EFFECT OF BAIT TYPES ON CATCHABILITY OF BILLFISH IN TUNA LONGLINE FISHERY IN SRI LANKA

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Billfish represent three groups of species of marlins, sailfish and swordfish which can be considered as the third largest group of fish reported in large pelagic fish production in Sri Lanka. Being a by-catch in the tuna longline fishery, a deterministic role in the catchability of billfish could be resulted from different bait types. This information would also be useful in exploring the potential to alter the catch in compliance with international obligations. The present study was based on logbook records of the Sri Lankan tuna longline fishery from 2016 to 2019, with an aim of assessing the catch efficiency of billfish species with respect to the bait types. During the period of study, it was noted that there were seven popular bait types; squids, bigeye scad (*Selar crumenophthalmus*), flying fish (family Exocoetidae), milkfish (*Chanos chanos*), Indian scad (*Decapterus* spp.), Sardine (*Sardinella* spp.) and artificial baits which represented 94.39 % in the fishery. Among those, squid was the most common bait while *Sardinella* spp. showed the least frequency in usage. Statistical analysis using Welch's analysis of variance (ANOVA) test for the catch rates of billfish have shown significant effects for different bait types. The longlines with Indian scad as a bait were reported with the highest average catch rate in terms of the number of fish per 1000 hooks: (4.0 ±2.6) followed by bigeye scad (3.7 ±2.3) while lowest was recorded with milk fish (2.6 ±2.1). The study revealed that there was a significant difference in the catch rates among different bait types ($F(6) = 534.17$, $p < 0.001$) while Tukey's post-hoc test further revealed that the significance could be detected among the all combinations except for flying fish-artificial; squid-artificial and sardine-milkfish. The results further showed that the highest catch rates of swordfish, blue marlin and striped marlin were recorded for Indian scads while sailfish and black marlin for bigeye scad. This study highlights the importance of bait types in catchability of billfish and the findings could be used to manage tuna longline fisheries.

Key words: Billfish, swordfish, tuna longline, baits, Indian scad, Sri Lanka

Introduction

Billfishes; the third largest group of large pelagic fish production in Sri Lanka, is mainly represented by five species; Indo-Pacific Blue Marlin (*Makaira mazara*), Black Marlin (*Istiompax indica*) and Striped Marlin (*Tetrapturus audax*), Indo-Pacific Sailfish (*Istiophorus platypterus*) and Swordfish (*Xiphias gladius*) (Haputhantri and Maldeniya, 2011). Billfish in Sri Lanka is reported as a by-catch of the tuna fisheries mainly in longliners and gillnetting in which a considerable proportion of swordfish can be observed in longliners (Bandaranayake et al., 2019). Therefore, a remarkable impact on billfish catchability could be expected upon the bait types (Gilman, 2020).

The bait is fundamental in longline fishing as the fishing method is greatly depend on the feeding behaviour of the target species (Løkkeborg et al., 2014). As a result, bait type influenced by chemical and visual attractiveness is one of the crucial factors in determining the success of longline fishing operations (Bach, et al., 2014) and this is also valid for billfishes. Managing bait type offers a potential tool to control species selectivity, hence catchability (Gilman et al., 2020). It is apperent that the expansion of Indian Ocean fisheries for billfish has limitations for several key fish stocks based on their stock status including blue marlin and striped marlin. Those stocks have been identified as overfished or subject to overfishing (IOTC WPB 20, 2022). On the otherhand, according to the recent stock assesments, the swordfish, one of the demanded fishery product in the export market (Europian Price Report, 2023; INFO Fish, 2023) has been identified as not overfished and not subject to overfishing with 98% probability (IOTC WPB 20, 2022), hence revelaing the potentiality to expand the fishery.

Among the five major billfish species found in the longline catches in Sri Lanka, swordfish is the dominant in terms of contribution to the total national fish production in Sri Lanka with around 46% of the total billfish catch (Bandaranayake et al., 2018). According to the fleets based on 2017-2021 the majority of swordfish catches are attributed to vessels flagged to Sri Lanka (29.2%) followed by Taiwan, China (17.9%) and EU (Spain) (6.5%) while the 25 other fleets catching swordfish contributed to less than 50% of the total catch in recent years (IOTC WPB 20, 2022).

Understanding the importance of bait type in manipulating the billfish catch rates and how we can use it in expanding Sri Lankan swordfish fishery, the present study was carried out to determine the effect of bait types on catchability of billfish species with special focuses on swordfish fishery in Sri Lanka.

