RESEARCH ARTICLE

Influence of Colors on the Catching Performance of Artificial Lures of Multiple Troll Line in Bongao Waters, Tawi-Tawi, Philippines

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ABSTRACT

Improving the efficiency of fishing gears to catch species and sizes selectively and to catch more fish with less fishing efforts are essential objectives in fisheries research. This study utilized a small-scale multiple troll line, using two different artificial lures, i.e., green and blue, to determine the color lure preference of fish catch, catch composition, relative abundance, and catch per unit effort. In addition, the length-weight relationships of the caught species were also investigated. The study was conducted in the Bongao waters, Tawi-Tawi, Philippines, through fishing samplings using two separate motorized boats with two gears. A total of 1,032 fishes were caught by multiple troll line, which identified nine species with relative abundance: frigate tuna juvenile *Auxis thazard* (37.11%), bullet tuna *Auxis rochei* (24.90%), eastern little tuna *Euthynnus affinis* (15.99%), bigeye scad *Selar crumenopthalmus* (15.21%), yellowfin tuna *Thunnus albacares* (3.01%), common dolphin fish *Coryphaena hippurus* (1.75%), double-lined mackerel *Grammatorcynus bilineatus* (1.16%), shortfin scad *Decapterus macrosoma* (0.58%), and skipjack tuna *Katsuwonus pelamis* (0.29%). There were 677 fishes (65.89%) and 355 fishes (34.41%) lured by green and blue artificial lures, respectively. Most of the caught species had a size distribution ranging from 21.5 cm to 30.5 cm for both lure colors. The slopes (b) of the length-weight relationships of the caught fishes ranged between 1.5473 (skipjack tuna) and 3.305 (bullet tuna). In terms of catch per unit effort (CPUE) for all the species caught, the multiple troll line with the green lure had the highest mean CPUE with 0.63±0.12 kg/hr, while the blue lure had a mean CPUE of 0.35±0.7 kg/hr, although there was no significant difference ($p > 0.05$). This study suggests that multiple troll lines with either green or blue lures are effective small-scale fishing gear to catch small tunas and tuna-like, especially frigate tuna, bullet tuna, and eastern little tuna.

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1. INTRODUCTION

In 2020 world marine capture production, the Philippines is among the major countries with a 2% share or roughly 1.76 million tonnes in terms of live weight (FAO, 2022). Being an archipelagic country with 7 641 islands, capture fisheries play a crucial role in providing sustenance, protein source, and export earnings (Tahiluddin and Terzi 2021; Tahiluddin and Sarri 2022). Small-scale fisheries, in particular, provide important yet underrated contributions to the economies of some of the world's poorest countries, rendering much of the animal protein needed by societies where food security remains a pressing issue (Andrew et al. 2007). In the Philippines, small-scale fisheries contribute substantially to the country's economy, supply the majority of the dietary fish requirement for millions of Filipinos who consume nearly 38 kg/capita/year, and offer direct employment to more than 1 million fishers (Perez et al. 2012). Small-scale fisheries are a form of fisheries carried out along coastal and inland waters with or without the use of vessels of 3 gross tons or less (BFAR 2019). In 2020, the production from the Philippine marine small-scale fisheries was about 950,000, contributing about 22% of the total production (PSA 2021). The major caught fish species in the small-scale marine fisheries in the country are mainly dominated by bigeye scad (*Selar crumenophthalmus*), Bali sardinella (*Sardinella lemuru*), frigate tuna (*Auxis thazard*), round-scad (*Decapterus maruadsi*), fimbriated sardines (*Sardinella fimbriata*), slipmouth (*Leiognathus*), squid (*Teuthoidea*), Indian mackerel (*Rastrelliger kanagurta*), yellowfin tuna (*Thunnus albacares*), and anchovies (*Engraulidae*) (BFAR 2019 ; Tahiluddin and Terzi 2021). Fishing gears, mainly belonging to the lines category, are among the most employed by fishers in small-scale fisheries in the Philippines (Balisco et al. 2019; Macale et al. 2020; Tahiluddin and Terzi 2021; Mohammad et al. 2022).

Troll line (trolling line) is a long line cast horizontally, equipped with hooks at the loose end. These hooks can be baited with either natural bait or an artificial lure. The entire setup is then pulled or towed behind a moving boat (Umali, 1950; Eyo and Akpati 1995). In the Philippines, troll line is one of the popular line fishing gears operated in the municipal waters across the entire Philippine waters (Baleta et al. 2017; Padios et al. 2017; Balisco et al. 2019; Macale et al. 2020; Mohammad et al. 2022). It is an active fishing gear that typically catches juveniles and adults' pelagic species, such as frigate tuna, Indian mackerel, and eastern little tuna (Babaran and Ishizaki 2011; Balisco et al. 2019). Multiple troll line or multiple hook troll line is among the most used fishing gears during the onset of summer and rainy seasons in Isabela, Philippines (Padios et al. 2017). In Tawi-Tawi, a province located in the Sulu Sea and part of the Sulu-Sulawesi marine ecoregion, which is renowned as one of the Philippines' most productive fishing grounds and nursery areas for small pelagic fish, fishers have been employing multiple troll lines for many years. This fishing technique primarily focuses on targeting small tuna species, such as frigate tuna, eastern little tuna, bullet tuna, and other similar pelagic fish species. Local fishers highly regard the multiple troll line due to its operational simplicity and affordability. It consists of essential components such as hooks, sinkers, monofilament nylon, silk cloth, and swivels. Locally known as "tondaan," this boat-operated fishing gear is constructed with different lures featuring various colors (Hapid A, interview with authors, 20 Mar 2020).

Studies on the influence of color on the catching efficiency of line fishing gears are sufficient (Tester and Nakamura 1957; Jester 1977; Okamoto et al. 2001; Hsieh et al. 2001; Asia and Garcia 2009; Moraga et al. 2015; Ateşşahin 2022). Some studies focused on the effects of colored baits in the longline fishery to mitigate the high bycatch of turtles (Swimmer et al. 2005; Yokota et al. 2009; Afonso et al. 2021). However, a large number of fishers and fisheries biologists have attempted and failed to find more efficient artificial lures or fishing baits for tuna fishing (Kawamura et al. 1981). In Tawi-Tawi, Philippines, local fishers have been playing on different lure colors of multiple troll line for many years to attract more catch. However, this was done in an unscientific way; hence, this study was initiated to fill in the gaps. After several trials in determining the most significant colors of lures, we came up with testing the influence of two different colors (green and blue) of lures of small-scale multiple troll line in municipal waters of Bongao, Tawi-Tawi, Philippines, and determined their catch composition, relative abundance, length-weight relationship, and catch per unit effort.

2. MATERIALS AND METHODS

2.1 Study site and duration

The study was conducted at Bongao municipal fishing grounds, Tawi-Tawi, Philippines (Figure 1), from March 15, 2020 to April 27, 2020.

