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A Synthesis Review of Sea Turtle Interaction Processes, Mitigation Measures and Its Limitations in Tuna Longline Fisheries

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A Synthesis Review of Sea Turtle Interaction Processes, Mitigation Measures and Its Limitations in Tuna Longline Fisheries

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Abstract

Sea turtle bycatch remains a major conservation concern in pelagic longline fisheries, and the use of large circle hooks and finfish bait has been widely promoted as a mitigation measure. This study reviewed published research evaluating the effects of hook type (J hooks, Japanese tuna hooks, and large circle hooks) and bait type (finfish and squid) on bycatch rates of bycatch species in pelagic longline fisheries of the Atlantic, Indian, and Pacific Oceans. A total of 32 study cases were compiled for hook comparisons and 14 for bait comparisons, and fisheries were classified as possibly shallow-set or deep-set. Most available studies focused on shallow-set fisheries. In these fisheries, sea turtle bycatch rates were generally higher when J hooks or Japanese tuna hooks were used compared with large circle hooks. Similarly, squid bait resulted in higher sea turtle bycatch rates or showed no significant difference relative to finfish bait. In contrast, shark species often exhibited higher catch rates with large circle hooks than with J hooks or Japanese tuna hooks, while finfish bait frequently produced higher shark catch rates than squid bait. These findings suggest a trade-off between reducing sea turtle bycatch and increasing shark bycatch. Evidence from deep-set fisheries was extremely limited. Only four hook-comparison studies and no bait-comparison studies were identified, and the single study examining sea turtle bycatch found no significant difference between Japanese tuna hooks and large circle hooks. Therefore, although large circle hooks and finfish bait are widely accepted as effective sea turtle mitigation measures in shallow-set fisheries, their effectiveness in deep-set fisheries remains largely unverified. Further research is needed to evaluate these measures in deep-set operations.

Introduction

Many sea turtle species are designated as endangered, and fisheries bycatch are one of the major threats they face in the ocean. In the pelagic ocean, tuna longline is one of the fisheries which are bycaught sea turtles. Regarding tuna longline fisheries in the WCPFC Convention area, CMM2018-04 which is conservation and management of sea turtles is described to mitigate impact on sea turtles. It is summarized as that the longline operations in a shallow-set manner are required to employ or implement at least one of the three methods which are to use only large circle hooks, to use only whole finfish for bait, and to use any other measure, mitigation plan or activity that has been reviewed by the Scientific Committee (SC) and the Technical and Compliance Committee (TCC) and approved by the Commission (WCPFC-CMM2018-04). In this fishery, tuna, billfish, and sharks are the primary target species; however, there are diverse fishing methods, including those in certain countries and regions that target bony fish such as dolphinfish and oilfish (Andraka et al. 2013; Wang et al. 2021). Typically, there is a close relationship between the target species and the depth at which longline gear is set; generally, gear and fishing methods are adopted such that hooks are positioned in shallow layers when targeting swordfish and dolphinfish, and in deeper layers when targeting bigeye tuna and albacore. Bycatch rate of sea turtles in longline fisheries tends to be much higher in shallow-set operations than deep-set operations; for this reason, bycatch mitigation measures are applied specifically to shallow-set operations.

Numerous studies have been conducted and reported on the bycatch of sea turtles in longline tuna fisheries (Foster et al. 2012; Coelho et al. 2015; Huang et al. 2016). Many of these studies have focused on evaluating differences in sea turtle bycatch rates resulting from variations in the types of hooks used in this fishery (J hook, Japanese tuna hook, circle hook, and Terashima hook; Yokota et al. 2006a; Mituhasi and Hall 2011) and the types of bait (finfish bait and squid bait) (Watson et al. 2005; Mejuto et al. 2008; Foster et al. 2012). Regarding the effectiveness of these bycatch mitigation measures of sea turtles, it has been reported that bycatch rates decrease in shallow-set longline fisheries, and that while hook ingestion decreases, the number of cases where hooks are caught around the mouth (such as on the upper and lower jaws or the tongue) increases (Read 2007; Santos et al. 2015). However, regarding the latter, a study examining post-release mortality rates based on hook location suggests that mortality rates do not differ between swallowed and mouth-hooked individuals; therefore, it remains unclear whether this contributes to reducing damage to individuals caused by bycatch (James et al. 2024).

