Global Ecology and Conservation 2 (2014) 181–189

Contents lists available at ScienceDirect

Global Ecology and Conservation

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

Original research article

Temporal hooking variability among sharks on south-eastern Australian demersal longlines and implications for their management

Matt K. Broadhurst[a], Paul A. Butcher[b], Russell B. Millar[c], Jen E. Marshall[a,*], Victor M. Peddemors[d]

[a] NSW Department of Primary Industries, Fisheries Conservation Technology Unit, PO Box 4321, Coffs Harbour, NSW 2450, Australia
[b] NSW Department of Primary Industries, National Marine Science Centre, PO Box 4321, Coffs Harbour, NSW 2450, Australia
[c] Department of Statistics, The University of Auckland, Private Bag 92019, Auckland, New Zealand
[d] NSW Department of Primary Industries, Sydney Institute of Marine Science, Mosman, NSW 2088, Australia

ARTICLE INFO

Article history:
Received 5 August 2014
Received in revised form 10 September 2014
Accepted 10 September 2014
Available online 22 September 2014

Keywords:
Bycatch mitigation
Carcharhinids
Carcharias taurus
Hook timer
Selectivity
Sphyrna

ABSTRACT

An experiment was done to quantify species-specific variation in temporal hooking rates from demersal longlines targeting various carcharhinids off south eastern Australia, with a view to reducing the incidental catches of protected species, including the scalloped hammerhead *Sphyrna lewini*, great hammerhead *Sphyrna mokarran* and grey nurse *Carcharias taurus*. The longline comprised a 9600 m mainline, separated into four sections (termed lines) each with 120 gangions (20 m apart) rigged with hook timers and 16/0 circle hooks baited with either sea mullet *Mugil cephalus* or eastern Australian salmon *Arripis trutta*. The mainline was deployed on each of 17 nights (between 19:30 and 23:30 h), with two lines retrieved after 7 and 14 h respectively. From a total of 8160 hooks, 246 timers were activated without hooking fish. Twenty-two species comprising 684 individuals were caught, including 52 *S. lewini*, 12 *C. taurus*, 11 *S. mokarran* and 1 loggerhead turtle *Caretta caretta*. Several environmental factors, including water temperature, moon phase and depth had mostly homogeneous, positive effects on catches. The only identified variables that might be used to considerably reduce the catches of *Sphyrna* were soak time and/or diurnal gear retrieval, with most individuals hooked during daylight. Simply mandating shorter deployments and within nocturnal retrieval might limit exploitation, especially among juveniles (<150 cm total length). For the studied fishery to approach sustainability, future research is required to investigate other gear modifications for improving size and species selectivity, and/or operational procedures for mitigating discard and escape mortalities.

1. Introduction

For the past 75 years, as part of a collectively managed commercial hook-and-line fishery in New South Wales (NSW) Australia, various large sharks including sandbar *Carcharhinus plumbeus*, common black tip *C. limbatus*, tiger *Galeocerdo cuvier*, dusky *C. obscurus* and spinner *C. brevipinna* routinely have been targeted (across all sizes) using demersal longlines (Macbeth et al., 2009). As part of commercial fishing reforms, the number of fishers was restricted in 1997, after which annual shark catches (150–220 mt of eviscerated weight) remained fairly steady until 2004–2007 when effort increased for

* Corresponding author. Tel.: +61 401347799.
E-mail address: j.marshall.27@student.scu.edu.au (J.E. Marshall).

http://dx.doi.org/10.1016/j.gecco.2014.09.005

carcharhinids; predominantly in response to international demand for fins (Macbeth et al., 2009). By 2007, total eviscerated weights had reached ∼460 mt p.a. Owing to what were considered unsustainable catches, restrictions were implemented at a total allowable combined catch of 160 mt for large shark species (i.e. carcharhinids) and a 500 kg weekly trip limit (Macbeth et al., 2009). Currently, the fishery is worth ∼A$5.6 million annually and although 337 endorsed fishers are permitted to use up to 1200 hooks per day, only ∼35% reported sharks in their annual catches between 2009 and 2013 (D. Ferrell—NSW DPI, pers comm).

