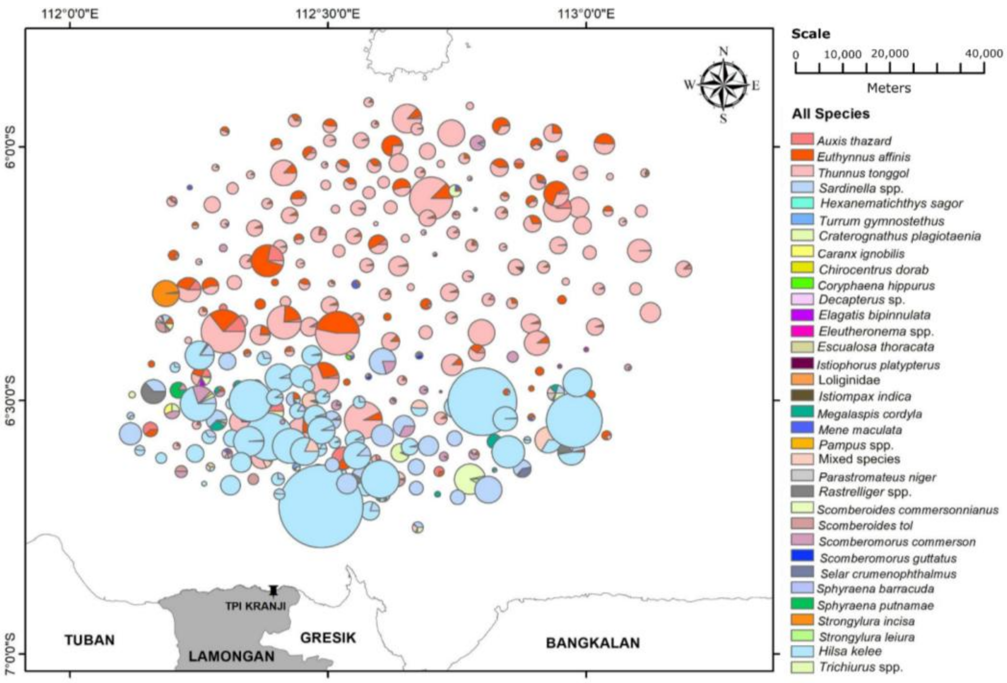

Figure 4. Fishing ground map from participatory mapping at TPI Kranji, Lamongan, East Java, Indonesia, from April to June 2022. The size of the nodes on the map represents the quantity of catch

The identification of tongkol and fish associated with tongkol, added to the mapping of fishing grounds, can be the basis for better fisheries management, especially at TPI Kranji in the future. The evaluation of catch composition generally only focuses on a few commodities, especially the major composition obtained (usually it's the main targeted species). As previously mentioned, this is one of the main problems of inaccurate or unclear evaluation data (Cerbule et al. 2022). At least, there is three large pelagic species dominate the commodity catch in the Java Sea, namely *E. affinis*, *T. tonggol*, and Spanish mackerel (genus *Scomberomorus*) (Ma'mun et al. 2019). The criteria of large or small pelagic fish is still debatable, but from the catch at TPI Kranji in this study, there are at least two species of large pelagic fish that were not evaluated, namely *Tylosurus crocodylus* (Péron & Lesueur, 1821) with the local name is oler or cendro, and *Carcharhinus sealei* (Pietschmann, 1913) with the national name is lanjaman shark (Andaresta et al. 2024). Based on study, the total catch from 2012 to 2015 in the North and South of the Java Sea, plus Bali, shows that small pelagic fish catches are dominant (Andriyono 2018). TPI Kranji's production is dominated by tongkol and *H. keele*, with contrasting fishing seasons. On the other hand, the dominance of small pelagic fishes in the North Java Sea usually is more in the catch of mackerel (genus *Rastrelliger*), white sardines (genus *Sardinella*), and other fishes (Mubarok et al. 2023). However, TPI Kranji has two species of *Rastrelliger* and two species of *Sardinella* from purse seine gear, but they do not dominate as well as tongkol or *H. keele*.