Methodology

Data on billfish landings from tuna longline fishery in Sri Lanka (2016-2019) was obtained from the logbooks, Catch per Unit Effort (CPUE or catch rate) was calculated to the number of fish caught per 1000 hooks. CPUE outliers were removed. Levene's test (Fox, J., 2015) was performed to assess the homogeneity of variances among different bait types. Statistical comparisons were made with Welch's analysis of variance (ANOVA) test. The top seven baits which represent 94.39 % of the data were considred in the analysis. Totally, 95216 observations (fishing events or operations) were considered for this analysis.

Results

Among the range of baits used in the Sri Lankan tuna longline fishery, it was noted that there were seven popular bait types; squids, bigeye scad (*Selar crumenophthalmus*), flyingfish (family Exocoetidae), milkfish (*Chanos chanos*), Indian scads (*Decapterus* spp.), sardines (*Sardinella* spp.) and artificial baits which represented 94.39 % of the fishery (Figure 1).

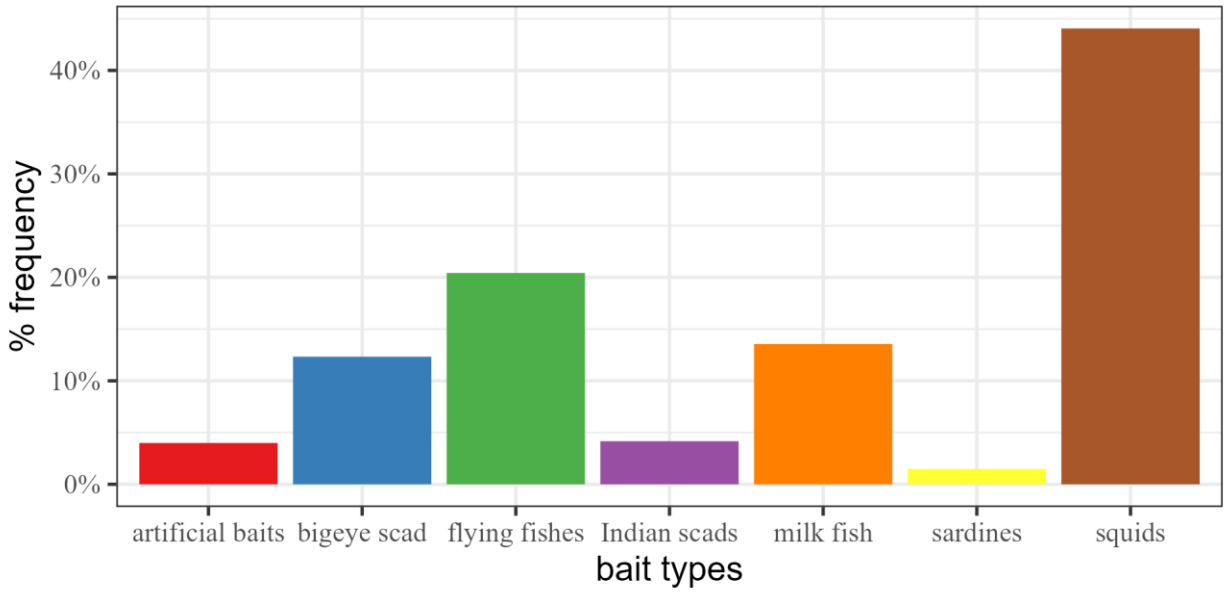

Fig 1 Frequency of use of different bait types over the concerned period (2016-2019)

Other baits include skipjack tuna, kawakawa, bullet tuna, and undefined fish species. Remarkable changes could be observed during the concerned period; 2016-2019, where as, a clear upward trend in the use of Indian scad and milkfish as a bait in the longline fishery could be observed since 2017 whereas an opposite trend was observed for squid. However, ardines. showed the least frequency in usage through out the years (Figure 2).

