Marine Policy 65 (2016) 68–75

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Influence of hook type on catch of commercial and bycatch species in an Atlantic tuna fishery

Hsiang-Wen Huang [a], Yonat Swimmer [b,*], Keith Bigelow [b], Alexis Gutierrez [c], Daniel G. Foster [d]

[a] Institute of Marine Affairs and Resource Management, Center of Excellence for the Oceans, National Taiwan Ocean University, Taiwan
[b] NOAA Fisheries, Pacific Islands Fisheries Science Center, Honolulu, HI, USA
[c] NOAA Fisheries, Office of Protected Resources, Silver Spring, MD, USA
[d] NOAA Fisheries Southeast Fisheries Science Center, Pascagoula, MS, USA

ARTICLE INFO

Article history:
Received 2 October 2015
Received in revised form
19 December 2015
Accepted 19 December 2015

Keywords:
Circle hook
Tuna
Sea turtle bycatch
Deep set longline
Regional fisheries management organization

ABSTRACT

Experimental sets were conducted on a Taiwanese deep set longline fishing vessel operating in the tropical Atlantic Ocean to evaluate the effects of relatively wide circle hooks vs. Japanese tuna hooks with respect to catch rates of both target and incidental species. On circle hooks there were significantly higher catch rates of bigeye tuna (*Thunnus obesus*), yellowfin tuna (*T. albacares*), swordfish (*Xiphias gladius*) and blue sharks (*Prionace glauca*) as compared to tuna hooks. Significantly higher rates of albacore (*T. alalunga*) and longbill spearfish (*Tetrapterus pfluegeri*) were caught on Japanese tuna hooks as compared to circle hooks. Overall, 55 sea turtles were incidentally captured, most ($n=47$) of which were leatherback turtles (*Dermochelys coriacea*), and capture rates were similar between hook type. Immediate survival rates (percentage alive) when landed were statistically similar for all major target fish species and sea turtles independent of hook type. Most (64%) sea turtles were hooked on the first and second branchlines closest to the float, which are the shallowest hooks deployed on a longline. Lengths of six retained species were compared between hook types. Of these, swordfish was the only species to show a significant difference in length by hook type, which were significantly larger on circle hooks compared to tuna hooks. Additional incentives to use circle hooks would be the increased catch rate in targeted bigeye tuna over traditional Japanese tuna hooks. This international collaboration was initiated in direct response to regional fisheries management organization recommendations that encourage member countries to conduct experiments aimed to identify means to reduce bycatch in longline fishing gear. Information presented may be useful for managers in developing international fisheries policies that aim to balance increases in commercial fishery revenue and endangered species protection.

1. Introduction

The incidental capture of non-target species occurs in a broad range of fisheries, including trawl gear, gillnets, purse seines and longlines and is of global concern [1]. Much attention has been directed at the deleterious effects of pelagic longline fishing (PLL), a gear type present in all the world's oceans that has been associated with high incidental catch and mortality of numerous incidentally-captured species [2,3]. Pelagic longline gear is generally set "shallow" when targeting swordfish (*Xiphias gladius*) while deeper lines are generally set when targeting tunas (*Thunnus spp.*), though there may be regional variations. The incidental catches of "non target" species can be divided into two types: incidental yet retained for either commercial value or utilization (eg., used as bait), or discarded as bycatch. Bycaught species are those that are generally released to sea given their lack of commercial value or due to their protection under the law, and thus species considered bycatch differs regionally. Marine mammals, sea birds, sea turtles and certain finfish are considered bycatch as they are protected under various national and international laws.

Extensive research has been undertaken to identify means to maximize capture of target species while minimizing the impacts to incidental captures, especially those that are protected under various laws. The likelihood of catching specific species is largely dependent on a suite of environmental and operational factors, such as seasonality, temperature, bait type, hook depth, etc. In PLL, important variables to consider can include specifics such as hook shape, hook size, bait type, gear depth, time of longline set and retrieval, and fishing location [3,12,13]. Recent research has identified a potential conservation value to the use of circle hooks,

* Correspondence to: 501 W. Ocean Blvd., Long Beach, CA 90802, USA.
E-mail address: yonat.swimmer@noaa.gov (Y. Swimmer).

http://dx.doi.org/10.1016/j.marpol.2015.12.016
0308-597X/

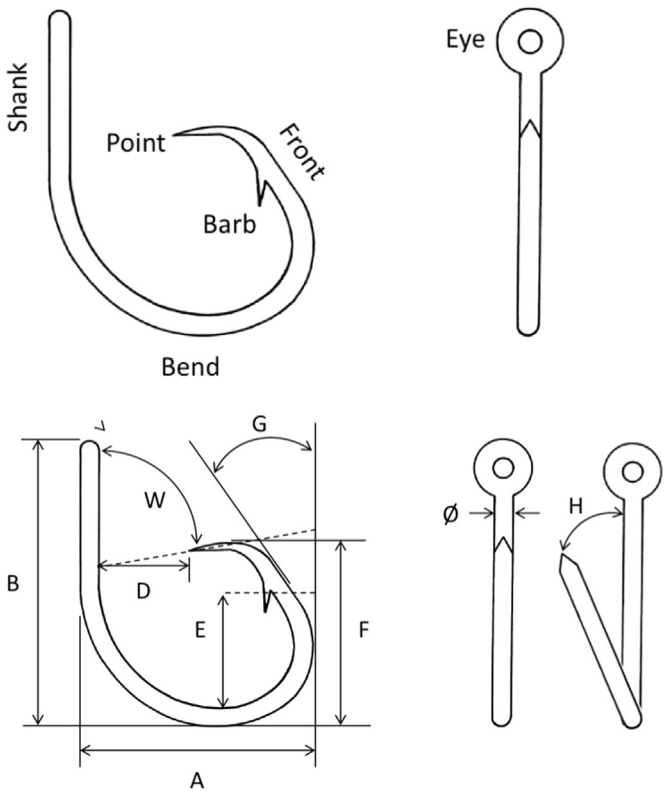

Fig. 1. Anatomy of a circle hook. Basic components (upper panel) and measurements (lower panel): minimum width (A); straight total length (B); gape (D); throat (E); front length (F); point angle (W); front angle (G); offset angle (H).