2.2 Multiple troll line preparations

Blue and green lures were chosen in the present study as reported by the fishers in the area and as verified in fishing trials. The mainline was made of monofilament nylon twine no. 30, while the branch line was made of monofilament nylon twine no. 10. J hook (VMC) no. 24 was attached to each branch line, with each gear having 100 hooks and provided with sinkers. The lures (green and blue) used in this study are made of folded strands of silk cloth. Each lure consists of 67 strands, which, when folded, double the number to 134 strands. The length of each lure is 2.5 cm. These two color of strands, with 50 each, were distributed and attached randomly to each hook. The specific measurements of these various components of the gear can be seen in Figure 2.

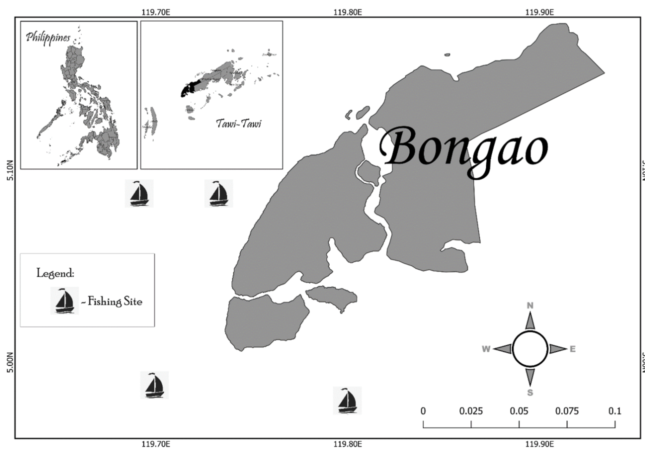

Figure 1. Map showing the location of fishing sites (boats) in the waters off Bongao, Tawi-Tawi, Philippines.

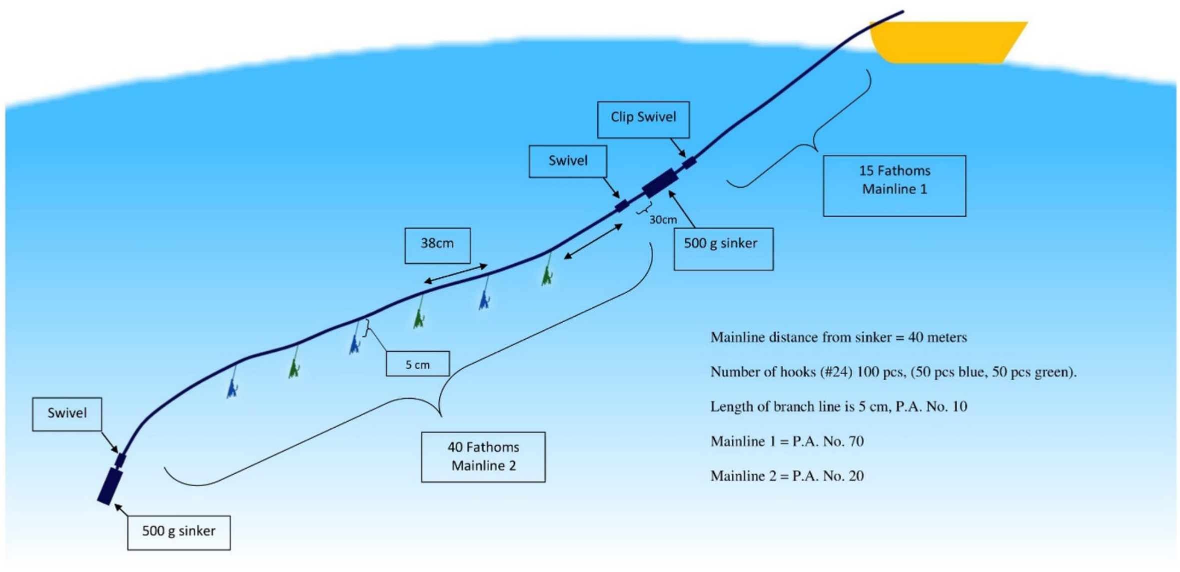

Figure 2. Multiple troll line set up during samplings.

2.3 Fishing sampling

A total of 46 fishing sets were conducted daily (5:30–7:30 AM and 5:30–7:30 PM) except during bad weather and depending upon the velocity of the water current in the fishing grounds. The fishing grounds are estimated to extend from 3 to 7 nautical miles from the shoreline of Sanga-Sanga Island, Bongao, Tawi-Tawi, Philippines, and with an estimated depth of 70 to 200 fathoms. Two motorized bancas (powered with a 13.0 horsepower Honda engine) were utilized, with two gears each conducting fishing simultaneously on the same fishing grounds. Each banca was manned by two fishers, one at the center and the other at the stern, who could take turns using the gears or man the banca. The gear required a constant speed of 1 knot by towing it to the hind part of the boat submerged at about 15 fathoms depth, and towed where the direction of the water current or against the water current or just counter-attack the forward direction of the school of fish to allow them to bite. Once there was a fish on the gear, the boat speed decreased to a very low speed and followed the curvature of the school of fish. Then, once the fish bit the lures, the boat stopped immediately, hauled the fish, and placed it in the designated basins according to the color of the lure used. The same procedure was repeated for another fishing set.

2.4 Catch composition and relative abundance

The number of fish and species caught were recorded according to different lures. Fishes caught were identified morphologically. The relative abundance of the fish catch was computed using the formula below:

$$\text{Relative Abundance} = \frac{\text{Number of species}}{\text{Total number of species}} x\ 100 \qquad (1)$$

2.5 Length-weight relationship

The weight was recorded to the nearest 0.5 cm and its length (total length) to the nearest 0.5 g. The total length and weight of all fishes were used to calculate the length-weight relationship using the formula suggested by Ricker (1975).

$$W = aL^b \qquad (2)$$

In this equation, W is the total weight (g), L is the total length of fish, 'a' is the intercept, and 'b' is the slope.

2.6 Catch per unit effort (CPUE)

Catch per unit effort (CPUE) was computed using the formula below.

$$\text{CPUE} = \frac{\text{Total catch(kg) day}^{-1}}{\text{Fishing time(hr)}} \qquad (3)$$

2.7 Statistical Analysis

The data on the CPUE expressed as mean±SEM was analyzed using a t-test in IBM SPSS version 20. The significant difference was set at $p<0.05$.

3. RESULTS

3.1 Catch composition and relative abundance

There were nine species caught by the multiple troll line with an overall total catch of 1,032 fishes: 383 frigate tuna (*Auxis thazard*), 257 bullet tuna (*Auxis rochei*), 165 eastern little tunas (*Euthynnus affinis*), 157 bigeye scad (*Selar crumenopthalmus*), 31 yellowfin tuna juvenile (*Thunnus albacares*), 18 common dolphin fish (*Coryphaena hippurus*), 12 double-lined mackerel (*Grammatorcynus bilineatus*), 6 shortfin scad (*Decapterus macrosoma)*, and 3 skipjack tuna juveniles (*Katsuwonus pelamis*).