In addition to the harvested catches, NSW demersal longliners historically have caught and discarded various unwanted organisms (collectively termed 'bycatch') (Macbeth et al., 2009). While few quantitative studies are available, it is known that bycatches can include threatened, endangered or protected (TEP) sharks, which under NSW state government classification include the great hammerhead *Sphyrna mokarran* (classified as vulnerable), scalloped hammerhead *S. lewini* (endangered), grey nurse *Carcharias taurus* (critically endangered) and great white *Carcharodon carcharias* (vulnerable). Populations of all four species have been seriously depleted through overfishing, but of particular concern is *C. taurus*, with an estimated Australian east coast population of fewer than 1662 individuals (Lincoln Smith and Roberts, 2010). The potential for at least some associated mortalities of these four species during discarding has raised concerns over negative impacts on stocks (Macbeth et al., 2009; Robbins et al., 2013) and the subsequent cascading ecological consequences (Stevens et al., 2000; Ferretti et al., 2010; Worm et al., 2013).

The sustainability issues faced by the NSW demersal longline fishery are by no means unique, with global concerns directed towards many elasmobranch fisheries (Barker and Schluessel, 2005; Walker, 2007; Worm et al., 2013). The key issues reflect the slow growth and time to reach maturity, followed by low fecundity and long reproductive cycles of many species (Stevens et al., 2000). Such life history strategies mean that although some shark fisheries can be sustainably managed, in many cases there is a high danger of over exploitation, especially among larger species (Walker, 1998; Ferretti et al., 2008).

Like all aquatic resources, pivotal to sustainably managing shark populations is species-specific information on their biology, habitats and ecology, and the factors affecting their selection among fishing gears (Barker and Schluessel, 2005; Walker, 2007). The latter is particularly important, because it can facilitate appropriate targeting, and minimise key components of unaccounted fishing mortality (Broadhurst et al., 2006).

Unaccounted fishing mortality has been separated into various subcomponents, although of greatest concern for passive gears such as longlines are mortalities associated with discarding (on board the vessel) and escaping or dropping off hooks. Seldom are these latter mortalities quantified, let alone included in total allowable catch calculations. Irrespective of the fishing gear, there are three broad applied strategies for minimising unaccounted fishing mortality, including: (1) spatial and temporal effort regulation—either within (Ward et al., 2008; Beverly et al., 2009) or among gears (Hazin et al., 2008); (2) gear modifications to improve species and size selection (Erickson et al., 2000; Ford et al., 2008); and (3) modified handling practices that minimise discard mortality (Gilman et al., 2005; Milliken et al., 2009).

All three strategies have different utilities depending on the fishery and gear configurations being assessed. Further, one or more methods can be used in isolation or consecutively (Broadhurst et al., 2006). For longlines, where fishing success strongly relies on appropriate deployment within the required spatial and temporal scales (Medved et al., 1985; Stoner and Kaimmer, 2008), quantifying species-specific factors affecting catches might help to minimise unwanted mortalities. This would be considered a coherent starting point for any shark fishery that seeks to alleviate collateral impacts, and perhaps might ideally precede technical gear modifications—especially with the recent advancements in vessel monitoring systems (i.e. to facilitate compliance). In some cases, regulating and enforcing spatial and temporal deployments might be considered a viable option for improving selectivity.

Given the logic above, and considering there are limited relevant scientific data, the main aim of this study was to explore the potential for differences in temporal hooking among key target and non-target species, and any explanatory factors for the NSW demersal longline fishery. A secondary aim was to use this information to suggest coherent mechanisms by which effort might be regulated to improve selectivity (i.e. within strategy 1 above).

2. Methods

The research was completed on board two longliners (14 and 19 m, respectively) deploying the same conventional fishing gear off northern New South Wales (NSW), Australia during 17 fishing trips in 2013 (23 and 24 January; 7–9 February; 7, 9, 10, 14, 29 and 30 April; 8, 12, 14 and 15 May; and 5 and 6 June). All sampling was opportunistically done within the conventional spatial (between Nambucca Heads-30°34′S153°13′E and Wooli-29°56′S153°26′E) and temporal (January to July) ranges of the northern NSW demersal longline fishery (described by Macbeth et al., 2009).

2.1. Fishing gear and sampling

The longline comprised a 9600 m, 3.2 mm diameter (Ø) monofilament polyamide (PA) mainline, separated into four 2400 m sections (termed 'lines') by weights (30 kg), and ropes (8 mm Ø, polypropylene) leading to floats (30 mm Ø; Fig. 1A). Each of the four lines had 120 gangions (attached 20 m apart), comprising a stainless-steel clip rigged with 3.6 m of 3.2 mm Ø monofilament PA separated with a 70 mm, 60 g swivel, and terminating in a 16/0 stainless-steel, non-offset circle hook