There are studies that have examined the mechanisms by which the use of fish bait and large circle hooks reduce sea turtle bycatch (Gilman and Huang 2016). In the case of finfish bait, they either bite it off or pull the entire bait off the hook to eat it, but when squid is used as bait, the sea turtle tends to swallow the entire squid and the hook at once (Stokes et al. 2011; Watson et al. 2005). Therefore, it is believed that sea turtles are less likely to be caught as bycatch when finfish bait is used than when squid bait is used. Regarding large circle hooks, it has been noted that even if swallowed, they rotate and hook onto the corners of the mouth, thereby reducing the likelihood of penetration into the stomach or esophagus and decreasing deep hooking (Gilman and Huang 2016; Read 2007). However, regarding the mechanism by which large circle hooks reduce bycatch, since a decrease in swallowing does not necessarily equate to a decrease in bycatch rates, it is presumed that other effects are at play (such as the hook being easier to dislodge due to being caught in the mouth); however, the specific factors remain poorly understood.

While it has been established that the use of large circle hooks in shallow-set longline fisheries is effective in reducing sea turtle bycatch, it has also been pointed out that the use of large circle hooks increases bycatch and mortality of shark species (Reinhardt et al. 2017; Semba et al. 2018; Ochi et al. 2024). While this measure is considered highly effective from the perspective of reducing sea turtle bycatch, it is clear that the introduction of large circle hooks is not a universal solution for all bycatch species when viewed from the perspective of minimizing the overall impact on all bycatch species.

In this study, we organize the findings reported to date regarding changes in hook types and bait species which are measures designed to reduce sea turtle bycatch and focus on the differences in bycatch rates by hook type and bait species for bycaught species, including sea turtles and sharks. Furthermore, we evaluated the extent and variety of existing research examples while considering operating depths to reflect the reality of diverse tuna longline fisheries. This was also intended to identify research areas where scientific knowledge is lacking.

Materials and methods

We collected scientific literature that evaluated the effects of hook type (J hooks, Japanese tuna hooks, and large circle hooks) and bait type (finfish bait and squid bait) on the catch rates of non-target species in pelagic longline fisheries in the Atlantic, Indian, and Pacific Oceans. A total of 32 study cases from 29 publications were compiled for the hook comparison (Table 1), and 14 study cases from 15 publications were compiled for the bait comparison (Table 2).

Fishing strategies related to the setting depth were classified into two categories: possibly shallow-set fisheries (including actual shallow-set) and deep-set. Studies explicitly described as deep-set fisheries in the original publications were classified as deep-set. All remaining studies were categorized as possibly shallow-set fisheries, which were considered based on the reported target depth of line setting, hooks between floats (HBF) and target species. Studies explicitly reporting analyses that combined both shallow-set and deep-set operations (e.g., Ward et al. 2009) were excluded from this review. For Swimmer et al. (2017), the reported HBF ranged from 3 to 12, with the majority of sets using 4 to 5 hooks. Therefore, the majority value was used for classification.

Only studies in which the effects of hook type or bait type could be evaluated independently were included in this review.

For the hook comparison, the number of study cases reporting significantly higher catch rates for J hooks or Japanese tuna hooks than for large circle hooks, significantly higher catch rates for large circle hooks, or no significant difference was summarized for each species (Table 3). Similarly, for the bait comparison, the number of study cases reporting significantly higher catch rates for finfish bait or squid bait, or no significant difference between bait types, was summarized for each species (Table 4). In addition, the minimum and maximum numbers of hooks and fishing sets were extracted from each publication whenever available.

Results

As a result of the review, 4 study cases from 3 publications were classified as deep-set fisheries, whereas 30 study cases from 26 publications were categorized as possibly shallow-set fisheries for the hook comparison (Table 1). For the bait comparison, 14 study cases from 15 publications were classified as possibly shallow-set, and no study existed for deep-set (Tables 2).

