Biological Conservation 160 (2013) 214–223

Contents lists available at SciVerse ScienceDirect

Biological Conservation

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

Circle hooks: Developing better fishing practices in the artisanal longline fisheries of the Eastern Pacific Ocean

Sandra Andraka [a,*], Moisés Mug [a], Martin Hall [b], Maite Pons [c], Lucas Pacheco [d], Manuel Parrales [e], Liliana Rendón [e], María L. Parga [f], Takahisa Mituhasi [g], Álvaro Segura [h], David Ortega [i], Erick Villagrán [j], Sara Pérez [j], Celina de Paz [k], Salvador Siu [k], Velkiss Gadea [l], Julián Caicedo [m], Luis A. Zapata [m], Jimmy Martínez [e], Pablo Guerrero [n], Michael Valqui [o], Nick Vogel [b]

[a] WWF, Latin America and the Caribbean Program, Curridabat, 400 m sur Plaza del Sol, P.O. Box 629-2350, San Francisco de Dos Ríos, San Jose, Costa Rica
[b] Inter-American Tropical Tuna Commission (IATTC), 8604 La Jolla Shores Drive, La Jolla, CA 92037-1508, USA
[c] Centro de Investigación y Conservación Marina (CICMAR), Giannattasio km. 30.5, El Pinar, Canelones CP 15008, Uruguay
[d] WWF, Panama Office, 235 Building, 1st Floor, Ciudad del Saber, Clayton CP 08160-7168, Panama
[e] Escuela de Pesca del Pacífico Oriental/WWF, Calle 34, Av. Flavio Reyes, Manta, Ecuador
[f] SUBMON, Rabassa 49-51, local 1, Barcelona 08024, Spain
[g] Overseas Fishery Cooperation Foundation of Japan, Minato-ku, Tokyo 107-0052, Japan
[h] WWF, Costa Rica Office, Curridabat, 400 m sur Plaza del Sol, P.O. Box 629-2350, San Francisco de Dos Ríos, San Jose, Costa Rica
[i] WWF, Oaxaca Office, Rincón del Acueducto No. 302, Fraccionamiento Acueducto, Oaxaca, Oax., Mexico
[j] WWF, Mesoamerican Reef Office, 15 ave. 13-45, Zona 10, Oakland, Guatemala City, Guatemala
[k] Centro de Desarrollo de la Pesca y la Acuicultura (CENDEPESCA), Oficinas Centrales, 13ª, Calle Oriente, Entre Final 1ª, Avenida Norte y Final Avenida Manuel Gallardo, Santa Tecla, Depto. La Libertad, El Salvador
[l] Fauna and Flora International (FFI), Calle Esperanza No 578, Reparto San Juan, Managua, Nicaragua
[m] WWF Colombia, Carrera 35 No. 4A-25, Cali, Colombia
[n] WWF Galápagos Calle Piqueros y 18 de Febrero, Puerto Ayora, Santa Cruz Island, Galapagos, Ecuador
[o] WWF Peru, Trinidad Morán 853, Lince, Lima 14, Peru

ARTICLE INFO

Article history:
Received 9 May 2012
Received in revised form 21 January 2013
Accepted 27 January 2013

Keywords:
Bycatch mitigation
Circle hooks
Surface longline fisheries
Sea turtles

ABSTRACT

Since 2004, governments and non-governmental organizations, together with the fishing communities from nine countries, from Mexico to Peru, have implemented joint efforts to reduce incidental mortality of sea turtles in artisanal longline fisheries of the Eastern Pacific Ocean (EPO). These countries are involved in a Regional Sea Turtle Bycatch Program to achieve this goal. Circle hooks have been proposed as a way to mitigate incidental mortality of sea turtles. Thus, we analyze the performance of circle hooks in relation to J-style and tuna hooks on the hooking rates of target and non-target species in the artisanal surface longline fisheries of three of the participating countries with the largest sample sizes (Ecuador, Panama and Costa Rica). These fisheries target mahi-mahi, *Coryphaena hippurus*, or a combination of tunas, billfishes and sharks (TBS), and use different techniques and gear configurations to catch their targets. For the TBS fishery we presented the results of comparisons between tuna hooks and 16/0 circle hooks from Ecuador, Panama and Costa Rica, and between tuna hooks and 18/0 circle hooks in Costa Rica. For the mahi-mahi fishery, we analyzed the performance of 14/0 and 15/0 circle hooks in Ecuadorian vessels and 16/0 circle hooks in Costa Rican vessels vs. the traditional J-style hooks. A total of 730,362 hooks were observed in 3126 sets. Hooking rates for target and non-target species were not consistent for all fisheries and countries analyzed. However, circle hooks reduced sea turtle hooking rates in most of the comparisons.

