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Effect of hook design on longline catches in Lakshadweep Sea, India

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ABSTRACT

Tuna longlining is considered as an ecofriendly, economical, species-selective and size-selective fishing technique suitable for harvesting sparsely distributed large predatory fishes. Many non-targeted and protected species like marine turtles, seabirds, cetaceans and sharks are also caught as bycatch in the pelagic longline gear. Investigations were undertaken to evaluate the effect of hook design on the longline catches in Lakshadweep Sea by comparing the species selection efficiency, bait holding efficiency and hooking pattern of the Japanese and circle hook designs. The results indicated that hook design has no effect on the catching efficiency, species selectivity and bait holding ability in pelagic longline fisheries in Lakshadweep Sea. The hooking pattern was found to be significantly different, indicating favorable hooking locations in the case of circle hooks. The results of the present study, indicated the positive effects of circle hooks in minimising the impact of bycatch by hooking on the fish favouring post-release survival of the species.

Keywords: Hook design, Lakshadweep Sea, Longline, Selectivity

Introduction

The pelagic longlines are currently used to commercially harvest the tuna and tuna like fishes worldwide. Longline is considered as a size selective gear (Bjordal, 1981). Even though it has been considered more eco-friendly than other fishing practices, the gear also interacts with non-target pelagic species and can be a threat to birds, sharks, turtles and dolphins (Belda and Sanchez, 2001; Polovina *et al.,* 2003; Lewison *et al*., 2004; Diaz, 2005). Tuna longlining has been undergoing many changes in the shape and structure for improving the fishing efficiency and to reduce bycatch (Ward and Hindmarsh, 2007). Hooks are the most important part in the gear and it varies in shape and size. Most commonly used hooks are 'J' hook, Japanese tuna hook and circle hook. 'J' hooks are not advisable because of the injury caused by deep hooking during the capture which reduces the post-release survival rate of the nontargeted animals like dolphins and turtles (Huse and Ferno, 1990). Japanese tuna hooks of 3.6 sun are commonly used in the tuna longlining by most of the tuna fishing fleets in the world (Beverly *et al.,* 2009). Japanese tuna hook has an intermediate style between 'J' hook and circle hook (Whitelaw and Baron, 1995). The overall hooking rate is reported to be very high in 'J' hooks (Kerstetter and Graves, 2006).

In tuna longlining, a potential technique to reduce unwanted bycatch of turtles is deep setting of the line (Beverly *et al*., 2009). Fishing mortality of bycatch species can be reduced by change in the hook design, hook size, decreasing interaction rates, decreasing the mortality during hauling, increase in post-release survival or by a combination of these approaches (Shapiro, 1950; Koike *et al.,* 1968; Ralston, 1982; Cortez-Zaragoza *et al.,* 1989; Lokkeborg and Bjordal, 1992; Erzini *et al*., 1998; Falterman and Graves, 2002; Kerstetter and Graves, 2006; Gilman *et al.,* 2006; Piovano *et al*., 2010; Curran and Bigelow, 2011).

Recently, attention has been given to circle hooks, having the point turned perpendicularly back to the shank as a means of bycatch mitigation. Fish caught by longlines are generally hooked in the mouth, particularly in the jaw or in the alimentary tract if the hook is swallowed (Huse and Ferno, 1990). Fish hooked in sensitive areas such as stomach, esophagus, and gills suffered greater mortality than those hooked in non-critical areas (Aalbers *et al*., 2004). Deep hooking can be significantly reduced by increasing the hook size (Grixtii *et al.,* 2007). Circle hooks have a tendency to slide over soft tissues and rotate resulting in the hook catching in the jaw (Cooke and Suski, 2004) causing minimum injury to the fishes resulting in enhanced post-release survival (Lokkeborg and Bjordal, 1992 ; Prince *et al.,* 2002; Skomal *et al*., 2002; Watson *et al*., 2004; Watson *et al.,* 2005; Bacheler and Buckel, 2006; Gilman *et al.,* 2006; Kerstetter *et al*., 2007; Read, 2007; Pacheco *et al.,* 2011; Swimmer *et al*., 2011). Several studies

indicated that circle hooks can produce higher catch rates than traditional 'J' hooks (Peeling, 1985; Montrey, 1999; Falterman and Graves, 2002; Poulsen, 2004; Yokota *et al*., 2006; Kerstetter and Graves, 2006; Kerstetter *et al*., 2007; Ward *et al*., 2009; Swimmer *et al*., 2011). Studies conducted by Yokota *et al.* (2006) and Pacheco *et al*. (2011) indicated that change in hook pattern have little effect on the catch composition.