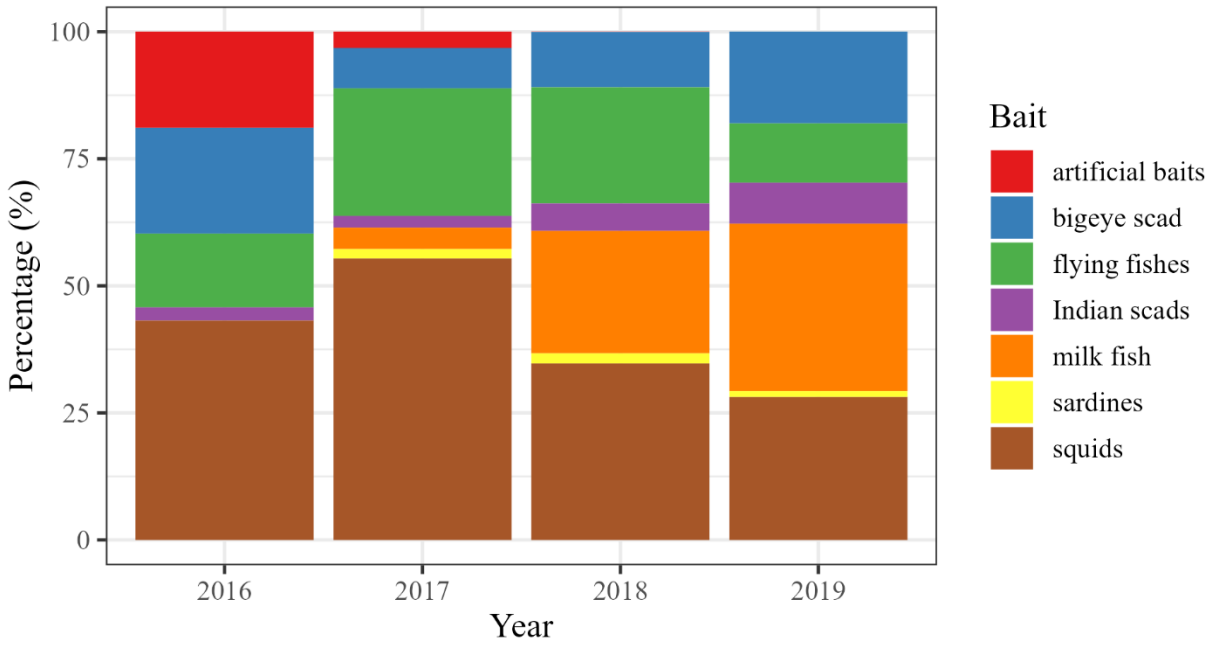

Fig 2 Different bait usage in the longline fishery in Sri Lanka from 2016 -2019

Based on the results of Levene's test for homogeneity of variance, the p-value is less than 0.001 indicating that the variability in CPUE is not the same across all bait types. Statistical analysis using Welch's analysis of variance (ANOVA) test for the catch rates of billfish have shown significant effects ($P< 0.05$) for different bait types (Fig 3, Table 1). The longlines with Indian scads as a bait were reported with the highest average catch rate in terms of the number of fish per 1000 hooks: (4.0 ±2.6) followed by bigeye scad (3.7 ±2.3), flying fish (3.29±2.32), artificial baits (3.23±2.12) squid (3.18±2.5) while lowest was recorded with milkfish (2.6 ±2.1) and sardines (2.76±2.08).