The numbers of study cases reporting significantly higher catch rates for each hook type (J hook, Japanese tuna hook, or large circle hook), as well as those reporting no significant difference between hook types, are summarized in Table 3. Similarly, the numbers of study cases reporting significantly higher catch rates for finfish bait or squid bait, or no significant difference between bait types, are summarized in Table 4.

1. Hook comparison

In the possibly shallow-set category, most studies reported significantly higher catch rates in large circle hooks than J hooks, or no significant difference between hook types, for shark species including night shark (*Carcharhinus signatus*), blue shark (*Prionace glauca*), silky shark (*Carcharhinus falciformis*), shortfin mako (*Isurus oxyrinchus*), and oceanic whitetip shark (*Carcharhinus longimanus*). Only one study reported significantly higher catch rates with J hooks than with large circle hooks for sharks. In contrast, most studies reported significantly higher catch rates in J hooks than large circle hooks for sea turtle species, including leatherback turtle (*Dermochelys coriacea*), loggerhead turtle (*Caretta caretta*), and olive ridley (*Lepidochelys olivacea*), as well as pelagic stingray (*Pteroplatytrygon violacea*). The number of studies which are compared between Japanese tuna hooks and large circle hooks were limited. For sharks, available results for night shark, blue shark, and silky shark generally showed significantly higher catch rates with large circle hooks, except for one study on blue shark that reported significantly higher catch rates with Japanese tuna hooks. For sea turtles, all available studies reported either significantly higher catch rates with Japanese tuna hooks or no significant difference between hook types.

Only four study cases were available for the deep-set category. No consistent pattern in the effects of hook type on catch rates was observed among species possibly because of the limited number of studies or the lack of clear differences among hook types. The bycatch rates of sea turtles were investigated in only a single study, which compared Japanese tuna hooks with large circle hooks (Huang et al. 2016). In that study, the bycatch rates pooled across all sea turtle species were compared between hook types, and no significant difference was found between Japanese tuna hooks and large circle hooks. Although no statistical analysis was conducted for species-specific bycatch rates, the study presented a table showing the numbers of bycaught individuals for each species based on the same number of hooks deployed. According to the table, one more loggerhead turtle was caught with Japanese tuna hooks, whereas one more leatherback turtle was caught with large circle hooks. For olive ridley turtles, the numbers of bycaught individuals were identical between the two hook types (Huang et al., 2016).

2. Bait comparison

In the possibly shallow-set category, most studies reported significantly higher catch rates with finfish bait than with squid bait, or no significant difference between bait types, for night shark, shortfin mako, porbeagle (*Lamna nasus*), and bigeye thresher shark (*Alopias superciliosus*). For the blue shark, the results were inconsistent among studies. In contrast, all available studies on sea turtles reported either significantly higher catch rates with squid bait or no significant difference between bait types.

No study existed for deep-set in the bait comparison.

Discussion

Numerous studies have been conducted on the comparison of bycatch rates between different hook types and bait types in pelagic longline fisheries. As summarized in the table in this study, these examples show that most of these studies have focused on shallow-set longline. This is likely because many of these studies were conducted with the aim of experimentally verifying the effects of different hook types and bait types on sea turtle bycatch rates, as well as to evaluate the effectiveness of bycatch mitigation measures after their implementation.