The relative abundances of the fish caught by the multiple troll line (Table 1) were 37.11% frigate tuna (25.77% for green lure, 11.34% for blue lure), 24.90% bullet tuna (15.89% green lure, 9.01% blue lure), 15.99% eastern little tuna (9.11% green lure, 6.88% blue lure), 15.21% bigeye scad (10.27% green lure, 4.94% blue lure), 3.01% yellowfin tuna (1.94% green lure, 1.07% blue lure), 1.75% common dolphin fish (1.36% green lure, 0.39% blue lure), 1.16% double-lined mackerel (0.77% green lure, 0.39% blue lure), 0.58% shortfin scad (0.29% green lure, 0.29% blue lure), and 0.29% skipjack tuna (0.19% green lure, 0.10% blue lure).

3.2 Size distribution of the caught fish

The overall size distribution (weight) of all caught fish was dominated by more than 151 g individuals, with the green lure having the highest number of individuals (485) than the blue lure (238), as shown in Figure 3. The size distribution in terms of

Table 1. Species composition and relative abundances of fishes caught by colored (green and blue) multiple troll line.

Species	N	Relative abundance (%)		
		Green lure	Blue lure	Total
Frigate tuna (*Auxis thazard*)	383	25.77	11.34	37.11
Bullet tuna (*Auxis rochei*)	257	15.89	9.01	24.90
Eastern little tuna (*Euthynnus affinis*)	165	9.11	6.88	15.99
Bigeye scad (*Selar crumenopthalmus*)	157	10.27	4.94	15.21
Yellowfin tuna juvenile (*Thunnus albacares*)	31	1.94	1.07	3.01
Common dolphin fish (*Coryphaena hippurus*)	18	1.36	0.39	1.75
Double-lined mackerel (*Grammatorcynus bilineatus*)	12	0.77	0.39	1.16
Shortfin scad (*Decapterus macrosoma*)	6	0.29	0.29	0.58
Skipjack tuna juvenile (*Katsuwonus pelamis*)	3	0.19	0.10	0.29
Total	**1 032**	**65.59**	**34.41**	**100.00**

the length (total length) according to species can be seen in Figures 4 to 12. Frigate tuna was dominated by an individual with a size range of 26.5–30.5 cm (Figure 4), with the highest number in green lure (166) compared to blue lure (61). A large number of bullet tuna individuals (102) were in the size range of 26.5–30.5 cm caught by the green lure and 21.5–25.5 cm caught by the blue lure (Figure 5). The most abundant eastern little tuna individuals had a size range of 21.5–25.5 cm (Figure 6), predominated by green lure (64) compared to blue lure (51). Bigeye scad individuals were dominated by a size range of 21.5–25.5 cm (Figure 7), both in green lure (65) and blue lure (32). Most yellowfin tuna, common dolphin fish, and skipjack individuals were within the size range of 21.5–25.5 cm in both lure colors (Figures 8, 9, and 10). Individuals of double-lined mackerel were mostly under the size range of 16.5–14.5 cm

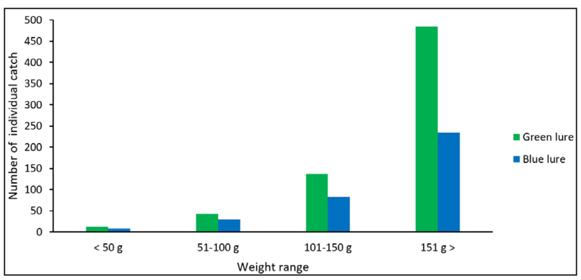

Figure 3. Size distribution (weight) of multiple troll line-caught fish (N = 1,032).

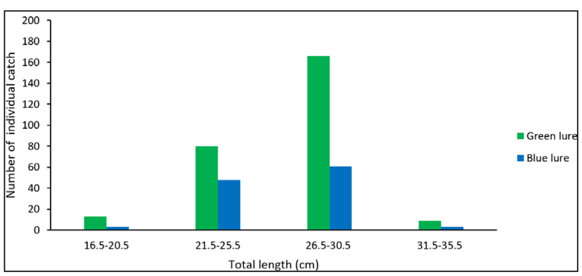

Figure 4. Size distribution (total length) of frigate tuna *A. thazard* (N = 383).

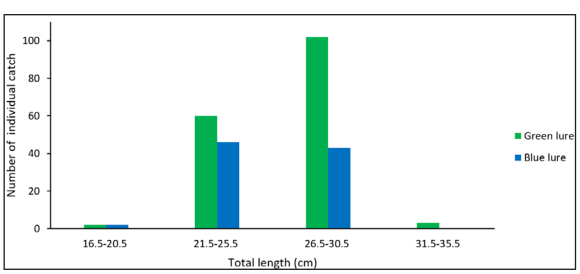

Figure 5. Size distribution (total length) of bullet tuna *A. rochei* (N = 257).

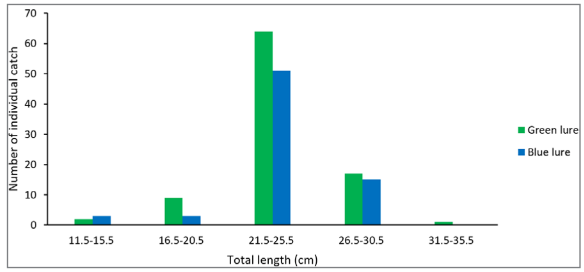

Figure 6. Size distribution (total length) of eastern little tuna *E. affinis* (N = 165).

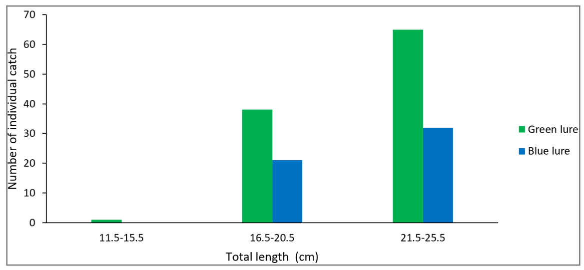

Figure 7. Size distribution (total length) of bigeye scad *S. crumenopthalmus* (N = 157).

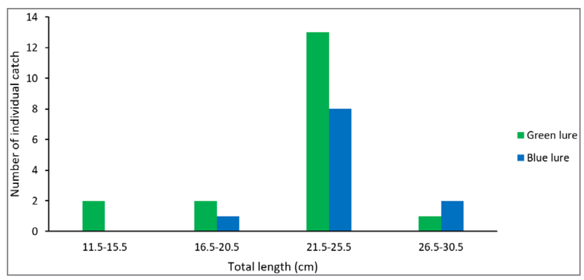

Figure 8. Size distribution (total length) of yellowfin tuna *T. albacares* (N = 31).

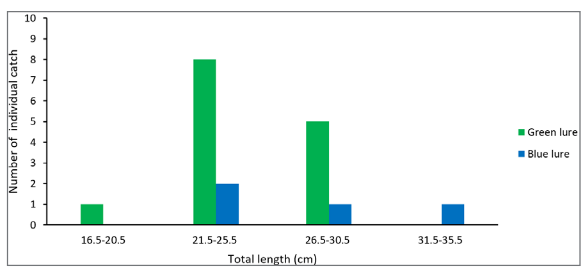

Figure 9. Size distribution (total length) of common dolphin fish *C. hippurus* (N = 31).