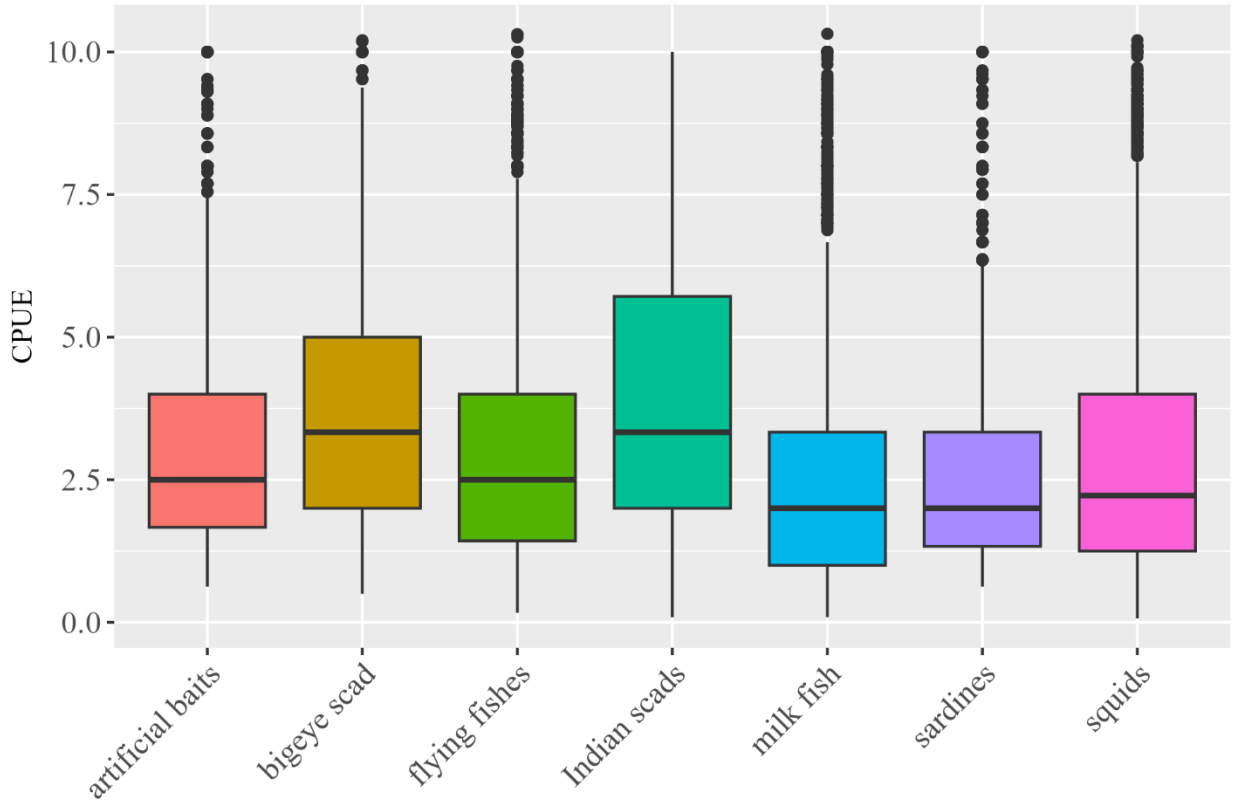

Fig 3 Catch rates of billfish by different bait types

Table 1 Catch rates of billfish by different bait types

Bait	Mean CPUE	SD
Artificial	3.23	2.12
Bigeye scad	3.78	2.37
Flying fish	3.29	2.32
Indian scad	4.01	2.64
Milkfish	2.61	2.13
Sardinella spp	2.76	2.08
Squid	3.18	2.50

The study revealed that there was a significant difference in the catch rates among different bait types ($F(6) = 534.17$, $p < 0.001$) while Tukey's post-hoc test further revealed that the significance could be detected among the all combinations except for flying fish-artificial; squid-artificial and sardine-milk fish (Table 2).

Table 2: Significance of dfferent bait types on billfish (all species) based on Tukey posthoc test

Baits	Difference	Significance (P value)
Bigeye scad-Artificial	0.5496	p < 0.001
Flying fish-Artificial	0.0608	**0.811**
Indian Scad-Artificial	0.7840	p < 0.001
Milkfish-Artificial	-0.6122	p < 0.001
Sardinella spp-Artificial	-0.4648	p < 0.001
Squid-Artificial	-0.0457	**0.931**
Flying fish-Bigeye scad	-0.4888	p < 0.001
Indian scad-Bigeye scad	0.2343	p < 0.001
Milkfish-Bigeye scad	-1.1618	p < 0.001
Sardinella spp-Bigeye scad	-1.0144	p < 0.001
Squid-Bigeye scad	-0.5956	p < 0.001
Indian scad-Flying fish	0.7232	p < 0.001
Milkfish-Flying fish	-0.6730	p < 0.001
Sardinella spp-Flying fish	-0.5256	p < 0.001
Squid-Flying fish	-0.1065	p < 0.001
Milkfish-Indian scad	-1.3961	p < 0.001
Sardinella spp-Indian Scad	-1.2488	p < 0.001
Squid-Indian scad	-0.8297	p < 0.001
Sardinella spp-Milkfish	0.1473	**0.322**
Squid-Milkfish	0.5665	p < 0.001
Squid-*Sardinella* spp	0.4191	p < 0.001

The species wise catch rate analysis of for billfishes further dipicted that the highest catch rates of swordfish, blue marlin and striped marlin were recorded for Indian scads while sailfish and black marlin for bigeye scad (Figure 4).