Bait holding effect of the hooks is an important factor for the successful fishing operation. It is very important that the baits should be remaining in the hook until the fish approached. Although, large number of studies have been conducted on the effect of hook design on the longline catches in the international waters, there are only limited works carried out in Indian waters. Hence, the present study was undertaken with the objective to find the effect of Japanese and circle hooks on overall hooking, species selection, bait holding ability and hooking locations by experimental longlining operations in Lakshadweep waters.

Materials and methods

Fishing operations were conducted off north of Agatti Island (10° 57' to 10° 58' N and 72° 16 to 72° 19' E) employing a converted pablo boat (*Noorjahan*, L_{OA} 7.6 m; 16.5 hp) equipped for experimental tuna longlining operation in Lakshadweep Sea. The depth of longline operation was 60 m. Bait used for this study was *Amblygaster clupeoides.* Line setting started in the dawn and usually took 1 h to complete. The soaking time varied from 2 to 4 h, depending on the weather conditions. Maximum number of branchlines shot was 100. Three sets of experiments were conducted to study the selectivity of hooks. Each set carried 25-50 hooks. Hook comparison trials used 14/0 non-offset circle hooks and 3.5 sun Japanese tuna hooks (Fig. 1). Each basket contained five hooks and

Fig. 1. Hooks used for the study- 14/0 circle hook (left) and 3.5 Japanese tuna hook (right)

care was taken to ensure alternating positions of each hook within the baskets along the mainline (*i.e.,* one basket would have C-J-C-J-C and the next would have J-C-J-C-J) (Kerstetter and Graves, 2006; Pacheco *et al.,* 2011). During hauling, the species, number, condition (live or dead), and hooking location were recorded. Length and weight of the fish were measured onboard. The catch data were pooled from each basket by hook type and was used for analysis. The catch rate for each operation was calculated as catch per 1000 hooks and expressed as the measure of catch per unit effort (CPUE).

Bait holding efficiency of the hooks were also compared. The bait holding efficiency of the hook was determined by counting the percentage of hooks which have baits left after a given soaking time. The baits which are either detached normally or taken away by the fishes were considered as lost. Holding the bait when the fish has not eaten or attended to, was considered as a desirable property of the hook.The bait holding efficiency of the hooks is expressed as a percentage of hooks retaining the bait out of the total number of hooks deployed. Hooking pattern of circle hooks and Japanese tuna hooks in the fish's body were analysed. The favourable hooking locations identified were lip and jaw, and other locations like throat, gut and foul hooking were considered as unfavourable hooking patterns

Statistical tests were performed using SPSS (IBM SPSS Statistics, Version 20). Catch composition, species selectivity, bait holding efficiency of hooks and hooking location by hook type was compared by chi-square test (Prince *et al.,* 2002; Pacheco *et al.,* 2011). Catch rate of hooks were analysed using generalised linear modeling (GLMs) with hook type and baiting type (Kerstetter and Graves, 2006; Ward *et al.,* 2009; Piovano, 2010). Test results were considered significant at 5% confidence level.

Results and discussion

Comparative evaluation of catch per unit effort (CPUE)

The data set had observations from a total of 123 hooks. Hooking rate was expressed as number of fish caught per 1000 hooks. A total of 17 fishes were caught during the experimental fishing operations which included three species of sharks (*Carcharhinus amblyrhynchos, Carcharhinus falciformis, Galecerdo cuvier*) and two species of bony fishes (*Thunnus albacares* and *Lutjanus* sp.*)*. Experimental fishing showed very high hooking rate for the Japanese hooks compared to circle hooks. The mean hooking rates for Japanese and circle hooks were 186.44 ± 51.13 and 112.9 ± 40.52 (mean ± SE), respectively (Fig. 2).