On the other hand, among the large number of studies conducted, there are only four cases comparing different hook types and no case comparing different bait types that explicitly target deep-set longline. The extent of these efforts varies by study; while some have been extensively investigated, research on shallow-set fisheries has not progressed as much. Furthermore, although changes in hook type and bait type are applied as measures to reduce sea turtle bycatch in shallow-set longline, there is only one study comparing hook types specifically addressing sea turtle bycatch in deep-set longline. In that study, the bycatch rates for loggerhead turtles, leatherback turtles, and olive ridleys were either the same or nearly equivalent between Japanese tuna hooks and large circle hooks (Huang et al. 2016). This strongly suggests that while these measures are effective in reducing sea turtle bycatch in shallow-set longline, they may not be as effective in deep-set longline, or that Japanese tuna hooks and large circle hooks may have equivalent effectiveness in reducing sea turtle bycatch. The fact that the mechanism by which large circle hooks reduce sea turtle bycatch in shallow-set longline is not well understood further supports the uncertainty regarding their effectiveness in reducing sea turtle bycatch in deep-set longline (Gilman and Huang 2016). On the other hand, regarding the mechanism by which changing bait species reduces bycatch, it has been shown that when finfish bait is used, sea turtles gradually nibble at it, making it less likely for them to become hooked and thus reducing the likelihood of bycatch (Watson et al. 2005; Stokes et al. 2011). Nevertheless, since there are no comparative studies between bait types in deep-set longline, it can be said that, at present, there is no scientific evidence supporting the effectiveness of large circle hooks or the use of finfish bait in reducing sea turtle bycatch rates in deep-set longline.

The number of comparative studies between hook types and bait types regarding the impact on bycatch rates of species other than sea turtles (i.e., sharks) varied by species. In shallow-set longline, with the exception of a single case, studies comparing J-hooks with large circle hooks, as well as Japanese tuna hooks with large circle hooks, have shown that large circle hooks either had higher bycatch rates than J-hooks or Japanese tuna hooks, or there was no significant difference. In deep-set longline, there were only cases involving night sharks and blue shark; the number of cases where J-hooks or Japanese tuna hooks resulted in higher bycatch rates, cases where large circle hooks resulted in higher bycatch rates, and cases where the bycatch rates were equivalent were roughly equal, making it impossible to assess the effect of different hook types in deep-set longline. Furthermore, a review study comparing bycatch rates between J-hooks and large circle hooks targeting shortfin mako sharks reported that significantly higher bycatch rates were recorded with large circle hooks (Reinhardt et al. 2017; Semba et al. 2018).

Regarding bycatch rates due to differences in bait types, studies exist only for shallow-set longline; however, with the exception of the blue shark, the majority of studies indicate that finfish bait results in higher bycatch rates than squid bait or show no significant difference, suggesting that the use of finfish bait increases bycatch rates of sharks. In the case of sharks, unlike lung-breathing sea turtles, the effect of differences in hook type and bait type on mortality may be equivalent in both shallow-set and deep-set longlines. However, since the primary habitat depths vary by shark species, it is thought that the composition of species caught as bycatch differs depending on the depth at which each fishing gear is deployed (Musyl et al. 2011). Since it has been noted that feeding methods and feeding ecology differ by taxonomic or species group (Motta and Wilga 2001), it is highly likely that the effectiveness of reducing bycatch through differences in hook type and bait species varies depending on the species caught. This strongly indicates that, from the perspective of assessing the impact on shark bycatch, there is currently high uncertainty regarding the effects of differences in hook type and bait type in deep-set longline.

Future studies and suggested recommendations

There is only one study on the comparison of bycatch rates of sea turtles and sharks based on differences in hook types and bait types in deep-set longline. Bycatch mitigation measures on sea turtles currently implemented in shallow-set longline have been shown to reduce sea turtle bycatch rates while increasing shark bycatch rates. Because the corresponding effects of these measures on sea turtle and shark bycatch rates in deep-set longline remain poorly understood, introducing measures that risk shifting bycatch burden from one species group to another cannot currently be recommended.

Addressing this information gap should therefore be regarded as a priority, and we propose the following recommendations to guide future research in this direction.

SC22 recommends that;

- information on the effects of different hook types and bait types on the bycatch rates of sea turtles and sharks in deep-set longline should be collected.
- deep-set longline refers to except for operations in which the majority of hooks are set at depths of 100 meters or less.
- methods for collecting information may include trial fishing using research vessels or commercial vessels, as well as observer programs; however, these methods are not limited to these examples.
- the collected information will be reported and reviewed at appropriate agenda items in future SC meetings.
- based on the collected information, when reviewing the CMM2018-04, consideration will be given to the positive and negative impacts on bycatch species such as sea turtles and sharks, as well as target species, and to the feasibility of the measures adapted in actual fishing practices.

