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Review of studies on catch rates of commercial and bycatch species by hook type using in pelagic tuna longline fisheries

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Abstract

A large circle hook is known as one of the mitigation measures for sea turtles in the pelagic longline fisheries. The advantage and disadvantage of implementations of large circle hook to the longline have long been discussed. Numerous studies have been conducted on the effectiveness of the J hook and large circle hook on the catch rates for target and non-target species. However, the information such as the differences in effectiveness between J hook and Japanese tuna hook or between shallow-set and deep-set is still unclear. This document overviewed catch rates by three hook types for target and non-target species reported in the published scientific papers and documents with the aim of organizing the existing information and clarification on the field which is lack of studies. Considering that lack of information about effect of Japanese tuna hook, effectiveness of large circle hook in deep-set and effect of large circle hook on catch rate of shark species, we recommend to consider SC14 that further research to evaluate the catch rates of target and non-target species especially sea turtles and sharks with using J hook, Japanese tuna hook, and large circle hook in deep-set longline should be needed to reduce the uncertainties of effectiveness for them by the implement of large circle hook.

Introduction

Pelagic tuna longline fishery often occurs incidental takes, generally called as bycatch, of sea turtles, sea birds and non-target shark and teleost species. In order to sustain pelagic longline, bycatch is one of the important issues that have to be addressed. Towards mitigation of bycatch especially for sea turtles and non-target sharks, a variety of fishing gears have been developed and improved (e.g. Afonso et al. 2012; Beverly et al. 2004; Gilman et al. 2006). Among the mitigation techniques, many scientists are particularly interested in the hook modifications including implements of large circle hook. As for hook modifications, a lot of studies about the effects of J, and large circle hooks on the catchabilities of target and non-target species have been conducted based on the experimental research or observations by scientific observers (e.g. Andraka et al. 2013).

Many studies showed effectiveness of the large circle hook to mitigate sea turtle bycatch (Gilman et al. 2006; Watson et al. 2005). In western and central Pacific, there is the conservation and management measures to reduce sea turtle bycatch. It is summarized as that the longline vessels targeting swordfish 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 CMM2008-03). In addition, it was also recommended that the commission note the scientific advice to expand the mitigation measures for sea turtles to deep-set longlines at the SC13 in 2017 (Common Oceans (ABNJ) Tuna Project 2017).

However, there are some problems and uncertainties underlying implementation of large circle hook. There is a variety of hook types in terms of shapes and sizes, which are separated into three groups, i.e. J hooks, Japanese tuna hooks and circle hooks (Mituhasi and Hall 2011; Yokota et al. 2006a). However, many reviewal studies have treated the Japanese tuna hooks as same with J hooks. Thus, the uncertainty still remains if the effects on the mitigating bycatch of the sea turtles are different between J hook and the Japanese tuna hook. Recent studies have pointed that the use of large circle hooks could increase bycatch rates for some shark species that are concerned about reduction of their populations and concluded that it should be carefully discussed in terms of the advantage and disadvantage of large circle hook application (Reinhardt et al. 2017; Semba et al. 2018). There is no information how the difference of fishing depth related to the target species effects on the catchabilities of sea turtles and sharks.

In this study, we compiled previous studies making comparison among J hooks, Japanese tuna hooks, and large circle hooks in operational experiments and reviewed in the aspects of difference in target depth and catch rates of target and non-target (sea turtles, sharks, rays and other teleost fishes) species with three hook types.

Materials and methods

We collected previous scientific literatures related to the studies on effects of J hook, Japanese tuna hook, and large circle hook on catch rates of target and non-target species in pelagic longline fisheries in the Atlantic, the Indian, and the Pacific Oceans. A total of 40 cases of 33 publications were reviewed and compiled with the catch rates of main target and non-target species (Table 1).