1. Introduction

One of the key issues affecting marine conservation and fisheries management on a global scale is incidental mortality of non-target species (bycatch) during fishing operations. There is widespread interest in understanding and assessing the impacts of fishing on marine ecosystems, but in many cases, lack of information makes such assessment fraught with uncertainty. Several studies were focused on industrial longline fisheries around the world (Kerstetter and Graves, 2006; Sales et al., 2010; Ward

* Corresponding author. Tel.: +506 8365 0845; fax: +506 2253 4927.
E-mail addresses: sandra.andraka@wwf.panda.org (S. Andraka), moisesmug61@gmail.com (M. Mug), mhall@iattc.org (M. Hall), maite.pons@cicmar.org (M. Pons), lucasrovira@yahoo.es (L. Pacheco), mano_parmar@hotmail.es (M. Parrales), lilianarendonm@hotmail.com (L. Rendón), mariluz@submon.org (M.L. Parga), mituhasi@fish.kagoshima-u.ac.jp (T. Mituhasi), alvaro.segurah@gmail.com (Á. Segura), dortega@wwfmex.org (D. Ortega), erick.villagran@gmail.com (E. Villagrán), sacapera@gmail.com (S. Pérez), celina_dpaz@hotmail.com (C.de Paz), salvadorsiu@gmail.com (S. Siu), velkiss.gadea@gmail.com (V. Gadea), julian_1@hotmail.com (J. Caicedo), lazapata@wwf.org.co (L.A. Zapata), jmartinez@mardex.com.ec (J. Martínez), pablo.guerrero@wwfgalapagos.org.ec (P. Guerrero), michael.valqui@gmail.com (M. Valqui), nvogel@iattc.org (N. Vogel).

0006-3207/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.01.019

et al., 2009; Yokota et al., 2006), but recent studies highlight the need to quantify the impacts of small-scale and artisanal fisheries on the different components of the megafauna that inhabit or migrate through the areas where those fisheries operate (Bugoni et al., 2008; Gillett, 2011; Lewison et al., 2004; Peckham et al., 2007). In the Eastern Pacific Ocean (EPO) the main incidental interactions of the longline fisheries targeting large pelagic fishes involve sea turtles (Largacha et al., 2005; Swimmer et al., 2010), although coastal gillnets also affect these populations (Peckham et al., 2007).

1.1. Artisanal longline fisheries of the region

Artisanal fisheries, which include a large number of small vessels (generally less than 10 m long), can collectively have a great impact on local turtle populations, and this issue is now gaining international attention (FAO, 2009). In the EPO, the artisanal longline fishery plays a significant role in local communities and economies (FAO, 2009; Peralta, 2009; Salas et al., 2011). There are surface and bottom longlines in this region. Surface longline fisheries can be classified in two large categories because of differences in hooks used and rigging; those targeting tunas (mainly yellowfin tuna, *Thunnus albacares*), billfishes (swordfish, *Xiphias gladius*, and marlins, *Makaira* spp., *Istiompax* spp., *Tetrapturus* spp. and *Kajikia* spp.) and sharks (dominated by Carcharhinidae) that will be abbreviated as TBS fisheries; and those targeting mahi-mahi, also called common dolphinfish, *Coryphaena hippurus* and referred to as mahi-mahi fisheries. A variety of fish species caught in both fisheries are listed in Appendix A. South American countries (i.e. Peru and Ecuador) show a marked fishing season for mahi-mahi in the austral summer and fish for TBS the rest of the year. Seasonal differences are less clear in other countries (from Costa Rica to Mexico) and there are vessels that pursue the same targets all year round depending on the availability of the resources in their fishing grounds. Panamanian TBS fishery targeting tuna shows a more consistent fishing season from April to August.