Furthermore, rare species were found at TPI Kranji, one of which is *Eleutheronema tridactylum* (Bleeker, 1849), the rarest species in the genus *Eleutheronema* (Xiao et al. 2022). This species has the same fishing ground as other *Eleutheronema*, namely *Eleutheronema tetradactylum* (Shaw, 1804) and *Eleutheronema rhadinum* (Jordan & Evermann, 1902). All three species are often considered as the same commodity with the local name laosan at TPI Kranji. The most common *Eleutheronema*, which is *E. tetradactylum*, is declared Endangered (EN) by the International Union for Conservation of Nature (IUCN) due to overexploitation and water pollution, while *E. rhadinum* has a smaller distribution, ranging from China to Indomalaya (Xiao et al. 2022). The distribution of *E. tridactylum* is smaller than that of *E. rhadinum*, this species is endemic from Thailand to Indonesia (Zhong et al. 2019). Study on *E. tridactylum* is very limited, and records of its occurrence are also very limited to date, so this area deserves better management to avoid local extinction of the biodiversity.

Annual production and fishing seasonal index

The total annual catch of tongkol at TPI Kranji fluctuated annually (Figure 5). The lowest production for *T. tonggol* occurred in 2013, with 778.25 tons, while the highest occurred in 2019, with 2,492.33 tons. The lowest production for *E. affinis* occurred in 2016, with 67.66 tons, while the highest occurred in 2023 with 565.72 tons. The lowest production for *A. thazard* occurred in 2022, with 23.45 tons, while the highest occurred in 2013, with 130.87 tons. Overall, the lowest total production of tongkol at TPI Kranji occurred in 2016, with 941.66 tons, while the highest occurred in 2019, with 2,945.39 tons. The average production of tongkol commodity at TPI Kranji from 2013 to 2023, in general, is 1,641.13 tons per year, specifically for *T. tonggol* is 1,265.47 tons per year, *E. affinis* is 311.48 tons per year, and *A. thazard* is 64.18 tons per year. The catch of *T. tonggol* was less than the average in almost all years except 2018, 2019, and 2023. *Euthynnus affinis* catch was less than the average in 2014, 2015, 2016, 2018 and 2022. The catch of *A. thazard* was less than the average in 2014, 2016, 2018, 2019, 2021, and 2022. The highest production of tongkol commodity at TPI Kranji is dominated by *T. tonggol* with a percentage of 77.11%, followed by *E. affinis* with 18.98%, and the most minor catch is *A. thazard* with 3.91%. The trend of tongkol production at TPI Kranji is varied, *A. thazard* at TPI Kranji has decreased up to 82.08% in 2022, compared to the catch in 2013. The highest catch of *A. thazard* occurred in 2013, making the trend of *A. thazard* always in decrease. *Euthynnus affinis* production experienced the sharpest decline in 2016 by 78.49%, compared to the 2013 catch, but tended to increase thereafter. The catch of *T. tonggol* tends always to increase from 2013, with an increase of 3.04% in 2022 up to 220.25% in 2019, considering that the lowest production did occur in 2013.

The fishing season for tongkol generally occurs twice a year, if calculated from January, which from January to March, and from October to December (Figure 6). The peak point of the average percentage production from 2013 to 2023 for *T. tonggol* and *E. affinis* occurs in November, with average production reaching 417% and 338%, respectively. The peak point of average percentage production of *A. thazard* occurred in March, reaching 256%. The average percentage production of tongkol commodities will decrease to below 100%, or below the Fishing Seasonal Index (FSI) point at different times: *T. tonggol* decreased in mid-March; *E. affinis* in late April; *A. thazard* in mid-April. The increase in average percentage to above FSI for *T. tonggol* and *E. affinis* occurred around the end of September, while *A. thazard* occurred in mid-October.