Generalised linear modeling (GLM) was carried out to find the influence of hooking rate by three factors

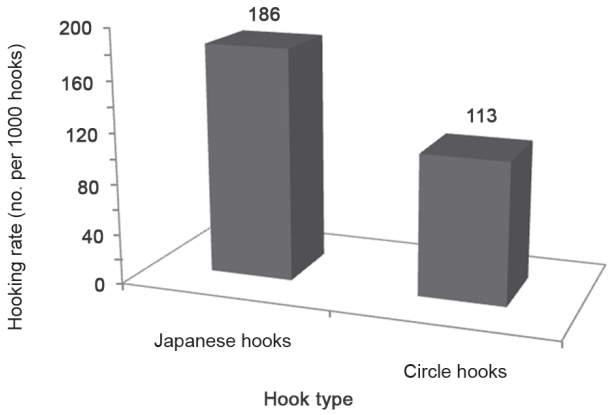

Fig. 2. Hooking rate of the two hook designs (mean hooking rate) observed for different species

reported to influence the hooking rate. The three factors considered were hook type (circle and Japanese), retention of bait and baiting pattern on the hook (vertical or horizontal). Binomial distribution with probit link was used for the GLM. The results indicated that there was no significant influence of any of these factors on the hooking rate expressed as present or absent. No statistically significant difference was noticed between the circle hook and Japanese hooks with respect to hooking rates observed by the Pearson's chi-square test with Yate's continuity correction (p = 0.36).

Selectivity of the hooks

Hooking rates (number per 1000 hooks) observed in Japanese hooks were 0 for tuna, 167 for sharks and 17 for other fishes (Fig. 3). Hooking rates observed were 32 for tuna, 64 for sharks, and 16 for other fishes, in the case of circle hooks. The study indicated the efficiency of the circle hooks in catching more tuna and fewer sharks compared to Japanese hooks. This characteristic of circle hooks can be effectively used for conservation of sharks. Both the Japanese hook and circle hook showed almost same

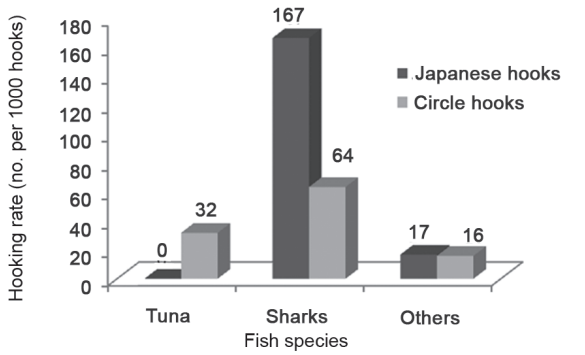

Fig. 3. The selectivity of hook design (mean hooking rate) observed for the different species in Japanese and circle hooks

hooking rate in catching fishes other than tuna and sharks (17/1000 and 16/1000 hooks respectively). No statistically significant difference was noticed in the species selectivity of the two hooks, using chi-square test (p = 0.515).

Bait holding efficiency of the hooks

Comparative analyses were carried out to understand the bait holding efficiency of the two different type of hooks. Three sets of experiments were conducted for the study using a total of 123 hooks. From the results, it was found that circle hooks were more effective in holding the bait (78%) than the Japanese hooks (73%) (Fig. 4). Chi-square test performed to compare circle hooks and Japanese hooks with respect to the bait holding properties showed no significant difference between the hook types (p= 0.67).

