

OPINION

PERSPECTIVES ON THE MORPHOLOGICAL ELEMENTS
OF CIRCLE HOOKS AND THEIR PERFORMANCE
IN PELAGIC LONGLINE FISHERIES

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ABSTRACT

Use of circle hooks is regarded as an effective method to reduce incidental mortality of non-targeted species (e.g., sea turtles) in longline fisheries. Currently, various types of circle hook are produced and distributed commercially. Many researchers worldwide have examined the effect of circle hooks on hooking location, catch rate, and/or mortality for various species, using different types of hooks of various shapes and sizes. However, much work remains to be done to quantify the effects of circle hooks on catch and mortality rates of both target and non-target species. Consideration of practical utility is also important to facilitate wider application of circle hooks in commercial fisheries. Here we focus on some elements of circle hook morphology, i.e., hook width, offset, and incurved point angle, and discuss their potential effects on hook function (i.e., hooking location, catch rate) and practical utility. Further empirical circle hook studies are required to verify the effects discussed here.

Use of circle hooks is regarded as an effective method for reducing incidental mortality of non-targeted species (e.g., sea turtles) in longline fisheries (Watson et al. 2005, Gilman et al. 2007). The distinct feature of a circle hook is its incurved point. Due to this morphological characteristic, the use of the circle hook has the potential to reduce deep-hooking, defined as hooks lodged in the esophagus or deeper, and subsequent mortality of hooked animals, since deep hooking is believed to more likely result in mortality than hooks lodged in the jaw. Circle hooks were originally used for catching demersal fishes under the assumption that they would improve retrieval of hooked fish, because fish are less likely to escape from circle hooks once hooked in the mouth.

Currently, a wide variety of circle hooks are produced and distributed commercially for both demersal and pelagic longline fisheries. Many researchers worldwide have examined the effect of circle hooks on anatomical hooking location, catch rate, and/or mortality for several species, using different types of hooks with various sizes and shapes. In pelagic longline fisheries, many studies have revealed that use of circle hooks reduced deep-hooking of non-target species (e.g., sea turtles; Watson et al. 2005), while impacts on the catch rate of tunas, sharks, and billfishes were small (e.g., Faltermen and Graves 2002, Kerstetter and Graves 2006, Yokota et al. 2006a, Diaz 2008). Larger-sized circle hooks are also known to reduce bycatch rates of sea turtles (Watson et al. 2005, Gilman et al. 2007).

Effects of circle hooks may vary among animal species, geographical area, or season. In addition, performance of circle hooks likely depends on hook morphology. The effects of hook morphology on catch rates of both target and non-target species should be measured quantitatively in a comparative manner. Moreover, the actual hook sizes and hook shapes of circle hooks often differ among manufactures. For example, circle hooks of the same size (e.g., 16/0 circle hooks) differ among product types or manufactures (Mituhasi and Hall 2011). Therefore, it is unwise to directly compare the hook size and shape based on non-standardized nominal hook specifications.

Yokota et al. (2006b) examined measurement points of circle hooks that are appropriate for morphological comparison and evaluation of the effect of hook design. Using their measurement methods, Yokota et al. (2006b) described shape, size, and other characteristics of various circle hooks, and made hook lists with photographs of the actual size of circle hooks. Mituhasi and Hall (2011) produced similar lists of hooks for researchers and at-sea observers to facilitate the identification of hooks used in artisanal longline fisheries in the eastern Pacific region. For the western Pacific region, Beverly and Park (2009) produced a pocket guide for longline terminal gear identification, which included full-scale drawings of various types of hooks. Such lists are helpful to share and exchange information on circle hooks and the results of fishing experiments.

There has been relatively little scientific examination of how individual elements of hook morphology affect circle hook performance. To evaluate circle hook performance, it would be ideal to distinguish the effect of each morphological element on hook function, e.g., hooking location, catch rates of target and non-target species. Consideration of the practical utility of a given hook is also important to facilitate wider adoption of circle hooks in commercial fisheries. Here we discuss some elements of circle hook morphology that could affect the function and practical utility of circle hooks, with a primary focus on hook width, offset, and incurved point. Terms for each morphological element of circle hook or measurement points are provided by Yokota et al. (2006b) and Mituhasi and Hall (2011).

