Biological Conservation 142 (2009) 2620–2630

Contents lists available at ScienceDirect

Biological Conservation

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

Estimating the odds of survival and identifying mitigation opportunities for common bycatch in pelagic longline fisheries

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ARTICLE INFO

Article history:
Received 7 October 2008
Received in revised form 13 May 2009
Accepted 8 June 2009
Available online 1 July 2009

Keywords:
Bycatch mitigation
Hooking survival
Circle hooks
Odds ratios
Swordfish
Tuna fisheries

ABSTRACT

To evaluate how fishing practices affect bycatch survival and to identify opportunities to reduce bycatch mortality, we estimated the odds of hooking survival for common bycatch species in the Canadian longline fishery for swordfish (*Xiphias gladius*) and tunas (*Thunnus* spp.) fishing in the North Atlantic. Generalized linear models, with binomial response, were based on 859 sets observed between 2001 and 2004 and were tested using data from 2005 and 2006. Bycatch included targeted species in poor condition or below regulatory size limits. Odds of survival were two to five times higher for swordfish, yellowfin tuna (*Thunnus albacares*), pelagic stingray (*Pteroplatytrygon violacea*), porbeagle (*Lamna nasus*) and blue shark (*Prionace glauca*) caught on circle hooks compared to J-hooks during the 2001–2004 period. Further, odds of severe hooking injuries decreased for three shark species caught on circle hooks. We found no conservation benefit for loggerhead turtles (*Caretta caretta*) from circle hook use. Increased circle hook use coincided with increased targeting and higher landings of tunas. Hooking survival rates and, therefore opportunities to reduce bycatch mortalities differed among the 10 species commonly discarded or released. Where the odds of survival to the time of release are high (e.g., loggerhead turtles, pelagic stingray, blue shark), methods to reduce post-release mortality can be considered. Where the odds of hooking survival are low (e.g., swordfish and longnose lancetfish, *Alepisaurus ferox*), methods to reduce encounter rates would have greater conservation impact.

1. Introduction

Opportunities to reduce bycatch mortality occur throughout the fishing process, from avoidance of areas or seasons with high concentrations of unwanted catch to handling practices that increase post-release survival (Hall, 1996). Multi-species commercial fisheries, such as pelagic longline fisheries for swordfish (*Xiphias gladius*) and tunas (*Thunnus* spp.), discard or release a range of species and size classes. Understanding differences in the likelihood of survival among these groups of animals helps identify opportunities to reduce bycatch mortality. For species, or sizes classes, that can survive the capture process, methods to reduce post-hooking mortality can be considered in fisheries and conservation management strategies. For bycatch with high hooking mortality levels, management strategies should focus on earlier stages in the capture process, such as minimizing encounter rates.

Hooking survival rates may differ among species and among size classes within species. In catch and release recreational fisheries, fishing choices such as hook and bait types used, retrieval time and handling practices affect both hooking survival rates and likely post-hooking survival, through hooking injury and severity (e.g., Muoneke and Childress, 1994; Prince et al., 2007; Reeves and Bruesewitz, 2007). Size effects, with smaller fish having lower survival rates, have been reported in commercial hook and line fisheries (e.g., Neilson et al., 1989; Milliken et al., 1999; Diaz and Serafy, 2005). Hooking survival rates for species caught on pelagic longline gear ranges from less than 10% to nearly 100% survival at haulback when the gear is retrieved (Ward et al., 2004; Kerstetter and Graves, 2006a). Estimates of post-release survival are similarly variable. Research using satellite telemetry has shown survival levels of 31% to 100% for a few bycatch species released from pelagic longline fisheries (e.g., Hays et al., 2003; Chaloupka et al., 2004; Kerstetter and Graves, 2006b; Moyes et al., 2006).

Pelagic longlines, consisting of a main line suspended by floats and with baited hooks hanging below, are used to fish swordfish and tuna worldwide. Although the general design is simple, differences in how and where the gear is fished (such as fishing depth, baits and hooks used, setting time and locations) affect catch rates of target and bycatch species (e.g., Stone and Dixon, 2001; Ward et al., 2004; Beverly et al., 2009). Much research in swordfish and

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0006-3207/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biocon.2009.06.010

tuna longline fisheries has focused on the use of circle hooks to reduce bycatch catch rates, hooking mortality and post-hooking mortality – especially among marine turtles (Watson et al., 2005; Read, 2007; Brazner and McMillan, 2008). The Canadian fleet began switching to circle hooks in 1996. Now, over three-quarters of the hooks fished are circle hooks (DFO, 2004; T. Atkinson, Hi-Liner Fishing Gear pers. comm., 2008). Increased circle hook use coincided with increased targeting and catch rates of bigeye (*Thunnus obesus*) and yellowfin tunas (*T. albacares*) and a shift from a competitive to an individual quota management system. Because of these changes in the Canadian pelagic longline fleet in the North Atlantic, this fishery offers a unique opportunity to evaluate efficacy of this bycatch reduction method in a rapidly changing commercial fishery.