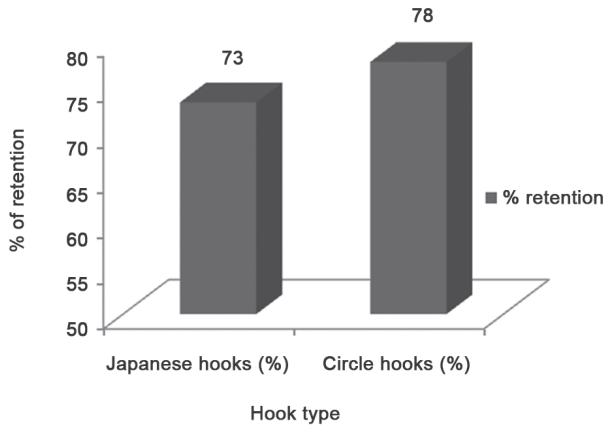

Fig. 4. Bait holding efficiency of circle and Japanese hooks

Hooking location

The major hooking locations were identified as lip, jaw, throat and gut, in addition to foul hooking. Hooking anywhere outside the body is referred as foul hooking. For comparing the effect of hook types on hooking locations, the observed hooking locations were catogorised into two groups *viz*., preferred and nonpreferred hooking locations. Lip and jaw were considered as the preferred hooking location since the removal of fish from the hook from these locations is more efficient which enhances the post-release survival rate of the fishes. Throat, gut and foul hooking are considered as non-preferred hooking locations as it may adversely affect the post-release survival of the fishes.

Twentyseven percent of the fish caught in Japanese hooks were hooked in the jaw. No lip-hooking was observed in the Japanese hooks. Japanese hooks dominated in the hooking of sensitive locations like throat, gut or stomach (deep-hooking) (Fig. 5). Throat hooking was found to be more in Japanese hooks (45%) than the circle hooks were (0%) and 27% of the fish caught by Japanese hooks were hooked in the deeper locations (gut).

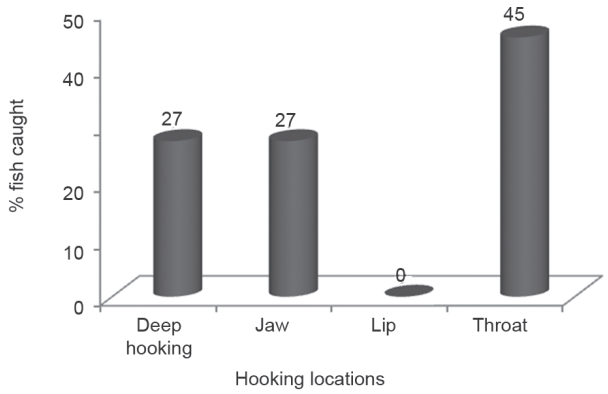

Fig. 5. Hooking pattern of Japanese hooks

About 86% of the fish caught by circle hook were hooked in the jaw followed by lip (14%) (Fig. 6). Many workers confirmed the efficiency of the circle hooks to catch the fish in the jaw (Huse and Ferno, 1990; Cooke and Suski, 2004). No throat-hooking and deep-hooking were observed with the circle hook (Yokota *et al.* 2006; Curran and Bigelow, 2011). No foul-hooking was recorded in either of the two hook types.

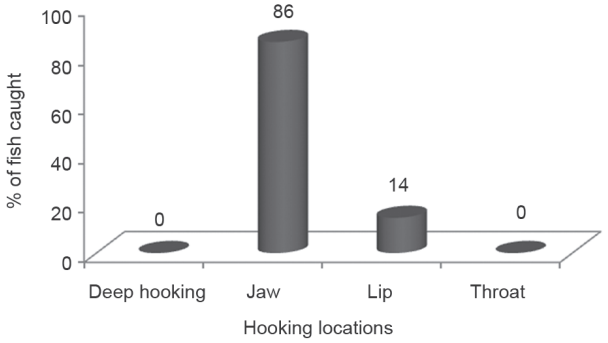

Fig. 6. Hooking pattern of circle hooks

Comparison of the hooking locations for all the species clubbed together with the two hook designs is depicted in the Fig. 7. Hundred percentage lip-hooking was recorded in the circle hook while no lip-hooking was observed in the Japanese hooks. Jaw-hooking was found to be high in circle hooks (67%) than Japanese hooks (33%). Throat and deep-hooking were not observed in the circle hooks. All these observations are in agreement with the previous studies conducted elsewhere on the effect of hook design on the hooking pattern in longline fish catch (Huse and Ferno, 1990; Skomal *et al.,* 2002; Cooke and Suski, 2004; Beverly, 2006; Ward *et al.,* 2009). Various hooking locations observed during the study are depicted in Fig. 8 to 11. Significant difference was noticed with regard to preferred and non-preferred hooking between the two hooks in Chi-square test ($p = 0.02$).