Fishing strategy related to the setting depth was divided all the cases in the publications used in this review into 3 categories; shallow-set, deep-set, and others. We used the number of hooks between floats (HBF) as a factor of the categorization. The shallow and deep sets were defined as the HBF of 10 hooks and less, and more than 10 hooks, respectively, based on the previous study (Common Oceans (ABNJ) Tuna Project 2017). If there was no information on the HBF or the study cases in both shallow-set and deep-set were included in a publication in the case, it was regarded as others. The number of study cases which recorded significantly higher catch rate in J hook versus large circle hook and Japanese tuna hook versus large circle hook, or the number of cases without significant difference was counted by each species. The smallest and largest number of HBF and number of hooks and sets observed were cited from the literatures by each species.

Results

As a result of review, the literatures for shallow-set, deep-set, and others were 25 cases of 21 literatures, 6 cases of 5 literatures, and 9 cases of 7 literatures, respectively (Table 2.1-3). The numbers of study cases with recording significantly higher catch rates of each species in J hook versus large circle hook, in Japanese tuna hook versus large circle hook, and without significant difference were shown by species in Table 3.1 and 3.2.

In the shallow-set, all the previous studies reported higher catch rates of large circle hook for tunas and sharks than those of J hook or no significant difference in catch rates between J hook and large circle hook. Oppositely, all the studies indicated higher catch rates of J hook for sea turtles and pelagic stingray than those of large circle hook. As for swordfish, two of 10 cases reported higher catch rates of J hook, a case reported higher catch rate of large circle hook, and the remaining 7 reported no significant difference in catch rates between J hook and large circle hook. All the cases for the other teleost fishes were reported no significant difference in catch rates between J hook and large circle hook. There were only 4study cases where catch rates of Japanese tuna hook and large circle hook were compared. Therefore, no specific outcome existed except for all the study cases for sea turtles which were reported higher catch rates of Japanese tuna hook or no significant difference between Japanese tuna hook and large circle hook.

Three study cases were available for the deep-set at this moment. Based on those, the hook type which was reported higher catch rates for each species was not always same among studies. However, it was noted that a study case on leatherback turtle and olive ridley reported no significant difference in bycatch rates between Japanese tuna hook and large circle hook.

Discussion

1. Catch rates on target and non-target species without sea turtles

There were 3 and 2 study cases, where swordfish catch rates of Japanese tuna hook were compared with those of large circle hook, available for shallow-set and deep-set, respectively. These were not consistent in the results among these study cases. Two of them, which covered shallow-set and deep-set, indicated higher catch rates of large circle hook for swordfish (Andraka et al. 2013; Huang et al. 2016) and the other two covering also shallow-set and deep-set were inversely showed higher swordfish catch rates of Japanese tuna hooks (Andraka et al. 2013; Curran and Bigelow 2011). The higher catch rate of Japanese tuna hook for albacore were reported consistently in all studies. The hook type which was reported higher catch rates for individual species from the shallow-set were roughly consistent among the studies, whereas there was no consistency for deep-set because of lack of the studies. It is strongly recommended to increase the number of studies with using J, Japanese tuna, and large circle hooks in deep-set for the evaluation of effects on catch rates for target, non-target and bycatch species.

Reinhardt et al. (2017) conducted meta-analysis where catch rates for target and non-target species were compared between J hook (including Japanese tuna hook) and circle hook and concluded that many of main target species and shark species recorded higher catch rates for large circle hook and sea turtles recorded higher catch rates for J hook. It means that large circle hook raises bycatch rate of sharks whereas it reduces bycatch rate of sea turtles. In addition, use of large circle hook may cause substantial increase of absolute mortality of shortfin mako shark in total, recently reported by Semba et al. (2018). They showed clearly that increase in bycatch rate induced by large circle hook was much higher than decrease of at vessel mortality rate by this hook, although previous study reported that the use of large circle hook reduces at vessel mortality of sharks (Godin et al. 2012). In conclusion, the use of large circle hook may not be always a be-all-end-all mitigation measures for all the bycatch species at this moment. It is needed to keep accumulating scientific knowledge.