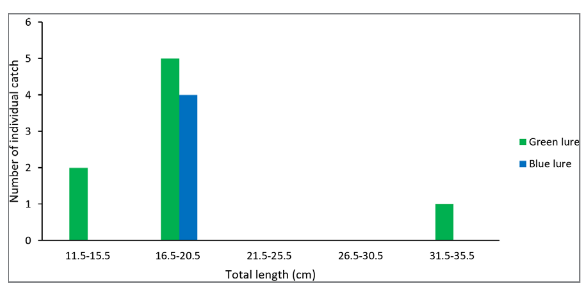

Figure 10. Size distribution (total length) of double-lined mackerel *G. bilineatus* (N = 12).

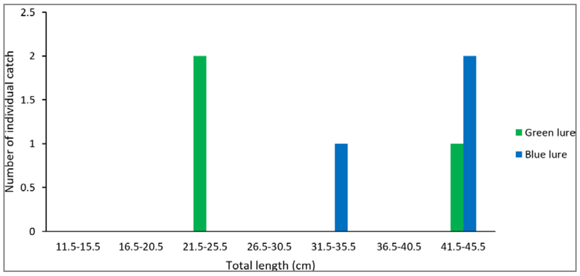

Figure 11. Size distribution (total length) of shortfin scad *D. macrosoma* (N = 6).

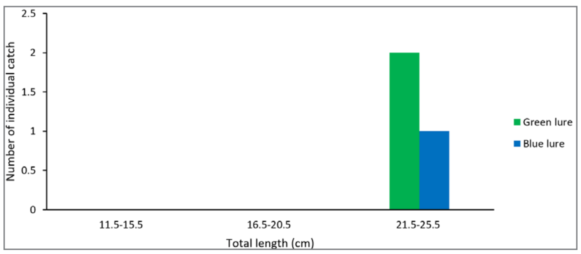

Figure 12. Size distribution (total length) of skipjack tuna *K. pelamis* (N = 3).

(Figure 11). Moreover, shortfin scad individuals were within the range of 21.5–45.5 cm (Figure 12).

3.3 Length-weight relationship of the caught species

The slopes (b) of the length-weight relationships of the caught species were 3.305 (bullet tuna), 3.2616 (eastern little tuna), 3.1393 (frigate tuna), 2.8977 (yellowfin tuna), 2.7733 (bigeye scad), 2.6748 (common dolphin fish), 2.6465 (double-lined mackerel), 1.9887 (shortfin-scad), and 1.5473 (skipjack tuna) as shown in Table 2 and Figures 13–21. The b values of bullet tuna, eastern little tuna, and frigate were greater than 3, which showed positive allometric growth ($b > 3$, t-test, $p < 0.05$). On the other hand, the b values for yellowfin tuna, bigeye scad, common dolphin fish, double-lined mackerel, shortfin-scad, and skipjack were less than 3, indicating negative allometric growth ($b < 3$, t-test, $p > 0.05$).

Table 2. Length-weight relationship of the caught fish species.

Species	Length-weight relationship			
	N	r^2	b	Growth type
Frigate tuna (*Auxis thazard*)	383	0.9107	3.1393	A+
Bullet tuna (*Auxis rochei*)	257	0.8809	3.305	A+
Eastern little tuna (*Euthynnus affinis*)	165	0.9696	3.2616	A+
Bigeye scad (*Selar crumenopthalmus*)	157	0.8977	2.7733	A-
Yellowfin tuna juvenile (*Thunnus albacares*)	31	0.94	2.8977	A-
Common dolphin fish (*Coryphaena hippurus*)	18	0.9255	2.6748	A-
Double-lined mackerel (*Grammatorcynus bilineatus*)	12	0.9963	2.6465	A-
Shortfin scad (*Decapterus macrosoma*)	6	0.9307	1.9887	A-
Skipjack tuna juvenile (*Katsuwonus pelamis*)	3	0.918	1.5473	A-

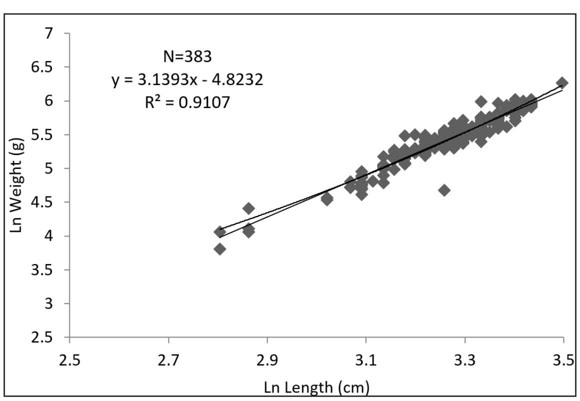

Figure 13. Length-weight relationship of frigate tuna (*A. thazard*).

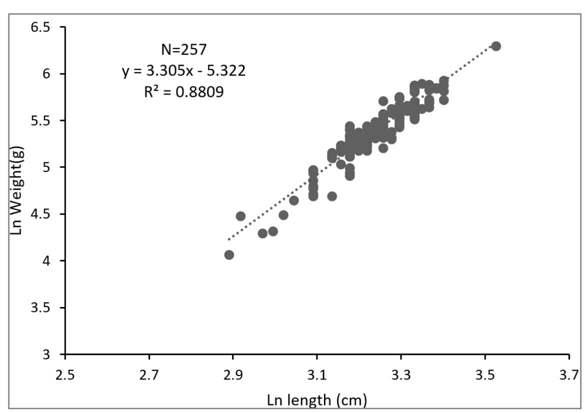

Figure 14. Length-weight relationship of bullet tuna (*A. rochei*).

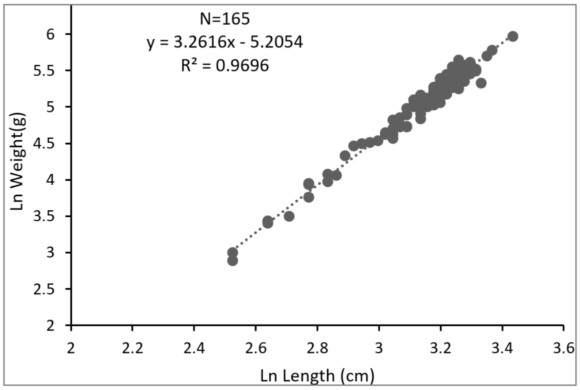

Figure 15. Length-weight relationship of eastern little tuna (*E. affinis*).

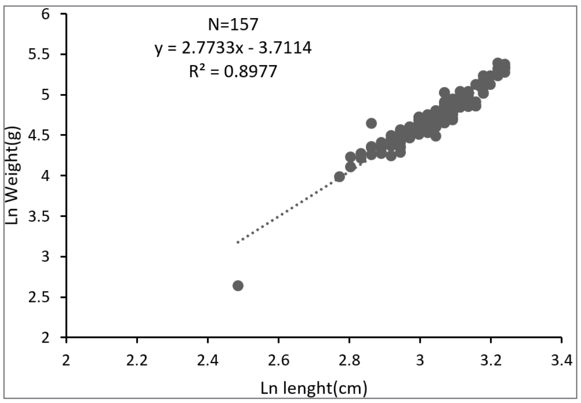

Figure 16. Length-weight relationship of bigeye scad (*S. crumenopthalmus*).