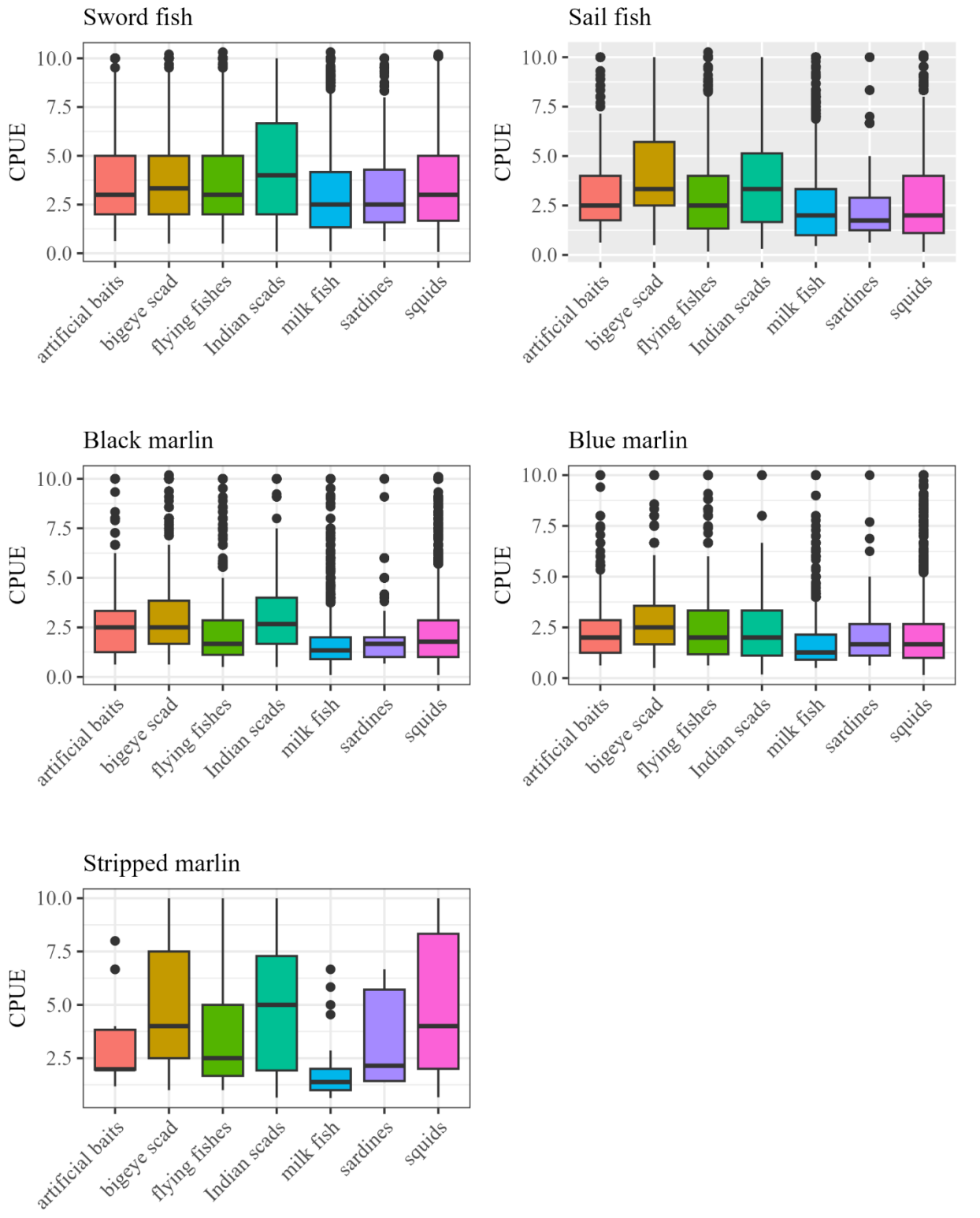

Fig 4 Catch rates of major billfish species by different bait types

The highest catch rates of Sword Fish, one of the main potentiality in fisheries expansion, was associated with Indian scad and showed a considerable positive significance (P<0.05) with all the other bait types (Table 3).