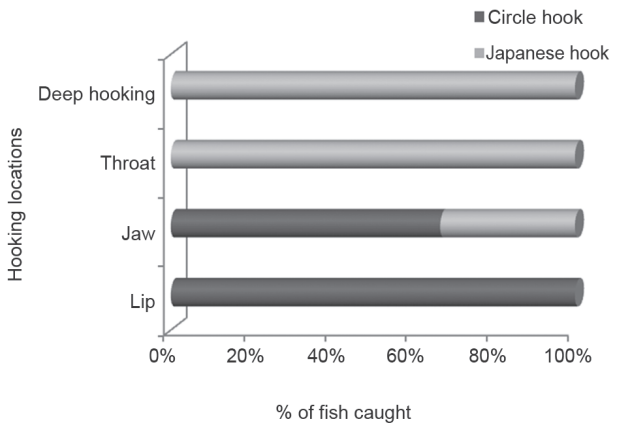

Fig. 7. Comparison of the hooking pattern of circle and Japanese hooks

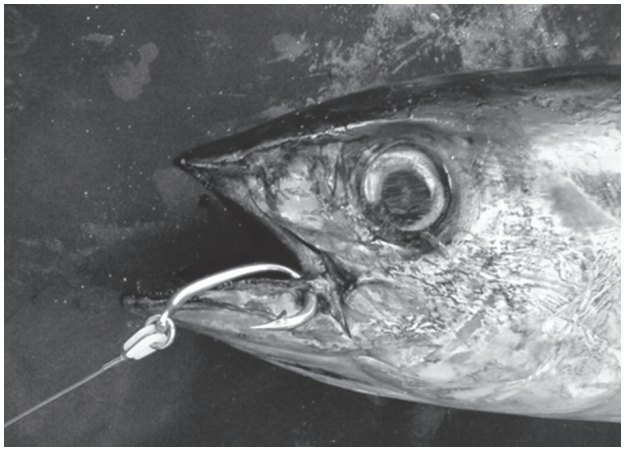

Fig. 8. Jaw-hooking by Japanese hook in *Thunnus albacares*

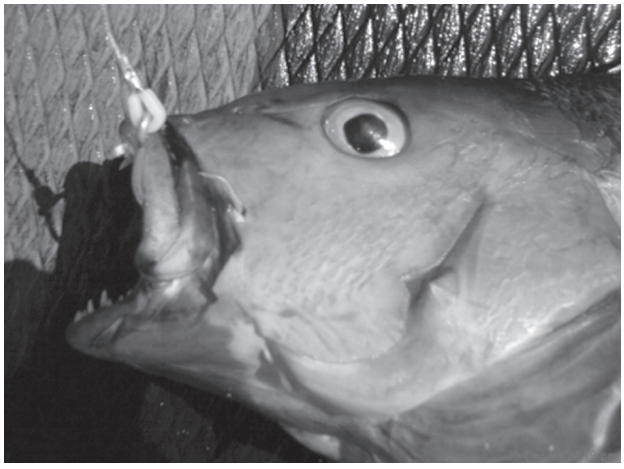

Fig. 9. Lip-hooking by circle hook in *Lutjanus* sp,

The study compared the effect of hook type on the overall catching efficiency expressed as number of fishes per thousand hooks. The mean hooking rate with respect to the Japanese hooks was 186.44 ± 51.13 and

Fig. 10. Throat-hooking by Japanese hook in *Thunnus albacares*

Fig. 11. Deep-hooking by Japanese hook in *Galecerdo cuvier*

112.9 ± 40.52 (mean ± SE) for circle hooks. However, the difference in hooking rate was not significant statistically. This is in agreement with studies of Yokota *et al.* (2006) and Pacheco *et al.* (2011) who observed no effect of hook type on the catch.