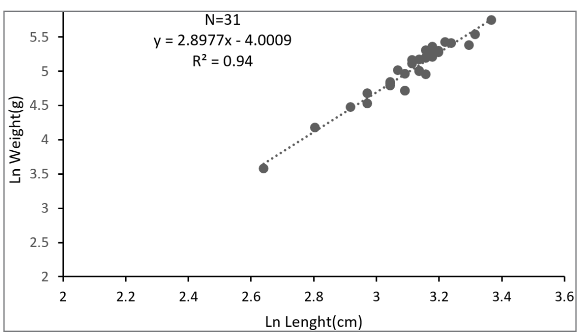

Figure 17. Length-weight relationship of yellowfin tuna juvenile (*T. albacares*).

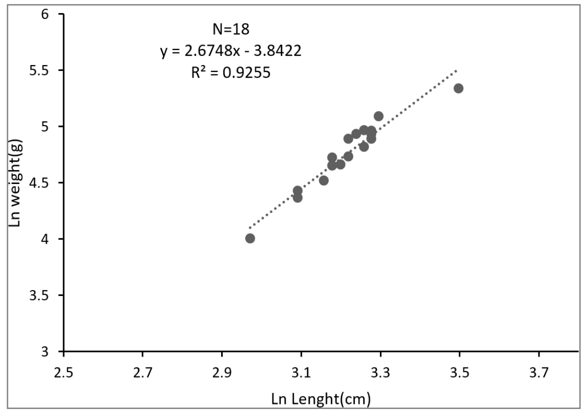

Figure 18. Length-weight relationship of common dolphin fish (*C. hippurus*).

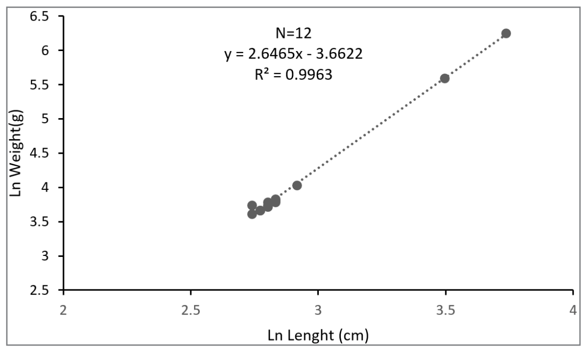

Figure 19. Length-weight relationship of double-lined mackerel (*G. bilineatus*).

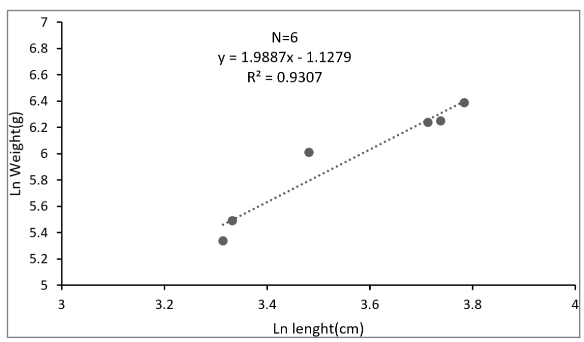

Figure 20. Length-weight relationship of shortfin scad (*D. macrosoma*).

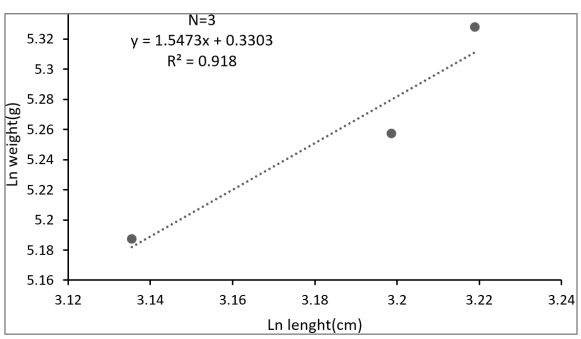

Figure 21. Length-weight relationship of skipjack tuna (*K. pelamis*)

3.4 Catch per unit effort (CPUE)

The multiple troll line with a green lure had the highest mean CPUE at 0.63±0.12 kg/hr, while the blue lure had a mean CPUE of 0.35±0.7 kg/hr for all species caught (Table 3). However, statistically, there was no significant difference ($p > 0.05$) among the lure colors.

4. DISCUSSION

Visual characteristic (e.g., color, shape, size, and movement) is among the factors that influence the searching, detecting, attack/feed behaviors for different prey by pelagic marine predators (Gilman et al. 2020). Therefore, it is necessary to study the appropriate preference for colored lures used in particular fishing gear, such as multiple troll lines. While green or yellow-green colors were significantly preferred as lures, background tanks, and light attractors in previous experiments conducted in longline fisheries (Okamoto et al. 2001; Hsieh et al. 2001; Afonso et al. 2021), the color of the lure in multiple troll lines did not affect the relative abundance, size distribution, and catch per unit effort of the caught pelagic species in the present study, despite observing higher numbers attracted to green lures compared to blue lures. This indicates that green and blue could be suitable colors for artificial lures to enhance the catching performance of multiple troll lines. The findings of the present study align with previous research. For instance, Tester and Nakamura (1957) reported that the catch records of tuna trolling showed no color preference for lure nor the form of the lure. Wilde et al. (2003) stated that lure color pattern did not affect the length of fish captured. In addition, lure color did not influence the CPUE or hooking injury in bass but appeared to have a negligible effect on the size of captured fish (Moraga et al. 2015). The previous study on color vision in tuna has suggested that yellowfin tuna, albacore, and bigeye tuna are likely color-blind and absent of color vision (Kawamura et al. 1981). Similarly, Crescitelli et al. (1977) found only a single visual pigment in retinal extracts of yellowfin tuna, little tuna, wahoo, black marlin, and *Makaira ampla*. To be capable of color vision, a fish must have two or more visual pigments whose absorbance spectra overlap and have neural interconnections that can compare the signals of the photoreceptors appropriately (Levine and MacNichol 1982).

In the present study, the top fish species caught by a multiple troll line with green and blue artificial lures were frigate tuna, bullet tuna, eastern little tuna, bigeye scads, and yellowfin tuna juvenile, with the most size distribution of 21.5–30.5 cm. Comparing these findings with the maximum lengths reported in the literature, it can be seen that the captured individuals in this study were generally smaller in size compared to their maximum potential length. According to Froese and Pauly (2023), the maximum lengths (forked length) for frigate tuna, bullet tuna, eastern little tuna, bigeye scads, and yellowfin tuna are 65 cm, 50 cm, 100 cm, 70 cm, and 239 cm, respectively. The fact that most of the caught individuals fell within the size range of 21.5 to 30.5 cm suggests that the fishing activity using a multiple troll line targeted mostly juvenile individuals or smaller-sized adults of these fish species. This could have implications for the overall population dynamics and the sustainability of these species, as the fishing pressure may be affecting the reproductive potential and growth of larger individuals. It is worth noting that the size distribution observed in this study may also be influenced by the choice of artificial lures (green and blue) used in the multiple troll lines. Lure color and design can attract specific species or sizes of fish, potentially biasing the catch composition. Further investigation into the lure preferences of different fish species and their size selectivity could provide valuable insights into optimizing fishing strategies and reducing the impact on vulnerable populations.