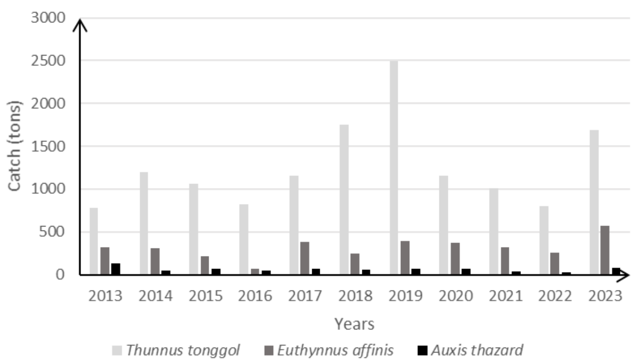

Figure 5. Annual production of tongkol landed at TPI Kranji, Lamongan, East Java, Indonesia, from 2013 to 2023. The highest production each year is *Thunnus tonggol* and the lowest is *Auxis thazard*

The fluctuation trends of tongkol, based on the results in this study, are still unclear, except for the *A. thazard*, this may occur due to exploitation or changes in oceanographic parameters. In general, tongkol is a strategic commodity in the international market. However, the exploitation of small pelagic fish can also have an impact on the stability of large pelagic fish populations, because of the relationship between both of them in nature (Hilborn et al. 2022), mainly if exploitation occurs directly to large pelagic commodities itselves, such as tongkol. Changes in oceanographic parameters significantly affect fluctuations in the tongkol commodity (Ishak et al. 2020), the movement of the west and east monsoon winds due to the monsoon cycle can affect temperature and other oceanographic parameters so that it can shift the fish population (Hidayat et al. 2021). Fishing grounds in the Java Sea shift annually (Dewi et al. 2020). Furthermore, the fishing season can be different from one place to another. The fishing season for tongkol commodities at the Lempasing Coastal Fishery Port (called PPP Lempasing in Indonesia), Bandar Lampung, from 2016 to 2020, resulting in the conclusion that it occurred from May to August, with peak fishing in June (Sari et al. 2021), inversely proportional to the tongkol fishing season at TPI Kranji. The seasonal difference may be caused by fish recruitment, migration, individual fish growth, temperature, and food availability (Wiryawan et al. 2020). Fishing season for tongkol is strongly proofed correlated to oceanography parameters as SST and Chlorophyll-*a* (Syamsuddin et al. 2018). Tongkol as *T. tonggol* in Java Sea only has one population, base on their genetic similarity (Al Malik et al. 2020), it's indicated possibility that different fishing season of tongkol around the Java Sea, caused by tongkol migration, as May to August in Bandar Lampung, and August to May in Lamongan.

Management of fishing efforts can be improved by utilizing information on fishing grounds, annual catch, and fishing season, such as the results in this study. FSI analysis is one way to improve the effectiveness and efficiency of fishing by evaluating the preparation of fishing to market the type of catch (Ishak et al. 2020), especially after being equipped with supporting data such as the fishing ground. The main factor in the success of a fishing effort is the accuracy in determining the fishing ground. Fishing ground information can be maximized by utilizing information and estimates of oceanographic parameters during fishing because oceanographic parameters also affect the distribution and abundance of fish resources. Such information can also be utilized for sustainable fish resource management in the future (Ma'mun et al. 2019). The results of the FSI analysis can be used to determine the fishing time and closed fishing season to maintain fish resource stocks (Macusi et al. 2021).