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Table 1. Summary of reviewed studies on the effects of hook type.

Reference	Fishing depth	Hooks between floats	No of hooks	No of sets	Hook type	Target	Ocean	Classification
Afonso et al. (2011)		5	7,800	12	J,C	TUN	EqAtl	Possibly Shallow-set
Afonso et al. (2012)		5	17,000	17	J,C	TUN, SWO	SW EqAtl	Possibly Shallow-set
Andraka et al. (2013)-1		2-3	356,674	2,068	T,C	TUN, BIL, SHK	E Pac	Possibly Shallow-set
Andraka et al. (2013)-2		3-12	75,509	110	T,C	TUN, BIL, SHK	E Pac	Possibly Shallow-set
Andraka et al. (2013)-3		3-5	134,643	248	T,C	TUN, BIL, SHK	E Pac	Possibly Shallow-set
Andraka et al. (2013)-4		3-5	75,041	122	T,C	TUN, BIL, SHK	E Pac	Possibly Shallow-set
Andraka et al. (2013)-5		5-6	46,496	261	J,C	DOL	E Pac	Possibly Shallow-set
Andraka et al. (2013)-6		3-6	151,673	317	J,C	DOL	E Pac	Possibly Shallow-set
Coelho et al. (2012) Santos et al. (2012)	20 - 50 m	5	305,352	221	J,C	SWO	EqAtl	Possibly Shallow-set
Coelho et al. (2015) Fernandez-Carvalho et al. (2015)	20 - 50 m	5	254,520	202	J,C	SWO	Trop NE Atl	Possibly Shallow-set
Cambie et al. (2012)		6-9	4,642	13	J,C	ABT	Med	Possibly Shallow-set
Domingo et al. (2009)		8	77,628	165	J,C	SWO, SHK	SW Atl	Possibly Shallow-set
Domingo et al. (2012)-1		5	39,822	61	J,C	SWO, SHK	SW Atl	Possibly Shallow-set
Domingo et al. (2012)-2		8	45,142	107	J,C	BSH	SW Atl	Possibly Shallow-set
Foster et al. (2012)		3or5	973,734	999	J,C	SWO, BET, BSH	NW Atl	Possibly Shallow-set
Kerstetter and Graves (2006)-1		5	14,040	39	J,C	YFT	NW Atl	Possibly Shallow-set
Kerstetter and Graves (2006)-2		5	16,560	46	J,C	SWO	GoM&Carib	Possibly Shallow-set
Kerstetter et al. (2007)		5	16,624	26	J,C	SWO	Eq S Atl	Possibly Shallow-set
Lima et al. (2023)		4or8	497,880	343	J,T,C	SWO, BSH	N Atl	Possibly Shallow-set
Minami et al. (2006) Yokota et al. (2006b)	shallow-set	4	48,600	52	T,C	SWO	NW Pac	Possibly Shallow-set
Mejuto et al. (2008)		5	430,299	342	J,C	SWO	N–S Atl	Possibly Shallow-set
Ochi et al. (2024)	shallow-set	4	286,368	306	T,C	SWO, BSH	NW Pac	Possibly Shallow-set
Pacheco et al. (2011)		5	50,170	81	J,C	SWO, BET	Eq W Atl	Possibly Shallow-set
Piovano et al. (2009)	18 - 50 m	5	29,254	30	J,C	SWO	Med	Possibly Shallow-set
Piovano and Gilman (2016)		-	-	1,679	J,C	TUN	S Pac	Possibly Shallow-set
Sales et al. (2010)	33 - 100 m	5-6	145,828	229	J,C	TUN, SHK	SW Atl	Possibly Shallow-set
Santos et al. (2013)	20 - 50 m	5	446,400	310	J,C	SWO	S Atl	Possibly Shallow-set
Watson et al. (2005)		3	427,382	489	J,C	TUN, SWO, SHK	NW Atl	Possibly Shallow-set
Carbonara et al. (2023)		-	5,040	7	J,C	SWO	C Med	Possibly Shallow-set
García-Cortés et al. (2009)		-	356,600	183	J,C	SWO	SE Pac	Possibly Shallow-set
Cuerran and Bigelow(2011)-1	deep-set	24.7±1.75	2,773,427	211	J,T,C	BET	C Pac	Deep-set
Cuerran and Bigelow(2011)-2	deep-set	24.7±1.75		1,182	J,T,C	BET	C Pac	Deep-set
Huang et al. (2016)	deep-set	16-17	407,677	200	J,T,C	BET	EqAtl	Deep-set
Promjinda et al. (2008)	50 - 300 m	15-20	6,277	13	J,C	TUN, BIL	BoB&And	Deep-set