The length-weight relationship of aquatic organisms gives essential information in a particular geographic region (Tesch 1971). Additionally, studies on the length-weight relationship provide crucial data for the assessment of fish population characteristics, understanding the growth, life cycle, ontogenetic changes, and fisheries resource protection (Seçer et al. 2021), which are critical for the decision-making process (Acarli et al. 2022). In the present study, the most abundant caught species (i.e., frigate tuna, eastern little tuna, and bullet tuna) showed positive

Table 3. Catch per unit effort (CPUE) of multiple troll line (N = 46).

Lure color	N	Min-Max CPUE (kg/hr)	Mean±SE CPUE (kg/hr)	T-test
Green lure	46	0.00 – 4.24	0.63±0.12	p>0.05
Blue lure	46	0.00 – 2.12	0.35±0.74	

allometric growth patterns, while the rest caught species showed negative allometric growth. Similar studies have been previously reported that frigate tuna showed positive allometric growth sampled across different oceans and seas (Mudumala et al. 2018; Mariyasingarayan et al. 2018; Petukhova 2019; Lelono and Bintoro 2019; Herath et al. 2019). For eastern little tuna, some reports that this fish exhibited isometric growth close to 3 (Rohit et al. 2012; Ahmed et al. 2015), but most reported that it likewise showed positive allometric growth (Al-Zibdah and Odat 2007; Arnenda et al. 2020; Herath et al. 2019; Lelono and Bintoro, 2019). For bullet tuna, it was reported that this fish showed positive allometric growth patterns (Herath et al. 2019), and other studies reported that its growth was minor allometric (Asrial et al. 2021). In the length-weight relationship, when b is less than 3, fish become slimmer with increasing length, and growth will be negatively allometric. In contrast, when b is greater than 3.0, fish become heavier, showing positive allometric growth and reflecting optimum conditions for growth (Jisr et al. 2018). Positive allometric growth means that as the individuals of a species grow larger in size, certain body parts or dimensions increase at a faster rate than the overall body size. In the case of frigate tuna, eastern little tuna, and bullet tuna in the present study, this implies that specific body parts or dimensions, such as the head, length of fins, or other relevant measurements, grow faster relative to the overall size of the fish as they mature. On the other hand, negative allometric growth indicates that certain body parts or dimensions increase at a slower rate compared to the overall body size. In the context of the other caught species in this study, it suggests that their body proportions change as they grow, with certain dimensions lagging behind the overall size increase. These findings have important implications for understanding the growth and development of the studied fish species. Positive allometric growth in frigate tuna, eastern little tuna, and bullet tuna in the present study may indicate specific adaptations or physiological changes related to their behavior, feeding habits, or ecological roles. It suggests that these species may exhibit distinctive morphological characteristics or specialized functions as they reach larger sizes. On the other hand, negative allometric growth in the remaining caught species in the present study suggests a different pattern of growth and development. It could indicate that these species have different strategies for allocating energy and resources as they grow, resulting in different proportions and morphological changes compared to the positive allometric species. Further investigation is necessary to determine this negative allometric growth's ecological and physiological implications. Understanding the growth patterns of different fish species is essential for fisheries management and conservation efforts. It provides insights into these species' life history and reproductive strategies. Furthermore, it helps in predicting population dynamics and assessing their vulnerability to fishing pressure. These findings can aid in developing appropriate size and catch limits to ensure the sustainable management of fish populations.

Catch per unit effort (CPUE) is the quantity of catch taken per unit of fishing gear. It can be utilized to measure the gear type's efficiency in terms of catch and is likewise used as a fish abundance index, which is theoretically, as the effort increases, catch also increases (Mamalangkap et al. 2018). CPUE can vary considerably because fish distributions are patchy, and fish show temporal and spatial variation in their activity and distribution patterns (Hubert and Fabrizio 2007). CPUE can change seasonally due to variations in growth, recruitment, and mortality; however, such changes may not be the same for all species or a given species in all habitats (Hubert and Fabrizio 2007). In this study, the CPUE ranged between 0.35±0.74 kg/hr and 0.63±0.12 kg/hr. The variability in CPUE values could be attributed to several factors, including variations in fishing effort, environmental conditions, and the effectiveness of the fishing gear. It is important to note that the CPUE is influenced by the abundance and behavior of the target species, as well as the fishing techniques employed. The higher CPUE value of 0.63±0.12 kg/hr indicates a greater catch rate per unit of fishing effort compared to the lower CPUE value of 0.35±0.74 kg/hr. This suggests that during the study period, the multiple troll line was more productive in capturing the target species at a higher rate. To the best of our knowledge, this is the first study to report the catch per unit effort (CPUE) specifically for multiple troll lines, making it challenging to compare our findings with other studies employing the same gear. However, to provide a point of reference, we compared our results with the CPUE values reported for troll lines in general. In a study conducted in Albay Gulf, Philippines, the mean CPUE for troll lines ranged between 8.88 and 10.32 kg/trip (Macale et al. 2020). The dominance of juvenile tuna species in the CPUE of a multiple troll line, using either green or blue artificial lures, in the present study underscores the importance and efficiency of this fishing gear for small-scale fisheries in Tawi-Tawi, Philippines.

The multiple troll line fishery has been a significant small-scale industry in Tawi-Tawi since the

1990s, providing an important source of fresh protein, specifically small tuna species, and supporting numerous local families. Over the years, each fisher has developed his own strategies, experimenting with various colors of artificial lures. The present study offers valuable insights to address the knowledge gap and hypothesis regarding which color, green or blue, is more effective in attracting fish. The findings of this study demonstrate that both green and blue artificial lures can effectively be used in the multiple troll line fishery to capture small tuna species, including frigate tuna, bullet tuna, eastern little tuna, bigeye scad, and yellowfin tuna juveniles. These results have significant implications as they provide guidance on the selection of lure color to optimize catches in the multiple troll line fishery. Fishers can make informed decisions based on this information, potentially improving their fishing efficiency and economic outcomes.

5. CONCLUSION

In conclusion, this study contributes to our understanding of the influence of color, specifically green and blue, in artificial lures on the catch performance of the multiple troll line. The findings indicate that the color of the lure does not significantly affect the catch performance of this fishing gear. Furthermore, the multiple troll line primarily caught tuna species, specifically frigate tuna, bullet tuna, and eastern little tuna, exhibiting positive allometric growth. Based on the results, it can be inferred that the multiple troll line, equipped with either a green or blue lure, is an effective small-scale fishing gear for targeting small tunas and tuna-like species. The findings suggest that fishers can utilize both green and blue lures without compromising their catch performance when using the multiple troll line. Overall, this study highlights the importance of gear selection and provides valuable insights for fishers in optimizing their fishing strategies. Using the appropriate color of artificial lures, fishers can effectively target and catch small tunas and tuna-like species using the multiple troll line. These findings contribute to the sustainable management of small-scale fisheries and the conservation of tuna populations in the study area.