2. Large circle hook as a mitigation measure for sea turtle

The results of this study showed that the large circle hook was effective for reduction of sea turtle bycatch in shallow-set. However, in the cases of deep-set, the effectiveness of large circle hook to reduce sea turtle bycatch was unclear because of limited information. In the result of Huang et al. (2016), the bycatch rate of leatherback turtle by Japanese tuna hook was not differ from that of large circle hook. The bycatch rates of loggerhead and olive ridley by Japanese tuna hook were also not differ from that of large circle hook. In addition, the mortality rates of olive ridley and leatherback turtle in Japanese tuna hook were not differ from that of large circle hook. Huang et al. (2016) indicated that the large circle hook may not so much effective as it has been mentioned.

We will discuss about reasons why the effects of mitigating bycatch on sea turtles for deep-set will be lower than the shallow-set's one. There are direct and indirect effects by the use of large circle hook on reducing bycatch rate of sea turtle. One of the indirect effects is change in hooking locations, in other words, the large circle hook will reduce occurrence of deep hooking with preventing to swallow and increase ratio of external or mouth hooking (Parga et al. 2015). It will be easier to de-hook if external or mouth hooking were increased, therefore it has potential to increase the chance of escape and decrease the number of individuals observed at line hauling. However, it is mainly effective for the shallow-set because the chances to breathe decrease for the lung breathing animal in deep-set. The cases are, for example, when the turtle was caught by the branch line close to a float or spent short time until hauling the branch line. The turtle will be dead in the deep-set before de-hooking even if the cases with external hooking were increased, therefore the bycatch rates with using large circle hook were not decreased. Gilman and Huang (2016) pointed that it is still unclear what is the most important effects of large circle hook, i.e. circle shape or large size on reducing hard-shelled sea turtle bycatch. They also pointed that the circle shape may be more effective to reduce leatherback bycatch than the large size of hook. These factors are essential to discuss on sea turtle bycatch especially in deep-set and further studies are necessary to clarify the mechanisms of bycatch and to improve the mitigation measures.

In the previous studies of sea turtle bycatch on deep-set, the ratios of sea turtle caught by the first and second branch line from the float were 64%, 100%, and 60% in Huang et al. (2016), Kim et al. (2006), and Kim et al. (2007), respectively. It indicates that the sea turtles are spending much time at around surface layer as it is also supported by the biological studies (Eckert 2006; Polovina et al. 2004). The fishing method where all the hooks of the longline gear are set at deeper than the water depth that sea turtles use frequently may be effective as another mitigation measure for sea turtles as it has been introduced before (Beverly et al. 2004; Shiode et al. 2005).

The effects of large circle hook and/or fish bait on mitigating bycatch of sea turtle were estimated for the deep-set through extrapolation of the reduction rates derived from the shallow-set (Common Oceans (ABNJ) Tuna Project 2017). However, we conclude that the effects of the mitigation measures on sea turtle may have the difference between shallow-set and deep-set, and effectiveness for reducing bycatch of sea turtles for deep-set is still unclear. It is needed to understand whether large circle hook is effective to reduce sea turtle bycatch in deep-set as well as shallow-set.

3. Future studies and Recommendations

In this review, we found that the uncertainties of effectiveness by the hook type difference for the catch rates of target and non-target species, especially sea turtles and sharks.

Considering with the results of this study, we recommend that the SC14 considers that further research to evaluate catch rates of target and non-target species, especially sea turtles and sharks using J hook, Japanese tuna hook, and large circle hook in deep-set longline should be needed.

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Table 1. The species list using in this study.

Common name	Scientific name
Tuna	
Bigeye	*Thunnus obesus*
Yellowfin	*Thunnus albacares*
Albacore	*Thunnus alalunga*
Skipjack	*Katsuwonus pelamis*
Billfish	
Swordfish	*Xiphias gladius*
Striped marlin	*Kajikia audax*
Sailfish	*Istiophorus platypterus*
Other teleost fish	
Wahoo	*Acanthocybium solandri*
Dolphin fish	*Coryphaena hippurus*
Escolar	*Lepidocybium flavobrunneum*
Longnose lancetfish	*Alepisaurus ferox*
Shark	
Blue shark	*Prionace glauca*
Shortfin mako	*Isurus oxyrinchus*
Bigeye thresher shark	*Alopias superciliosus*
Ray	
Palagic stingray	*Pteroplatytrygon violacea*
Turtle	
Leatherback turtle	*Dermochelys coriacea*
Olive ridley	*Lepidochelys olivacea*
Loggerhead turtle	*Caretta caretta*
Green/Black turtle	*Chelonia mydas*

Table 2.1. Summaries of reviewed literatures by study case categorized as shallow-set.