Abbreviations: Ocean names are abbreviated as follows: Atl, Atlantic; Pac, Pacific; Eq, Equatorial; N, North; S, South; E, East; W, West; Med, Mediterranean; C, Central; GoM, Gulf of Mexico; Carib, Caribbean; BoB, Bay of Bengal; And, Andaman Sea. Hook types are abbreviated as J (J hook), C (circle hook), and T (Japanese tuna hook). Species abbreviations follow FAO 3-alpha species codes where available; TUN denotes tuna species, SHK denotes shark species, and BIL denotes billfish species.

Table 2. Summary of reviewed studies on the effects of bait type.

Reference	Fishing depth	Hooks between floats	No of hooks	No of sets	Bait type	Target	Ocean	Classification
Coelho et al. (2012) Santos et al. (2012)	20 - 50 m	5	305,352	221	Squid,Finfish	SWO	EqAtl	Possibly Shallow-set
Coelho et al. (2015) Fernandez-Carvalho et al. (2015)	20 - 50 m	5	254,520	202	Squid,Finfish	SWO	TropNE Atl	Possibly Shallow-set
Foster et al. (2012)		3or5	973,734	999	Squid,Finfish	SWO, BET, BSH	NW Atl	Possibly Shallow-set
Mejuto et al. (2008)		5	430,299	342	Squid,Finfish	SWO	N–S Atl	Possibly Shallow-set
Ochi et al. (2024)	shallow-setting	4	286,368	306	Squid,Finfish	SWO, SHK	NW Pac	Possibly Shallow-set
Santos et al. (2013)	20 - 50 m	5	446,400	310	Squid,Finfish	SWO	S Pac	Possibly Shallow-set
Santos et al. (2024)	shallow-setting	5	92,225	105	Squid,Finfish	SWO, BSH	NE Trop Atl EqAtl	Possibly Shallow-set
Swimmer et al. (2017)-1	shallow-setting	4-5	9,611,623	11,811	Squid,Finfish	SWO	Pac	Possibly Shallow-set
Swimmer et al. (2017)-2		4-5	6,605,840	9,610	Squid,Finfish	TUN, SWO	Atl	Possibly Shallow-set
Yokota et al. (2009)	40 – 90 m	4	36,480	38	Squid,Finfish	SWO, BSH	NW Pac	Possibly Shallow-set
Watson et al. (2005)		3	427,382	489	Squid,Finfish	TUN, SWO, SHK	NW Atl	Possibly Shallow-set
García-Cortés et al. (2009)		-	356,600	183	Squid,Finfish	SWO	SE Pac	Possibly Shallow-set
Brazner & McMillan (2008)		-	-	1,288	Squid,Finfish	TUN, SWO	NW Atl	Possibly Shallow-set
Báez et al. (2010)		-	-	795	Squid,Finfish	SWO	W Med	Possibly Shallow-set

Abbreviations: Ocean names are abbreviated as follows: Atl, Atlantic; Pac, Pacific; Eq, Equatorial; N, North; S, South; E, East; W, West; Med, Mediterranean. Species abbreviations follow FAO 3-alpha species codes where available; TUN denotes tuna species, and SHK denotes shark species.

Table 3. The number of study cases recording significantly higher catch rates using J hook and tuna hook versus large circle hook and without significant difference. The range of hooks between floats and number of hooks and sets observed were cited from the literature by each species.