HOOK WIDTH.—Hook width is an element that is related to deep-hooking of target and non-target species. Logic dictates that animals with a small mouth size would have more difficulty in swallowing a wider hook, and as a result, deep-hooking should decrease with increasing hook width. Furthermore, hook width is expected to be related to catch rates of animals. For example, several studies have shown that larger and wider hooks had lower catch rates of sea turtles (Watson et al. 2005, Gilman et al. 2007). However, the effects of hook width may vary among geographical areas because the species and size composition of sea turtles (and other species) may also vary among fishing areas. Several experimental results are available for catch rates of fishes (Piovano et al. 2009, Sales et al. 2010, Curran and Bigelow 2011, Pacheco et al. 2011), which depend on the ratio of hook width to animal species and size (in particular mouth size). Therefore, it is important to quantify the degree to which hook size dictates fish size and species selectivity (Erzini et al. 1996, Erzini et al. 1997, Yamashita et al. 2009).

In some longline fisheries, practical utility may be impaired by excessive hook widths. In Japanese pelagic longline fisheries, branch lines are detached from the mainline, coiled, and then stored in basket boxes during line hauling. Hooks are

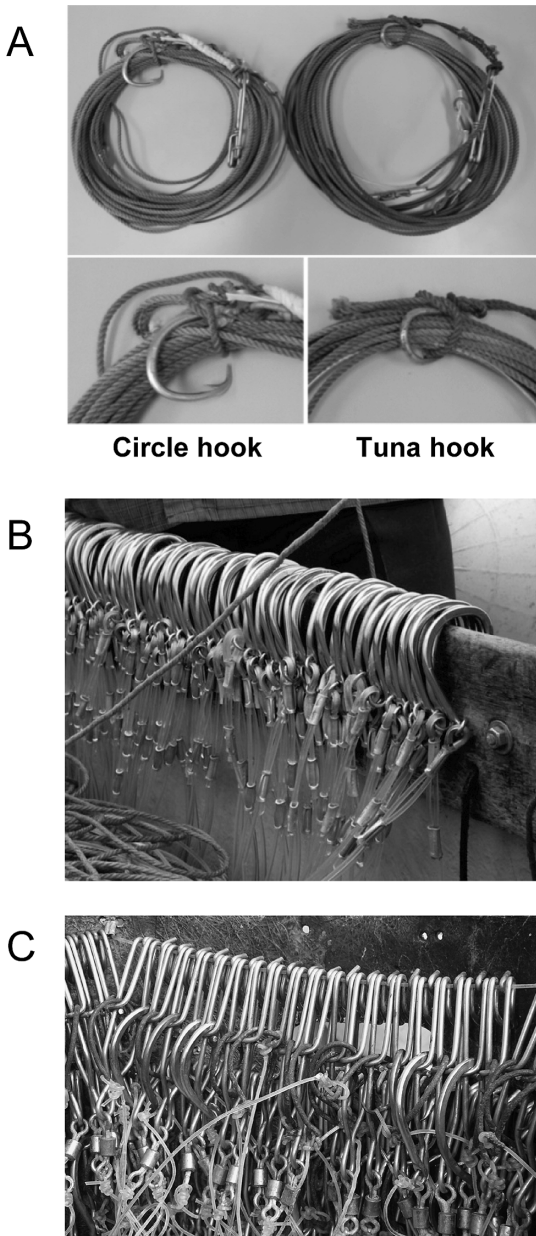


Figure 1. Branch line storages in some pelagic longline fisheries [(A) Japanese style, (B) Ecuadorian style, (C) and Panamanian style].

placed onto the coiled branch line and knotted tightly to the line (Fig. 1A). However, larger circle hooks are relatively difficult to fasten tightly because part of the hook (i.e., from the bend to the point) protrudes from the coiled line (Fig. 1A). Loosely-tied branch lines are more likely to entangle with each other in the basket boxes and the point of the hook protruding from the coiled line may become tangled with other branch lines stored in the box. Therefore, additional care and labor may be required

to avoid line problems of this kind during longline setting. Study quantifying entanglement rates and finding solutions to this problem (if it is significant) are warranted.

OFFSET.—There is some concern that circle hooks with large offset may not reduce deep-hooking of non-target species, in particular sea turtles. It is generally believed that a large offset angle would negate the effect of circle hooks in reducing catch rates of sea turtles and might increase the incidence of foul hooking. However, a small offset angle has little impact on sea turtle catch rates. Some guidelines for sea turtles (e.g., FAO 2005) recommend offset angles of $<10^\circ$, although there is little scientific basis for this threshold. Swimmer et al. (2010) reported that comparative fishing experiments using 14/0 circle hooks with and without a 10° offset resulted in no significant differences in the catch rates of sea turtles between the two types of hooks.

With regard to practical utility, the offset angle is expected to primarily influence the baiting process. Baiting of hooks becomes easier with larger offset angles, particularly with circle hooks that have incurved points because the point bent sideways relative to the shank facilitates the baiting process. However, studies demonstrating if, and by how much (i.e., time cost), baiting is impaired at different degrees of offset have not been conducted.