Reference	Hooks between floats	No of hooks	No of sets	Target	Ocean	With or without using in our study*
Afonso et al. (2011)	5	7,800	12	Tuna	Equatorial Atlantic	T
Andraka et al. (2013)	2-3	356,674	2,068	Tuna, Billfish, and Shark	Eastern Pacific	T
Andraka et al. (2013)	3-5	134,643	248	Tuna, Billfish, and Shark	Eastern Pacific	T
Andraka et al. (2013)	3-5	75,041	122	Tuna, Billfish, and Shark	Eastern Pacific	T
Domingo et al. (2009)	8	77,628	165	Swordfish and Sharks	South western Atlantic	T
Domingo et al. (2012)	5	39,822	61	Swordfish and Pelagic Sharks	South western Atlantic	T
Domingo et al. (2012)	8	45,142	107	Blue Shark	South western Atlantic	T
Kerstetter and Graves (2006)	5	14,040	39	Yellowfin	North western Atlantic	T
Kerstetter and Graves (2006)	5	16,560	46	Swordfish	Gulf of Mexico Caribbean	T
Kerstetter et al. (2007)	5	16,624	26	Swordfish	Equatorial Atlantic	T
Minami et al. (2006)	4	48,600	52	Swordfish	North western Pacific	T
Pacheco et al. (2011)	5	50,170	81	Swordfish and Bigeye	Equatorial Atlantic	T
Piovano et al. (2009)	5	29,254	30	Swordfish	Mediterranean	T
Sales et al. (2010)	5-6	145,828	229	Tunas and Sharks	South western Atlantic	T
Santos et al. (2012)	5	305,352	221	Swordfish	Equatorial Atlantic	T
Watson et al. (2005)	3	427,382	489	Tuna, Swordfish, and Shark	North western Atlantic	T
Afonso et al. (2012)	5			Tuna and Swordfish	Equatorial Atlantic	F
Bolten and Bjorndal (2005)	4			Swordfish	North eastern Atlantic	F
Cambiè et al. (2012)	6-9			Atlantic Bluefin	Mediterranean	F
Coelho et al. (2012)	5			Bigeye, Yellowfin, and Swordfish	Equatorial Atlantic	F
Coelho et al. (2015)	5			Swordfish	Equatorial Atlantic	F
Fernandez-Carvalho et al. (2015)	5			Swordfish and Blue shark	Equatorial Atlantic	F
Foster et al. (2012)	5			Swordfish, Bigeye, and Blue shark	North western Atlantic	F
Mejuto et al. (2008)	5			Swordfish	North to South Atlantic	F
Yokota et al. (2006b)	4			Swordfish and Blue shark	North western Pacific	F

* The study case used in our study: T; non-use: F

Table 2.2. Summaries of reviewed literatures by study case categorized as deep-set.

Reference	Hooks between floats	No. of hooks	No. of sets	Target	Ocean	Remarks*[1]	With or without using in our study*[2]
Curran and Bigelow (2011)	24.7±1.75	2,773,427	211	Bigeye	Central Pacific	J vs C	T
Curran and Bigelow (2011)	24.7±1.75		1,182	Bigeye	Central Pacific	T vs C	T
Huang et al. (2016)	16-17	407,677	200	Bigeye	Equatorial Atlantic		T
Kim et al. (2006)	17	44,100	21	Tuna and Billfish	Eastern Pacific		F
Kim et al. (2007)	16	62,464	28	Tuna and Billfish	Eastern Pacific		F
Promjinda et al. (2008)	15-20	6,277	13	Tuna and Billfish	Bay of Bengal and Andaman Sea		F

*[1] "J", "C", and "T" mean J hook, circle hook, and Japanese tuna hook, respectively.
*[2] The study case used in our study: T; non-use: F

Table 2.3. Summaries of reviewed literatures categorized as other.