which is a fish hook whereby the point of the hook curves inward perpendicular to the shank (Fig. 1), leaving the point less exposed compared to other hook types [4–6]. It is presumed that this shape results in failed attempts to digest the baited hook and can also reduce the frequency of "foul-hooking" that results when an animal is incidentally snagged by an exposed hook point. The shape differences between circle hooks and other tuna hooks is likely a contributing factor to species' catchability given that circle hooks are generally considerably wider in their width (*A*) dimension (Fig. 1).

It is widely believed that circle hooks may result in less serious injury to both fishes and bycatch species due to the increased probability of external hooking on the body as compared to more frequent internal ingestion of narrower J-hooks or tuna hooks [7]. External hookings are generally considered to result in less severe injury and with a higher likelihood of post-release survival as compared to damage caused by internal ingestions. The potential for higher rates of survival is especially valuable for discarded or bycatch species that are released to sea with the expectation of high rates of survival, thereby minimizing population-level effects from the fisheries interactions.

Of particular concern regarding incidental captures is that of sea turtle bycatch. All sea turtle species are listed as endangered or threatened and are protected under both Taiwanese and U.S. laws. Numerous studies have shown relatively high rates of sea turtle captures in longline gear in all major ocean basins including the Atlantic Ocean[4,8,9], Pacific Ocean [10–13], and Mediterranean Sea [14,15]. Given the potentially negative impacts on sea turtle populations due to capture in longline fisheries, in particular leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) turtles, there has been extensive research toward identifying mitigation methods to reduce rates of incidental capture and increase the probability of survival in the event of a fisheries interaction. The use of relatively large (wide) circle hooks in combination with finfish bait has been shown to significantly reduce the frequency of sea turtle hooking compared to J-shaped hooks or tuna hooks with squid bait in a number of longline fisheries [4,16,17].

Based on the numerous conservation values attributed to circle hooks, particularly in shallow-set swordfish-targeted fisheries, the United States (U.S) has mandated use of circle hooks and finfish as bait in shallow set longline fisheries in the Pacific Ocean. U.S. fisheries targeting highly migratory species in the Atlantic and Gulf of Mexico are required to use circle hooks but not necessarily fish bait. More information on U.S. fishing regulations aimed to protect sea turtles can be found at www.nmfs.noaa.gov/pr/species/turtles/regulations.htm. Internationally, some regional fisheries management organizations (RFMOs) encourage circle hook use in shallow set longline fisheries (e.g., Western and Central Pacific Fisheries Commission Conservation and Management Measure 2008-03). The majority of tuna RFMOs have adopted measures requesting members to conduct experimental research on circle hooks for their longline fleets (e.g., Inter-American Tropical Tuna Commission Resolution 07-03).

Adoption of relatively wide circle hook use may be hindered by concerns that use of circle hooks may result in reduced capture rates of target species, in particular swordfish, which has been previously reported [4,7,16]. There have also been reports of similar catch rates of swordfish between circle hooks and traditional hooks in experimental fisheries [18,31]. Despite efforts to standardize even at the level of terminal gear, the variability in findings suggest the importance of factors such as bait type as well as hook dimensions in species' catchabilities. Unlike the numerous findings of reduced capture of swordfish on circle hooks, however, there are consistent findings that capture rates for tuna species are often higher on circle hooks compared to J and tuna hooks [4,8,18].

Despite extensive research aimed to determine the conservation benefit of circle hook use in shallow set longline fisheries, there is limited information on how hook shape influences capture rates of bycatch species in deep-set tuna longline fleets. In the case of sea turtles, it is well established that capture rates of sea turtles caught on deep set longline gear are substantially lower than on shallower set hooks [19,20], which is consistent with the relatively shallow distribution of sea turtles throughout their ranges [21–23]. However, the depth of deep set gear often results in a high probability of mortality due to drowning, as seen in relatively deep dwelling olive ridley turtles captured in a North Pacific Ocean longline fishery [24]. It remains unclear how circle hook use in a deep set fishery affects the capture rates of bycatch species.

This collaborative international research was conducted in direct response to RFMO recommendations that encourage member countries to conduct experiments aimed to identify means to reduce bycatch in longline fishing gear. Of the three Taiwanese longline fleets operating in the Atlantic Ocean, the bigeye tuna fleet in the tropical areas has the highest rate of sea turtle captures compared to the albacore (*Thunnus alalunga*) fleets in the north and south Atlantic [25]. The primary goals of this study were to better understand the potential conservation value of using circle hooks in a deep set tuna fishery. Specifically we looked at relationships between hook type on catch composition of target and non-target species, the rates of immediate survival (percentage of animals alive at gear retrieval–haul back), as well as catch sizes as a function of hook type. This work represents a unique collaboration between the U.S. and Taiwanese governments. Working in conjunction with industry, this study compared the catch rates of target species, such as bigeye tuna (*T. obesus*), yellowfin tuna *(T. albacares)*, swordfish, and bycatch (discarded) species (e.g., sea turtles) using 18/0 circle hooks and a traditional Japanese style tuna hook (4.2 sun) in a deep set longline fishery in the tropical Atlantic Ocean.