1.2. Sea turtles of the Eastern Pacific

Five species of sea turtles; olive ridley, *Lepidochelys olivacea*, black/green, *Chelonia mydas*, hawksbill, *Eretmochelys imbricata*, loggerhead, *Caretta caretta*, and leatherback, *Dermochelys coriacea* are found in the EPO. The olive ridley is the most abundant and most commonly captured by the coastal longline fisheries followed by the black/green sea turtle (Largacha et al., 2005; Swimmer et al., 2010). The remaining three species are much less common and they are subject of conservation concerns. For example, the Pacific populations of leatherback sea turtle are severely depleted (Limpus and Limpus, 2003; Sarti Martinez et al., 1996; Spotila et al., 2000), and are listed as critically endangered by the International Union for Conservation of Nature (IUCN, 2012). At their main nesting beaches in Mexico and Costa Rica, the reduction in the number of nesting turtles has reached 90% and 95% of the levels in the 1980s (Santidrián Tomillo et al., 2007; Sarti Martinez et al., 2007). These declines have been caused by multiple factors: egg poaching, predation on females or hatchlings from domestic or wild predators, environmental degradation and habitat loss (Wallace and Saba, 2009). But the incidental mortality caused by fisheries is clearly an important factor, because of the overlap of fishing grounds with sea turtle habitats and migratory routes (Shillinger et al., 2008).

1.3. The Eastern Pacific Regional Sea Turtle Bycatch Program

The program began in Ecuador in 2004, and has since expanded to 8 other countries: Mexico, Guatemala, El Salvador, Nicaragua, Costa Rica, Panama, Colombia and Peru. This participatory program involves the voluntary testing of circle hooks to reduce the mortality of sea turtles (Gilman et al., 2006; Watson et al., 2005), and other activities such as training of fishers in on-board sea turtle handling techniques to improve the survival of the turtles released after hooking or entanglement. Given the social and economic conditions in which these fisheries operate, it is necessary to achieve the objective without diminishing the productivity of the fisheries, and the efficiency of their operations.

This program was funded, organized and implemented by international and national NGOs, regional fisheries management organizations, national fisheries agencies and fishers cooperatives from the countries involved. It is the first truly regional, large scale, and consistent experimental effort to test circle hooks in multiple fisheries in the world.

1.4. Goal

Circle hooks can affect sea turtle mortality in at least three ways: (A) reducing the hooking rates of sea turtles; (B) reducing the proportion of sea turtles that are encountered dead at haulback; or (C) reducing the proportion of deep-hookings which are assumed to increase post-release survival (Ryder et al., 2006). The information from (A and B) is quite easy to acquire, and comes from direct observations. The information needed to evaluate in (C) is more complicated to obtain (Parga, 2012), and will be the outcome of tagging experiments (Swimmer et al., 2006), laboratory studies, or other ways to measure the likelihood of survival after hooking in different locations of the sea turtle body (external or internal).

In this study we focus on (A) analyzing the performance of circle hooks in relation to J-style hooks on the hooking rates of target and non-target species in the artisanal surface longline fisheries from the countries in which the Program had a longer period of study (Ecuador, Panama and Costa Rica). Some data for the other participating countries are available in different reports (e.g. Hall et al., 2007, 2008; Largacha et al., 2005; Mug et al., 2008).

2. Material and methods

2.1. Sampled fleet

The longline's main lines used in the region are made of two different materials; a buoyant type, polypropylene (PP) or polyethylene (PE) cordages, and a non-buoyant type, polyamide (PA) monofilament. Almost all longline vessels from Ecuador used the first type, while the latter is principally used by the longline fleets from Panama and Costa Rica. There are distinctive differences in gear geometry between the two types of longlines. A feature of surface longlines made of PP or PE cordages is that the mainline extends at or just below the surface of the sea because of its positive buoyancy. Therefore, all hooks are set at approximately the same depth. In contrast, PA monofilament, because of its negative buoyancy has a tendency to sink and forms a more pronounced catenary curve. Table 1 shows the principal configuration of longline gears used in the countries analyzed.

A variety of fishing hooks are used in longline fisheries of the region (Mituhasi and Hall, 2011). Fishers from Ecuador, Panama and Costa Rica use tuna hooks for TBS longlines although nominal hook sizes differ among countries (Table 1). For mahi-mahi, J-style hooks are used in Ecuador and Costa Rica. The sizes of these hooks in Ecuador (Nos. 4 and 5) are smaller than those used in Costa Rica (No. 2). In the case of Panama, no comparisons were analyzed in the present study because mahi-mahi fishers use only circle hooks (mainly 14/0) since at least 25 years ago.

There are also regional characteristics in longline baits. Jumbo flying squid, *Dosidicus gigas* is the main bait species for both TBS