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AUTHORS CONTRIBUTIONS

Ajik JO: Conceptualization, Investigation, Data analysis, Writing-Original draft preparation. **Palla RP:** Writing- Reviewing and Editing, Supervision. **Loque FS:** Writing- Reviewing and Editing. **Palla SQ**: Writing-Reviewing and Editing. **Gomes DK***:* Writing-Reviewing and Editing. **Armada NA**: Writing-Reviewing and Editing. **Guanzon Jr NG:** Writing-Reviewing and Editing. **Tahiluddin AB**: Data analysis, Writing-Original draft preparation, Writing-Reviewing and Editing.

CONFLICTS OF INTEREST

We declare no conflict of interest in doing this work.

ETHICS STATEMENT

This study did not deal with live animals nor humans as subjects.

REFERENCES

Acarli D, Kale S, Çakır K. 2022. Length–Weight Relationships of Eighteen Fishes and a Cephalopod from Gökçeada Island, Northern Aegean Sea, Turkey. Thalassas: An International Journal of Marine Sciences. 38(1):479–486. https://doi.org/10.1007/s41208-022-00408-6

Ahmed Q, Yousuf F, Sarfraz M, Mohammad Ali Q, Balkhour M, Safi SZ, Ashraf MA. 2015. *Euthynnus affinis* (little tuna): fishery, bionomics, seasonal elemental variations, health risk assessment and conservational management. Frontiers in Life Science. 8(1):71–96. https://doi.org/10.1080/21553769.2014.961617

Al-Zibdah M, Odat N. 2007. Some findings related to the fishery status, growth, repoduction biology and feeding habit of two scombrid fish from the Gulf of Aqaba Red Sea. Lebanese Science

Journal. 8(2):3–20.

Afonso AS, Mourato B, Hazin H, Hazin FH. 2021. The effect of light attractor color in pelagic longline fisheries. Fisheries Research. 235:105822. https://doi.org/10.1016/j.fishres.2020.105822

Andrew NL, Béné C, Hall SJ, Allison EH, Heck S, Ratner BD. 2007. Diagnosis and management of small-scale fisheries in developing countries. Fish and Fisheries. 8(3):227–240. https://doi.org/10.1111/j.1467-2679.2007.00252.x

Arnenda GL, Setyadji B, Wiratmini NI, Wijana IMS. 2020. Biological aspects, catching aspects and fishing ground of eastern little tuna or kawakawa (*Euthynnus affinis* (cantor, 1849)) based on the fishing gear at WPP 572. Saintek Perikanan: Indonesian Journal of Fisheries Science and Technology. 16(3):199–207.

Asrial E, Arapat Y, Hadi UK, Kalih LA, Liliyanti MA, Rosadi E, Rathnayake IN. 2021. The Length-Weight Relationship and Condition Factors of Bullet Tuna Landed at the Tanjung Luar Fishing Port, Indonesia. Jurnal Ilmiah Perikanan dan Kelautan. 13(1):1–10. https://doi.org/10.20473/jipk.v13i1.22585

Asia FB, Garcia RR. 2009. Catching efficiency of multiple handline operated in payaw areas. Asian Fisheries Science. 22(1):309–317. https://doi.org/10.33997/j.afs.2009.22.1.029

Ateşşahin T. 2022. The effect of artificial lure type and environment conditions on the short-time post-release mortality of two recreational fished *Luciobarbus* species. Journal of Applied Ichthyology. 38(1):53–62. https://doi.org/10.1111/jai.14278

Babaran RP, Ishizaki M. 2011. Profile of Payao (floating artificial reef or fish attracting device) fisheries of the Philippines. In: Global Change: Mankind-Marine Environment Interactions: Proceedings of the 13th French-Japanese Oceanography Symposium. Springer Netherlands. pp. 49-53.

Baleta FN, Beltijar JG, Bolaños JM. 2017. Design, fabrication and operation of fishing gears used along the coastal areas of Isabela, Philippines. International Journal of Fisheries and Aquatic Studies. 5(2):319–323.

Balisco RA, Tahajudjin CJ, Vigonte AC. 2019. Fishing gears and their common catch in two coastal areas of Palawan, Philippines: Implications to fisheries management. International Journal of Fisheries and Aquatic Studies. 7(2):216–222.

[BFAR] Bureau of Fisheries and Aquatic Resources. 2019. Philippine fisheries profile 2018. PCA Compound, Elliptical Road, Quezon City, Philippines.

Crescitelli, F, Dvorak CA, Eder DJ, Granda AM, Hamasaki D, Holmberg K, Hughes A, Locket NA, McFarland WN, Meyer DB, and others. 1977. The visual system in vertebrates (Handbook of sensory physiology). Volume VII/5. Berlin: Springer-Verlag.

Eyo E, Akpati CI. 1995. Fishing gears and fishing methods. In: Ezenwaji HMG, Inyang NM, Orji EC, editors. Proceedings of the UNDP-Sponsored Training Workshop on Artisanal Fisheries Development. Held at University of Nigeria, Nsukka, October 29 – November 12, 1995. pp. 143–159.

FAO. 2022. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome: FAO. https://doi.org/10.4060/cc0461en

Froese RD, Pauly D. 2023. FishBase. World Wide Web electronic publication. [Accessed 16 October 2023]. https://fishbase.net.br/search.php

Gilman E, Chaloupka M, Bach P, Fennell H, Hall M, Musyl M, Piovano S, Poisson F, Song L. 2020. Effect of pelagic longline bait type on species selectivity: a global synthesis of evidence. Reviews in Fish Biology and Fisheries. 30(3):535–551. https://doi.org/10.1007/s11160-020-09612-0

Herath DR, Perera HACC, Hettiarachchi GHCM. 2019. Some biological aspects and molecular variations in frigate tuna, Auxis *thazard* of the coastal waters around Sri Lanka. Journal of the National Science Foundation of Sri Lanka. 47(3):333–340. https://doi.org/10.4038/jnsfsr.

v47i3.9427

Hsieh KY, Huang BQ, Wu RL, Chen CT. 2001. Color effects of lures on the hooking rates of mackerel longline fishing. Fisheries science. 67(3):408–414. https://doi.org/10.1046/j.1444-2906.2001.00276.x

Hubert WA, Fabrizio MC. 2007. Relative abundance and catch per unit effort. Analysis and interpretation of freshwater fisheries data. Bethesda, Maryland: American Fisheries Society. pp. 279–325.