Tongkol diversity analysis

The diversity analysis results varied greatly depending on the species, number of individuals, and/or time. The Sa values (Table 3) for *T. tonggol* showed a declining trend from February to April, respectively 82.6%; 54.2% and 10.7%. The Sa values for *E. affinis* showed an increasing trend, respectively 16.6%; 38.1% and 73.4%. The Sa values for *A. thazard* showed a similar trend to *E. affinis*, respectively 0.8%; 7.8% and 15.9%. Based on Sa values, *T. tonggol* dominated the number of individuals caught in February and March, while *E. affinis* dominated in April. Sa values for the whole catch were dominated by *T. tonggol* with a percentage of 70.3%, followed by *E. affinis* with 25.9% and *A. thazard* with 3.8%. The Sa analysis results can be combined with the H' and C values (Table 4) to see the dominant species. The C values in February and April were categorized as high dominancy and Moderate, respectively 0.709 and 0.576, while in March it was categorized as low dominancy with a value of 0.444. In contrast to the C values, the H' values for all months was categorized as low, respectively 0.497, 0.898, and 0.758. The C and H' values tended to be opposite, as in March, which had the highest H' value, but the lowest C value at once.

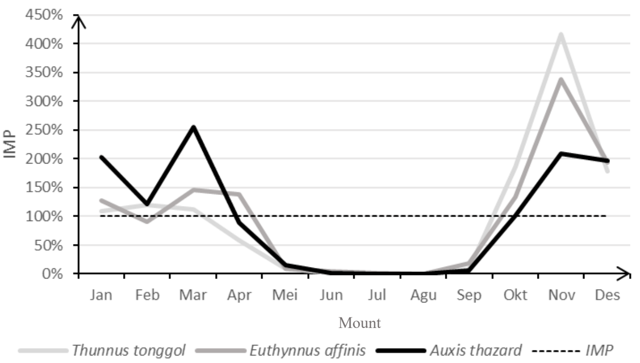

Figure 6. Fishing Seasonal Index (FSI) of tongkol at TPI Kranji, Lamongan, East Java, Indonesia, from 2013 to 2023. The peak fishing of *Thunnus tonggol* and *Euthynnus affinis* occurs in November, while for *Auxis thazard* occurs in March

Table 3. The Sa value for each species of tongkol at TPI Kranji, Lamongan, East Java, Indonesia, during the three months of observation was calculated based on the number of individuals caught

Fish	February	March	April	Whole catch
Thunnus tonggol	82.6%	54.2%	10.7%	70.3%
Euthynnus affinis	16.6%	38.1%	73.4%	25.9%
Auxis thazard	0.8%	7.8%	15.9%	3.8%

Table 4. H' and C values for tongkol catches at Kranji TPI, Lamongan, East Java, Indonesia, each month during the observation period based on the number of individuals caught

Month	Diversity (H')		Dominancy ©	
	Value	Category	Value	Category
February	0.497	Low	0.709	High
March	0.898	Low	0.444	Low
April	0.758	Low	0.576	Moderate
Whole catch	0.722	Low	0.563	Moderate

Based on the whole catch for three months, the tongkol commodity had an H' value of 0.722 and was categorized as low diversity, while it had a C value of 0.563 and was categorized as moderate dominancy. The monthly tongkol catch and the whole catch for the three months of observation were all categorized as low diversity based on the H' values. Based on the C and Sa values, there is dominated by *T. tonggol* in February and March, then by *E. affinis* in April. However, the C value for each month is categorized as varying, ranging from low to high dominance. These results indicate that there are differences in the peak season for each species based on the number of individuals each month, and the population size is not equal between species.