Comparative analysis of the species selection ability of hooks indicated that the number and species composition of fish caught in longline can be influenced by the hook design, which is in agreement with observations by Huse and Feno (1990) and Erzini *et al.* (1998). The tuna hooking rate was observed to be high in circle hooks (32/1000 hooks) compared with Japanese hooks (0/1000 hooks). Circle hooks have been reported to be more effective in catching tuna than Japanese hooks (Kerstetter and Graves, 2006; Yokota *et al.,* 2006; Kerstetter *et al.,* 2007; Ward *et al.,* 2009). Shark catch was found to be high in Japanese hooks (167/1000 hooks) than circle hooks (64/1000 hooks). These results agree with the observations of Watson *et al.* (2005) who confirmed the efficiency of circle hooks to catch more tuna and fewer sharks, than Japanese hooks. The hooking rate of fishes other than tuna and sharks was found to be 17/1000 hooks and 16/1000 hooks respectively for the Japanese and circle hooks and the results indicated that, type of hook design do not have any significant effect on catching fish species other than tuna and sharks in Lakshadweep Sea.

Holding the bait when the fish has not either eaten or attended, is considered as a superior property of the hook. The percentage retention of baits for the circle hooks was higher with a value of 78%, compared to 73% observed for the Japanese hooks. However the differences observed were found to be statistically not significant. There is not much information available on the effect of hook type on the bait holding properties and hence a comparison of the results with previous work was not possible. Lokkeborg and Bjordal (1992) pointed out that the hook size significantly affects the bait loss, but in this study, only one size of the hook was used and hence a comparison between hook size and bait loss was not performed. Ralston (1982); Otway and Craig (1993) and Grixtii *et al.* (2007) indicated that hook size and bait sizes did not significantly affect bait loss. More studies are necessary with different hook sizes and bait types to determine the effect of hook type on bait holding capacity.

It has been reported that the hook type significantly influenced the hooking pattern on the fish (Huse and Ferno, 1990; Skomal *et al.,* 2002; Cooke and Suski 2004; Beverly, 2006; Ward *et al.,* 2009). Results of the present study confirm the effect of hook design on the hooking location in fish. Fish caught in the longline are generally hooked in the mouth mainly in the jaw or in the alimentary tract (Huse and Ferno, 1990). Circle hooks ranked first in jaw and lip-hooking (86% and 14% respectively) which are considered as preferred hooking locations which facilitate the post-release survival rate by making minimum injury to the fish. This finding agrees with the previous works of Huse and Ferno (1990) and Cooke and Suski (2004) which showed the efficiency of circle hooks to hook fish in the jaw and lip areas. Throat-hooking (45%) and deep-hooking or intestinal-hooking (27%) were found to be high in Japanese hooks, which creates maximum injury to the fish caught. Cooke and Suski (2004), Yokota *et al.* (2006) and Curran and Bigelow (2011) have shown that hooking in the more sensitive locations like gut and throat can be effectively minimised by use of circle hooks. The results of the present study support the use of circle hooks as a conservation tool to reduce post-release mortality rate in the pelagic longline fisheries, as has been recommended by several workers (Prince *et al.,* 2002; Skomal *et al.,* 2002; Watson *et al.,* 2004; Kim *et al.,* 2006; Yokota *et al.*, 2006; Ward *et al.,* 2009; Curran and Bigelow, 2011; Pacheco *et al.,* 2011).

The outcome of the study clearly indicated that the circle hooks are superior to the Japanese hooks in terms of reduction in bycatch and the results are in concurrence with studies elsewhere which report the efficacy of circle hooks in bycatch reduction. The study suggests the use of circle hooks as a technical measure in the longline fisheries, to make this fishing gear more eco-friendly and sustainable. Further studies with large sample size and with different sizes of hooks are needed, The probable influence of seasonal and other factors on the hooking rate also needs to be investigated.

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