Set	Species	No. of cases recording significantly higher or non-significantly different catch rate			No. of cases recording significantly higher or non-significantly different catch rate			No. of hooks	No. of sets	References
		J hook	Circle hook	Non significant	Tuna hook	Circle hook	Non significant			
Possibly Shallow-set	**Shark**									
	All sharks	1		1				-	1,679	Piovano and Gilman (2017)
	Night shark		4	1		2		7,800 - 356,674	12 - 2,068	Afonso et al. (2011),Andraka et al. (2013)-1,Andraka et al. (2013)-4, Andraka et al. (2013)-6, Pacheco et al. (2011) ,Santos et al. (2012)&Coelho et al. (2012),Coelho et al. (2015)&Fernandez-Carvalho et al. (2015)
	Blue shark		6	6	1	2	1	5,040 - 973,734	7 - 2,068	Afonso et al. (2011),Andraka et al. (2013)-1,Andraka et al. (2013)-3,Domingo et al. (2009),Pacheco et al. (2011) ,Sales et al. (2010),Santos et al. (2012)&Coelho et al. (2012),Watson et al. (2005), Coelho et al. (2015)&Fernandez-Carvalho et al. (2015),Foster et al. (2012),Mejuto et al. (2008),Minami et al. (2006) &Yokota et al. (2006b) ,Lima et al. (2023),Ochi et al. (2024),Carbonara et al. (2023),García-Cortés et al. (2009)
	Silky shark		1	1		1		7,800 - 305,352	12 - 306	Afonso et al. (2011),Santos et al. (2012)&Coelho et al. (2012),Ochi et al. (2024)
	Shortfin mako		1	5				39,822 - 497,880	61 - 343	Domingo et al. (2012) -1,Sales et al. (2010),Santos et al. (2012)&Coelho et al. (2012),Coelho et al. (2015)&Fernandez-Carvalho et al. (2015),Lima et al. (2023),García-Cortés et al. (2009)
	Oceanic whitetip shark		1	1				7,800 - 305,352	12 - 221	Afonso et al. (2011),Santos et al. (2012)&Coelho et al. (2012)
	Ray									
	Stingrays	5	1	1		1		5,040 - 430,299	7 - 2,068	Andraka et al. (2013)-1,,Domingo et al. (2012) -2,Kerstetter and Graves (2006)-1,Pacheco et al. (2011) ,Mejuto et al. (2008),Carbonara et al. (2023),Piovano and Gilman (2017),Andraka et al. (2013)-5
	Sea tutrle									
	All sea tutrle	3			3		1	75,041 - 427,382	110 - 489	Andraka et al. (2013)-2,Andraka et al. (2013)-3,Andraka et al. (2013)-4,Andraka et al. (2013)-5, Andraka et al. (2013)-6, Coelho et al. (2015)&Fernandez-Carvalho et al. (2015)
	Hard shell	1						254520	202	Coelho et al. (2015)&Fernandez-Carvalho et al. (2015)
	Leatherback turtle	6		1				50,170 - 973,734	81 - 999	Pacheco et al. (2011) ,Sales et al. (2010),Santos et al. (2012)&Coelho et al. (2012),Watson et al. (2005),Coelho et al. (2015)&Fernandez-Carvalho et al. (2015),Foster et al. (2012),Mejuto et al. (2008)
	Loggerhead turtle	7		6				4,642 - 973,734	7 - 999	Domingo et al. (2009),Minami et al. (2006),Piovano et al. (2009) ,Sales et al. (2010),Watson et al. (2005),Cambie et al. (2012),Foster et al. (2012),Mejuto et al. (2008),Santos et al. (2013) ,Lima et al. (2023),Carbonara et al. (2023),García-Cortés et al. (2009)
	Olive ridley	2		2	2			50,170 - 356,674	81 - 2,068	Andraka et al. (2013)-1,Andraka et al. (2013)-2,Andraka et al. (2013)-3, Andraka et al. (2013)-6, Pacheco et al. (2011) ,Santos et al. (2012)&Coelho et al. (2012)
Deep	**Shark**									
	All sharks									
	Night shark	1						6,277	13	Promjinda et al. (2008)
	Blue shark	1		1	1	1		6,277 - 2773,427	13 - 1,182	Curran and Bigelow (2011)-1,Curran and Bigelow (2011)-2,Huang et al. (2016) ,Promjinda et al. (2008)
	Silky shark									
	Shortfin mako									
	Oceanic whitetip shark									
	Ray									
	Stingrays	1			1			2,773,427	211 - 1,182	Curran and Bigelow (2011)-1,Curran and Bigelow (2011)-2
	Sea tutrle									
	All sea tutrle						1	407,677	200	Huang et al. (2016)
	Hard shell									
	Leatherback turtle									
	Loggerhead turtle									
	Olive ridley									