Reducing harm to or mortality of bycatch – defined here as captured animals returned to the sea, either discarded dead or released alive – is a management and conservation focus. Bycatch from this pelagic longline fishery includes species of listed by international conservation organizations, such as leatherback (*Dermochelys coriacea*) and loggerhead turtles (*Caretta caretta*); commercially fished species for which there are landings or size-based regulations such as bluefin tuna (*Thunnus thynnus*) and swordfish; and species such as pelagic stingray (*Pteroplatytrygon violacea*) and blue shark (*Prionace glauca*), for which there are limited or non-existent markets. Many of these species are common bycatch in other pelagic longline fisheries. Our objectives here are: (1) to identify bycatch species or size classes more (or less) likely to survive the capture process, (2) to identify those fishing variables that increase the odds of bycatch survival during capture and post-release, and (3) to evaluate how changes to fishing practices, directed at reducing harm or mortality levels of bycatch, affect numbers of landed catch. Information on species and size-specific hooking survival will help in evaluating mitigation strategies, and in developing fishery and conservation management plans for the suite of species discarded or released from pelagic longline gear.

2. Methods

2.1. Fisheries observer data

Data were obtained from the international observer program database, created and maintained by the Population Ecology Division of the Canadian Department of Fisheries and Oceans (DFO). As part of an ongoing monitoring program, fisheries observers identify species, estimate or measure animal length, and record whether bycatch were discarded dead or released alive. Fisheries observers do not record fish status (alive or dead) for fish brought onboard and later landed. Observers quickly assess bycatch release status, based on injuries and movement, when the gear is retrieved and bycatch are alongside the vessel. Bycatch release status is coded as unable to determine, alive (with and without injury), dead, shark bit and moribund. We reduced the release status category to alive and dead. Shark bit, moribund, and dead bycatch were coded as dead. Bycatch of unknown status were not included in these analyses.

Information on fishing operations such as location, starting and ending time, and details of gear configuration (i.e., longline length, hook type, bait used) are also recorded. The Canadian pelagic longline fleet fishes in the Northwest Atlantic along the Scotian Shelf and Grand Banks, and in international waters where other fleets also target pelagic fish (Fig. 1). The fleet is active from May through to November. There is no Canadian pelagic longline fleet fishing for swordfish or tunas in the Pacific. Since 2001, observer deployments are intended to reflect the spatial and temporal distribution of the fleet. Annual observer coverage, expressed as a percentage of sea days fished, has ranged from 5% to 18%. Gear is generally set shallow to fish in the upper 20 m (Brazner and McMillan, 2008).

Prior to the 2001 fishing season, observers' tasks were primarily related to landed species; length estimates or release condition of bycatch were not consistently recorded (M. Showell, DFO, pers. comm., 2006). We, therefore, chose data collected during the period 2001–2004 to model the effects of hook type, soak time and animal length on the odds of bycatch survival. Circle hooks (size 16/0) are the most common hook type used in this fishery (Brazner and McMillan, 2008) followed by J-hooks and offset J-hooks, either 8/0 or 9/0 (Fig. 2). Offset J-hooks had a 20–30° offset, similar to control hooks used by Watson et al. (2005). Soak time (T) was calculated as median set duration. Times were recorded at four points during each set: start and end of setting, and start and end of hauling. To determine the mid-point or median soak time, we averaged the shortest time hooks were in the water (end of setting until start of hauling) with the longest soak time (start of setting to end of hauling). Lengths (L), measured or estimated, included sea turtle carapace length, swordfish lower jaw fork length and fork length

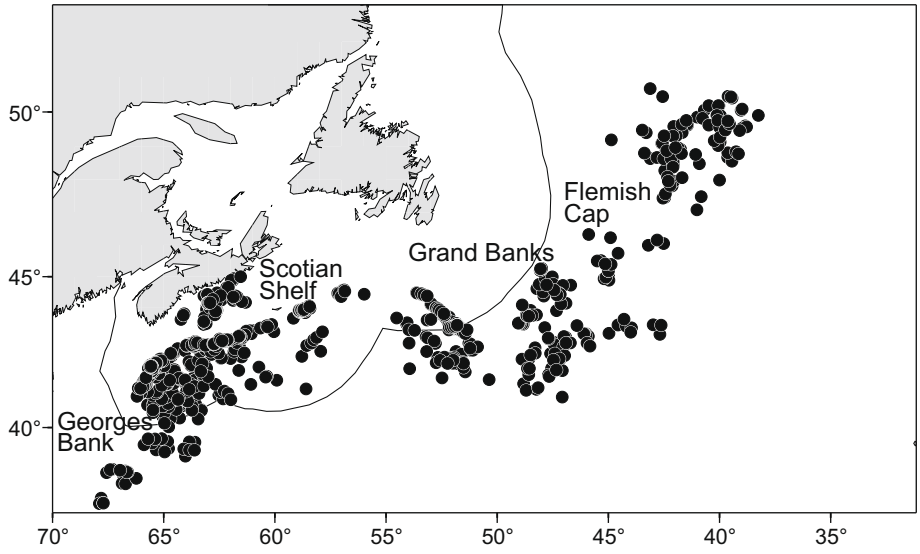

Fig. 1. Distribution of observed sets of the Canadian Atlantic pelagic longline fisheries for swordfish and tuna fished between 2001 and 2004. Boundary of the Canadian exclusive economic zone shown.