Reference	Hooks between floats	Target	Ocean	Remarks
Carruthers et al. (2009)	Undescribed	Swordfish and Tunas	North western Atlantic	Gear is generally set shallow to fish in the upper 20 m
Diaz (2008)	Undescribed	Yellowfin	Gulf of Mexico	U.S. pelagic longline observer program
García-Cortés et al. (2009)	Undescribed	Swordfish	South eastern Pacific	Surface
Garrison (2003)	Undescribed	Swordfish	Gulf of Mexico	
Largacha et al. (2005)	Undescribed	Bigeye	Eastern Pacific	
Piovano and Gilman (2016)	Undescribed	Tunas		Fijian pelagic observer program
Ward et al. (2008)	6-8	Swordfish	South western Pacific	
Ward et al. (2008)	About 30	Albacore	South western Pacific	
Ward et al. (2008)	10-12 / 30	Tunas	South western Pacific	

Table 3.1. The number of study cases of shallow-set with recording significantly higher catch rates in J 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 literatures by each species.

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			Hooks between floats (min-max)	No. of hooks (min-max)	No. of sets (min-max)	Reference
	J hook	Circle hook	Non significant	Japanese tuna hook	Circle hook	Non significant				
Tuna										
Bigeye		3	4			2	2-8	16,624-427,382	26-2,068	Andraka et al. (2013); Domingo et al. (2009); Domingo et al. (2012); Kerstetter and Graves (2006); Kerstetter et al. (2007); Pacheco et al. (2011); Sales et al. (2010); Watson et al. (2005)
Yellowfin		3	3		1	2	2-8	16,624-356,674	26-2,068	Andraka et al. (2013); Domingo et al. (2009); Domingo et al. (2012); Kerstetter and Graves (2006); Kerstetter et al. (2007); Pacheco et al. (2011); Sales et al. (2010)
Albacore		4	2				3-8	14,040-145,828	39-229	Domingo et al. (2009); Domingo et al. (2012); Kerstetter and Graves (2006); Pacheco et al. (2011); Sales et al. (2010)
Skipjack						2	2-5	134,643-356,674	248-2,068	Andraka et al. (2013)
Billfish										
Swordfish	2	1	7	1	1	1	2-8	16,624-356,674	26-2,068	Andraka et al. (2013); Domingo et al. (2009); Domingo et al. (2012); Kerstetter and Graves (2006); Kerstetter et al. (2007); Pacheco et al. (2011); Piovano et al. (2009); Sales et al. (2010); Watson et al. (2005)
Striped marlin						1	2-3	356,674	2,068	Andraka et al. (2013)
Sailfish	1		2		1	2	2-5	16,624-356,674	26-2,068	Andraka et al. (2013); Kerstetter and Graves (2006); Kerstetter et al. (2007); Pacheco et al. (2011)
Other teleost fish										
Wahoo			3		1		5-8	16,624-45,142	26-107	Andraka et al. (2013); Domingo et al. (2012); Kerstetter et al. (2007); Pacheco et al. (2011)
Dolphin fish			6			3	2-6	16,624-356,674	26-2,068	Andraka et al. (2013); Domingo et al. (2012); Kerstetter and Graves (2006); Kerstetter et al. (2007); Pacheco et al. (2011); Sales et al. (2010)
Escolar			4			1	2-8	16,560-356,674	46-2,068	Andraka et al. (2013); Domingo et al. (2012); Kerstetter and Graves (2006); Pacheco et al. (2011)
Longnose lancetfish	—	—	—	—	—	—	—	—	—	
Shark										
Blue shark		4	5	1	1	1	2-8	7,800-427,382	12-2,068	Andraka et al. (2013); Domingo et al. (2009); Domingo et al. (2012); Kerstetter and Graves (2006); Kerstetter et al. (2007); Pacheco et al. (2011); Sales et al. (2010); Watson et al. (2005)
Shortfin mako		1	4			1	2-8	39,822-356,674	61-2,068	Andraka et al. (2013); Domingo et al. (2009); Domingo et al. (2012); Pacheco et al. (2011); Sales et al. (2010)
Bigeye thresher shark						1	2-3	356,674	2,068	Andraka et al. (2013)
Ray										
Palagic stingray	2		1		1		2-8	14,040-356,674	39-2,068	Andraka et al. (2013); Domingo et al. (2012); Kerstetter and Graves (2006); Pacheco et al. (2011)
Turtle										
Leatherback turtle	4		1				3-8	50,170-427,382	81-489	Andraka et al. (2013); Domingo et al. (2009); Domingo et al. (2012); Pacheco et al. (2011); Sales et al. (2010); Santos et al. (2012); Watson et al. (2005)
Olive ridley	1		1	2		1	2-5	50,170-356,674	81-2,068	Andraka et al. (2013); Pacheco et al. (2011); Santos et al. (2012)
Loggerhead turtle	3		3	1			3-8	29,254-427,382	30-489	Andraka et al. (2013); Domingo et al. (2009); Domingo et al. (2012); Minami et al. (2006); Piovano et al. (2009); Sales et al. (2010); Watson et al. (2005)
Green/Black turtle			1	2		1	2-5	50,170-356,674	81-2,068	Andraka et al. (2013); Pacheco et al. (2011); Sales et al. (2010)