Table 4. The number of study cases recording significantly higher catch rates using Fish bait and versus Squid bait and without significant difference. The range of hooks between floats and number of hooks and sets observed were cited from the literature by each species.

Set	Species	No. of cases recording significantly higher or non-significantly different catch rate			No. of hooks	No. of sets	References
		Finfish	Squid	Non significant			
Possibly Shallow-set	**Shark**						
	Night shark	1		1	92,225 - 305,352	105 - 221	Santos et al. (2012)&Coelho et al. (2012),Santos et al. (2024)
	Blue shark	2	3	3	36,480 - 973,734	38 - 999	Santos et al. (2012)&Coelho et al. (2012),Watson et al. (2005),Foster et al. (2012),Mejuto et al. (2008),Ochi et al. (2024),Yokota et al. (2009),Santos et al. (2024),García-Cortés et al. (2009)
	Shortfin mako	4		3	36,480 - 973,734	38 - 999	Santos et al. (2012)&Coelho et al. (2012),Foster et al. (2012),Mejuto et al. (2008),Ochi et al. (2024),Yokota et al. (2009),Santos et al. (2024),García-Cortés et al. (2009)
	Porbeagle	1			973,734	999	Foster et al. (2012)
	Bigeye thresher shark	1		1	254,520 - 305,352	202 - 221	Santos et al. (2012)&Coelho et al. (2012),Coelho et al. (2015)&Fernandez-Carvalho et al. (2015)
	Ray						
	Pelagic stingray		1	1	36,480 - 92,225	38 - 105	Yokota et al. (2009),Santos et al. (2024)
	Sea tutrle						
	All Sea tutrle		2		92,225 - 305,352	105 - 221	Santos et al. (2012)&Coelho et al. (2012),Santos et al. (2024)
	Hard shell		1		254,520	202	Coelho et al. (2015)&Fernandez-Carvalho et al. (2015)
	Leatherback turtle		4	4	254,520 - 9611,623	202 - 11,811	Santos et al. (2012)&Coelho et al. (2012),Watson et al. (2005),Coelho et al. (2015)&Fernandez-Carvalho et al. (2015),Foster et al. (2012),Mejuto et al. (2008),Santos et al. (2013),Swimmer et al. (2017)-1,Swimmer et al. (2017)-2
	Loggerhead turtle		9	2	36,480 - 9611,623	38 - 11,811	Watson et al. (2005),Foster et al. (2012),Mejuto et al. (2008),Santos et al. (2013),Ochi et al. (2024),Yokota et al. (2009),García-Cortés et al. (2009) ,Brazner & McMillan (2008),Báez et al. (2010),Swimmer et al. (2017)-1,Swimmer et al. (2017)-2
	Olive ridley		2	1	92,225 - 430,299	105 - 342	Santos et al. (2012)&Coelho et al. (2012),Mejuto et al. (2008),Santos et al. (2024)
Deep	**Shark**						
	Night shark						
	Blue shark						
	Shortfin mako						
	Porbeagle						
	Bigeye thresher shark						
	Ray						
	Pelagic stingray						
	Sea tutrle						
	All Sea tutrle						
	Hard shell						
	Leatherback turtle						
	Loggerhead turtle						
	Olive ridley						