INCURVED POINT.—An incurved point is a distinguishing attribute of circle hooks. For both target and non-target species, increasing incurved points should result in less deep-hooking and more hooking in the jaw or mouth. The incurved point angle also affects the dehooking and hook retrieval process. Hooks with large incurved point angles require more care and effort when attempting to remove the hook, especially for sea turtles. A large twisting movement is required to remove a circle hook with a large incurved point angle. However, only limited space and angle are often available in the buccal cavity of hooked animals to twist circle hooks using dehookers.

Increase in the angle of the incurved point also requires greater care when baiting hooks, as well as when handling branch lines during line setting. In Japanese pelagic longline fisheries, hooks are taken from coiled branch lines for baiting during line setting. In the most rapid deployment case, one branch line is cast every 5 s, and therefore fishermen are required to handle branch lines as smoothly and quickly as possible. When fishermen remove circle hooks from coiled branch lines, hooks sometimes entangle with branch lines, causing line setting problems. In Ecuadorian artisanal longliners, hooks are placed side by side on a wooden bar in the order in which they are attached on the line (Fig. 1B). During line setting, fishermen remove hooks from the bar quickly to bait and cast them smoothly. Circle hooks with greater incurved point angles are more likely to create difficulties for the fishermen when they are removing the hooks because incurved points of the hooks get stuck into the bar more easily. Modification of hook storage methods which do not force the fishermen to alter their line setting procedures could be a pragmatic solution to alleviate this problem. In contrast, incurved point angle does not affect line setting performance in monofilament longlines, which are widely used in the United States and Central American countries. In these fisheries, each hook is hung on a snap of respective branch line (Fig. 1C). Fishermen can remove circle hooks from the snaps quickly and easily, even if the hooks have greater incurved angle. Thus, with regard to the incurved point, it is necessary to find the balance between the effectiveness of reducing deep-hooking and the logistics of gear use. Likewise, finding the appropriate

balance among incurred point angle, offset, and hook width is a key issue in the design of circle hooks (Yokota et al. 2006b).

OTHER FACTORS.—The straight total length of the shank is another important factor in hook design, as is front length for many of the same reasons mentioned in relation to hook width. While we emphasize the importance of distinguishing the effect of individual elements of hook morphology, it is also important to evaluate these effects in light of the total hook design.

Another issue is the cost of manufacturing hooks, as manufacturing costs increase with hook size. Hook prices also depend on market demand. For example, in Japan, when large-sized circle hooks (size: 5.2 sun) were substituted for conventional tuna hooks (size: 3.8 sun), the costs more than doubled. Clearly, consideration of cost issues is also important when considering the introduction of circle hooks to commercial fisheries.

SUMMARY.—There are several aspects of circle hook design that could affect their function and practical utility, but that have not been quantitatively tested. We argue that such testing is necessary (Yokota et al. 2006b, Mituhasi and Hall 2011) to not only reduce catch rates and/or deep-hooking rates of non-target species while maintaining catch rates of target species, but also to ensure the practical utility of circle hooks in each longline fleet.

When a commercial longline fleet is considering the adoption of circle hooks, it is useful to present fishermen with several designs of circle hooks. This would provide opportunities for fishermen to choose and test preferable fishing hooks that could meet their specific requirements for function, practical utility, and cost. Circle hooks designed by fishermen themselves should also be taken into consideration if these circle hooks provide similar benefits. For example, some Japanese fishermen use custom-designed hooks improved through years of their own experience. Scientists should respect their experience and perform quantitative evaluation of circle hooks combining scientific information with the knowledge and technology of fishermen and hook manufacturers.

We also should consider the interaction of particular circle hook designs with other factors such as setting depth, bait type, and size. In this respect, we should not depend solely on the use of circle hooks to solve the bycatch issues. For instance, use of fish bait is quite effective in reducing sea turtle bycatch in pelagic longline fisheries—fish bait can reduce catch rates of sea turtles (approximately 70%) as compared to squid bait (Watson et al. 2005, Yokota et al. 2009). Deep-setting longline gear also has the potential to reduce sea turtle bycatch (Shiode et al. 2005, Beverly et al. 2009). The effectiveness and feasibility of each mitigation measure may be fishery-specific. Because available mitigation measures depend on fishing styles, area, target and non-target species, and other variables, successful measures will necessitate a combination of alternative measures. Each fishery should be considered separately and an optimum solution for sustainable fisheries selected based on best available science and fishermen's experience. Further research is key for improved conservation and management of fishery resources.

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