Jester DB. 1977. Effects of color, mesh size, fishing in seasonal concentrations, and baiting on catch rates of fishes in gill nets. Transactions of the American Fisheries Society. 106(1):43–56. https://doi.org/10.1577/1548-8659(1977)106<43:EOCMSF>2.0.CO;2

Jisr N, Younes G, Sukhn C, El-Dakdouki MH. 2018. Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. The Egyptian Journal of Aquatic Research. 44(4):299–305. https://doi.org/10.1016/j.ejar.2018.11.004

Kawamura G, Nishimura W, Euda S, Nishi T. 1981. Color vision and spectral sensitivity in Tunas and Marlins. Bulletin of the Japanese Society of Scientific Fisheries. 47(4):481–485. https://doi.org/10.2331/suisan.47.481

Lelono T D, Bintoro G. 2019. Population dynamics and feeding habits of *Euthynnus affinis, Auxis thazard*, and *Auxis rochei* in South Coast of East Java waters. IOP Conference Series: Earth and Environmental Science. 370:012054. https://doi.org/10.1088/1755-1315/370/1/012054

Levine JS, MacNichol EF. 1982. Color vision in fishes. Scientific American. 246(2):140–149. https://doi.org/10.1038/scientificamerican0282-140

Macale AMB, Candelaria AP, Dioneda Sr RR. 2020. Catch and fishing effort statistics of fisheries in Albay Gulf, Philippines. Aquaculture, Aquarium, Conservation & Legislation. 13(6):3330–3337. http://www.bioflux.com.ro/docs/2020.3330-3337.pdf

Mamalangkap MD, Mokamad UK, Ayub SM. 2018. Assessment of Small Pelagic Species Landed in ARMM, Sulu Sea. The Philippine Journal of Fisheries. 25(1):183–192. https://doi.org/10.31398/tpjf/25.1.2017C0016

Mariyasingarayan Y, Danaraj J, Vajravelu M, Ayyappan S. 2018. Length-weight relationship and diet composition of frigate tuna (*Auxis thazard*) from Parangipettai, southeast coast of India. International Journal of Science Inventions Today. 7(1):9–16.

Mohammad HS, Ebbah JH, Sahiyal KM, Tahiluddin AB. 2022. An assessment of small-scale fisheries in Tandubas, Tawi-Tawi, southern Philippines. Menba Journal of Fisheries Faculty. 8(1):10–22.

Moraga AD, Wilson AD, Cooke SJ. 2015. Does lure colour influence catch per unit effort, fish capture size and hooking injury in angled largemouth bass?. Fisheries Research. 172:1–6. https://doi.org/10.1016/j.fishres.2015.06.010

Mudumala VK, Farejiya MK, Mali KS, Karri RR, Uikey DE, Sawant PA, Siva A. 2018. Studies on population characteristics of frigate tuna, *Auxis thazard* (Lacepede, 1800) occurring in the north west coast of India. International Journal of Life-Sciences Scientific Research. 4(2):1639–1643.

Okamoto M, Kawamura G, Tanaka Y. 2001. Selectivity of color of lure by Japanese sea bass *Lateolabrax japonicus* under different background colors. Bulletin of the Japanese Society of Scientific Fisheries (Japan). 67(3):449–454 https://doi.org/10.2331/suisan.67.449

Padios HG, Baleta FN, Mallillin J. 2017. Influence of seasonal variation on the utilization and catch composition of fishing gears in Palanan, Isabela seashore, Philippines. International Journal of Fisheries and Aquatic Studies. 5(1):314–318. https://www.fisheriesjournal.com/archives/2017/vol5issue1/PartE/5-1-24-288.pdf

Perez ML, Pido MD, Garces LR, Salayo ND. 2012. Towards sustainable development of small-scale fisheries in the Philippines: Experience and lessons learned from eight regional sites. Lessons Learned Brief 2012-10. WorldFish, Penang, Malaysia. https://hdl.handle.net/20.500.12348/1000

Petukhova NG. 2019. Life history parameters for frigate tuna Auxis *thazard* in the Northeast Atlantic. International Commission for the Conservation of Atlantic Tunas (ICCAT) Collective Volume of Scientific Papers. 76(7):169–173. https://www.iccat.int/Documents/CVSP/CV076_2019/n_7/CV76007169.pdf

[PSA] Philippine Statistics Authority. 2021. Fisheries Statistics of the Philippines 2018–2020, Vol. 29. Quezon City, Philippines. p. 320.

Ricker WE. 1975. Computation and interpretation of biological statistics of fish populations. Bull Fish Res Board Can. 191:392.

Rohit P, Chellappan A, Abdussamad EM, Joshi KK, Koya KP, Sivadas M, Ghosh S, Margaret Muthu Rathinam A, Kemparaju S, Dhokia HK, et al. 2012. Fishery and bionomics of the little tuna, *Euthynnus affinis* (Cantor, 1849) exploited from Indian waters. Indian Journal of Fisheries. 59(3):37–46. http://eprints.cmfri.org.in/9104/1/Pratibha_33-42.pdf

Seçer B, Sungur S, Çiçek E, Mouludi-Saleh A, Eagderi S. 2021. Length-weight relationship and condition factor of endemic genus Seminemacheilus (Teloestei=Nemacheilidae) for Turkey. Limnol Freshw Biol. 4(3):1152–1155. https://doi.org/10.31951/2658-3518-2021-A-3-1152

Swimmer Y, Arauz R, Higgins B, McNaughton L, McCracken M, Ballestero J, Brill R. 2005. Food color and marine turtle feeding behavior: Can blue bait reduce turtle bycatch in commercial fisheries?. Marine Ecology Progress Series. 295:273–278. https://doi.org/10.3354/meps295273

Tahiluddin AB, Terzi E. 2021. An Overview of Fisheries and Aquaculture in the Philippines. J. Anatolian Env. and Anim. Sciences, 6(4):475–486. https://doi.org/10.35229/jaes.944292

Tahiluddin AB, Sarri JH. 2022. An overview of destructive fishing in the Philippines. Acta Natura et Scientia. 3(2):116–125. https://doi.org/10.29329/actanatsci.2022.352.04

Tesch FW. 1971. Age and growth. In: Ricker WE, editor. Methods for assessment of fish production in fresh waters. Oxford: Blackwell Scientific Publications. pp. 98–130

Tester AL, Nakamura EL. 1957. Catch rate, size, sex, and food of tunas and other pelagic fishes taken by trolling off Oahu, Hawaii, 1951-55. Spec. Sci. Rep. Fish. 250:1–25. https://books.google.com.ph/books?hl=en&lr=&id=3wOiH9Ee-EacC&oi=fnd&pg=PA3&dq=Tester+AL,+-Nakamura+EL.+1957.+Catch+rate,+size,+-sex,+and+food+of+tunas+and+other+pe-lagic+fishes+taken+by+trolling+off+O-ahu,+Hawaii,+1951-55.+Spec.+Sci.+Rep.+-Fish.+250:1%E2%88%92

Umali AF. 1950. Guide to the classification of fishing gear in the Philippines. US Fisheries and Wildlife Service, Research Report 17.

Wilde GR, Pope KL, Durham BW. 2003. Lure-size restrictions in recreational fisheries. Fisheries. 28(6):18–26. https://doi.org/10.1577/1548-8446(2003)28[18:LRIRF]2.0.CO;2

Yokota K, Kiyota M, Okamura H. 2009. Effect of bait species and color on sea turtle bycatch and fish catch in a pelagic longline fishery. Fisheries Research. 97(1–2):53–58. https://doi.org/10.1016/j.fishres.2009.01.003