The restricted population size of *A. thazard* based on catch weight and number of individuals at the TPI Kranji, raises concerns about the fisheries sustainability and various possible factors that leading to its population declining trends. The peak fishing season for *T. tonggol* and *E. affinis* occurs in November, while for *A. thazard* it occurs in March. Despite entering the peak fishing season, the Sa value of *A. thazard* never dominated from February to April 2022, ranging from 0.8% to 15.9%, and based on the whole catch data over three months, it was only 3.8% of total tongkol catch. The population of *A. thazard*, with annual catch data from 2014 to 2023 that has never been greater than the 2013 catch record, requires greater attention both at the TPI Kranji and in the Java Sea or FMA 712 itself. Several studies on *A. thazard* address issues related to reproduction, recruitment, and mortality rates. Water temperature can influence the pre-oviposition and oviposition periods, with an ideal SST of 30.2° to 31.0°C. Temperatures above or below this range can inhibit gonadal maturation and development. *A. thazard* in the region of South China Sea spawns from March to May (Zhou et al. 2022). Other data indicate that gonadal maturation of *A. thazard* in the Babuyan Channel, Philippines, begins from January to April (Calicdan-Villarao et al. 2017). The potential for spawning season similarity may occur in the Java Sea, considering the peak fishing season is in March. Overexploitation of *A. thazard* during the spawning season may be a major factor in the declining population trend at the TPI Kranji. Furthermore, this is also related to recruitment and mortality rates from fishing activities. Mortality rates due to fishing increased annually, exceeding the natural mortality rates in the Babuyan Channel (Calicdan-Villarao et al. 2017). The mortality rate is strongly related to estimation of exploitation and declining fish stocks. Both fishing mortality and natural mortality decrease the survival rate and stock size in the population (Rahelimoghadam et al. 2024). Considering the migratory capabilities and potential differences between fishing grounds and spawning grounds (Calicdan-Villarao et al. 2017), combined with the global warming issue that can affect the SST, integrated management areas at the national and even global levels are urgently needed.

Discussion

The commodity of Tongkol in the Indo-Pacific, including the Java Sea, has rapidly increased in catches, thus requiring holistic and comprehensive information to support its sustainability. Studies such as stock assessment are critical for management development, including ecological studies, population dynamics, fisheries and ecology. The migration of tongkol is strongly related to the monsoon cycle, while its distribution is related to ontogeny (Griffiths et al. 2020). The different fishing seasons in different places around the Java Sea or FMA 712, considering the indication that the tongkol in this area is one population that is only limited to the neritic area, very rarely found outside the neritic area (Al Malik et al. 2020; Griffiths et al. 2020), causes particular concern. Analyses using Catch Per Unit Effort (CPUE) values conducted in FMA 712, one of which is in Indramayu, suggest that catches have already surpassed MEY and MSY levels. Additional fishing effort in these areas needs to be stopped, preferably reduced (Bintoro et al. 2022). The same is considered to be suggested at TPI Kranji, due to the trend of stock decline, especially for *A. thazard*. Protection of associated species should also be considered, due to the diversity of tongkol diet. For example, *T. tonggol* was reported to prey on a variety of taxa such as those from the families Platychepalidae, Callionymidae, Mullidae, Leiognathidae, Gobiidae and Nemapteridae (Griffiths et al. 2020), although the associated species of these families were not recorded in these data, as they are generally not caught using purse seines. However, tongkol are predators that feed on a very wide range of fish, including some of the species recorded in this study, such as those from the families Dorosomatidae, Carangidae, Menidae, etc.

Based on the results and discussion, this study highlights some important points that were found. Systematic morphological identification for tongkol landed at TPI Kranji, Lamongan in this study, can be used as a field guide, since it has been adjusted to the field conditions. The identification accuracy can be used as a basis for sustainable management in the future, especially within the study area. This study has mapped 38 species fishing grounds including tongkol, based on purse seine catch at TPI Kranji. The annual catch of *A. thazard* shows a downward trend when compared to the catch from 2013, this decline is a warning of the species' overexploitation in FMA 712. The results showed that the tongkol commodity from 2013 to 2023, entered the fishing season around August to April, which coincided with the west monsoon season. Tongkol caught in TPI Kranji have to stop the additional fishing effort when the peak fishing season, preferably reduced due to their overexploited issues, especially in the peak season of *A. thazard*. The management to associated species have to be considered to the additional factors that can reduced tongkol stocks by the undiversed or limited prey avaibility. The integrated study and management for national and even global levels, are highly suggested immidiately. Future research of tongkol in FMA 712, could be conducting further biological analysis as genetics, both of tongkol and the associated species.

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