Table 3.2. The number of study cases of deep-set with recording significantly higher catch rates in J 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 literatures by each species.

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			Hooks between float (min-max)	No. of hooks (min-max)	No. of sets (min-max)	Reference
	J hook	Circle hook	Non significant	Japanese tuna hook	Circle hook	Non significant				
Tuna										
Bigeye			1		1	1	16-25<	407,677- <2,773,427	200-1,182	Curran and Bigelow (2011); Huang et al. (2016)
Yellowfin			1	1	1		16-25<	407,677- <2,773,427	200-1,182	Curran and Bigelow (2011); Huang et al. (2016)
Albacore			1	2			16-25<	407,677- <2,773,427	200-1,182	Curran and Bigelow (2011); Huang et al. (2016)
Skipjack			1			1	an average of 25	<2,773,427	211-1,182	Curran and Bigelow (2011)
Billfish										
Swordfish			1	1	1		16-25<	407,677- <2,773,427	200-1,182	Curran and Bigelow (2011); Huang et al. (2016)
Striped marlin			1	1			an average of 25	<2,773,427	211-1,182	Curran and Bigelow (2011)
Sailfish	—	—	—	—	—	—	—	—	—	—
Other teleost fish										
Wahoo	1			1			an average of 25	<2,773,427	211-1,182	Curran and Bigelow (2011)
Dolphin fish	1			1			an average of 25	<2,773,427	211-1,182	Curran and Bigelow (2011)
Escolar			1	1			an average of 25	<2,773,427	211-1,182	Curran and Bigelow (2011)
Longnose lancetfish	1			1			an average of 25	<2,773,427	211-1,182	Curran and Bigelow (2011)
Shark										
Blue shark	1			1	1		16-25<	407,677- <2,773,427	200-1,182	Curran and Bigelow (2011); Huang et al. (2016)
Shortfin mako	—	—	—	—	—	—	—	—	—	—
Bigeye thresher shark			1	1			an average of 25	<2,773,427	211-1,182	Curran and Bigelow (2011)
Ray										
Palagic stingray	1			1			an average of 25	<2,773,427	211-1,182	Curran and Bigelow (2011)
Turtle										
Leatherback turtle						1	16-17	407,677	200	Huang et al. (2016)
Olive ridley						1	16-17	407,677	200	Huang et al. (2016)
Loggerhead turtle	—	—	—	—	—	—	—	—	—	—
Green/Black turtle	—	—	—	—	—	—	—	—	—	—