Table 3: Significance of dfferent bait types on swordfish catch rates (based on Tukey posthoc test)

Bait	Difference	Significance (P value)
Bigeye scad-Artificial	0.1927	0.091
Flying fish-Artificial	0.0626	0.965
Indian scad-Artificial	0.7858	**P<0.001**
Milkfish-Artificial	-0.4734	**P<0.001**
Sardinella spp-Artificial	-0.4062	**0.004**
Squid-Artificial	0.1038	0.062
Flying fish-Bigeye scad	-0.1301	**0.04**
Indian scad-Bigeye scad	0.5932	**P<0.001**
Milkfish-Bigeye scad	-0.6661	**P<0.001**
Sardinella spp-Bigeye scad	-0.5988	**P<0.001**
Squid-Bigeye scad	-0.0888	0.258
Indian scad-Flying fish	0.7233	**P<0.001**
Milkfish-Flying fish	-0.5359	**P<0.001**
Sardinella spp-Flying fish	-0.4687	**P<0.001**
Squid-Flying fish	0.0413	0.819
Milkfish-Indian scad	-1.2592	**P<0.001**
Sardinella spp-Indian scad	-1.1920	**P<0.001**
Squid-Indian scad	-0.6820	**P<0.001**
Sardinella spp-Milkfish	0.0672	0.993
Squid-Milkfish	0.5772	**P<0.001**
Squid-*Sardinella* spp	0.5100	**P<0.001**

Discussion

Bait is one of the main factors influencing the sucsuss of longtine operations (Lokkeborg et al., 2014; Kumar et al., 2016). Fish capture rates on baited fishing gear such as longlines can diverge substantially from direct- relationships with fish abundance as the gear depends upon the thresholds for response to bait cues, feeding motivation, and sensory capabilities (Stoner, 2004). Nonetheless, the effect of bait types on the catchability of commercially important fish species particularly for billfish is not well documented in the Indian Ocean. Mejuto et al., (2010) stated that the standardized mean CPUE values would suggest having a positive or negative impact on the catch rates of the different billfish species for the combination of the different hook and bait types. Therefore, the information on effects of baits will be fundamental in manipulating the catches based on future demand and potentialities.

Since the bait type has a significant effect on the catch rates of tuna in longline fishery in Sri Lanka (Gunasekera and Haputhantri, 2021) a notable effect can also be expected in catch rates of billfishes as a by-catch. The results of present study on the catch rates by different bait types suggested that the use of Indian scads and bigeye scad as baits were more effective for catching billfish in the longline fishery than the use of squids, milkfish, flying fishes, and artificial baits. In contrast, based on a qualitative review, Gilman et al., (2020) showed that squids have been identified as one of the prominent bait concerning forage fish bait used in the tuna longline fishery due to significantly higher catch rates of tunas and istiophorid billfishes. However, the declining trend of use of squids could have low numbers of hooked unwanted incidental catch of endangered, threatened, and protected (ETP) species, as longline fisheries with squid as a bait have experienced hooking of sea turtles (Watson et al., 2005). Furthermore, Jayasinghe et al., (2019) reported that minimam number of entaglements of threatened and conserved species in the longline fisheries in Sri Lanka. A comparison of the effectiveness of different baits further revealed that milkfish which has been introduced as potential bait to reduce the import cost (about1200 million LKR in 2019) for baits and thereby save foreign exchange (Gunasekera and Haputhantri, 2021) showed considerably less effectiveness on the catch rates of all the billfish species. In consideration of the efficiency of Indian scads in targetting both yellowfin tuna and billfishes particularly swordfish, it is advisable to promote Indian scads as a bait in the tuna longline fishery. There is a continuous large scale harvest of Indian scad throughout the year in the country (Ariyarathna and Amarasinghe, 2012) and it is suggested to conduct a bio-economic feasibility study with a cost-benefit analysis before implementation. In addition, Gilman et al., (2020) mentioned that selection of bait and target species

is a specific relationship among the two species. Each target species prefers specific bait size (Lokkeborg and Bjordal, 1992), bait quality (Januma, 2003) and bait firmness (Pingguo, 1996). Not only the bait type but also other factors such as time of the operation, type of the hook, fishing area and the season are also have impacts on selection of species (Coelho et al., 2012; Foster et al., 2012). Studies consdersing above factors should be initiated to explore selection patterns and catchability of bill fishes, while recommending bait (Indian scads) in Sri Lankan longline fishery. As an initial step, this study highlights the importance of bait types in the catchability of billfish hence, the findings could be used to manage tuna longline fisheries also with special focus on expansion of swordfish fishing industry.

Conclusions

Bait type showed significant effect on billfish catch rates in Sri Lankan tuna longline fishery where Indian scads has the highest potentiality. Use of Indian scads as a bait could be recommended in expanding the sword fish fishery in Sri Lanka. Conducting species-specific studies on the effect of pelagic longline bait type are also recommended while considering the ecological effects on the stock status of both Indian scad and billfish species, and socioeconomic effects on food security. Also, the management and conservation demands of fish stocks need to be addressed.

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