Fisheries Research 175 (2016) 35–42

Contents lists available at ScienceDirect

Fisheries Research

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

Ray bycatch in a tropical shrimp fishery: Do Bycatch Reduction Devices and Turtle Excluder Devices effectively exclude rays?

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ARTICLE INFO

Article history:
Received 15 January 2015
Received in revised form 3 November 2015
Accepted 11 November 2015

Keywords:
Bycatch
Rays
Tropical shrimp trawling
Turtle Excluder Device
Bycatch Reduction Device

ABSTRACT

Worldwide, many species of elasmobranchs (Chondrichthyes: Elasmobranchii) are currently threatened by marine fisheries activity and are on the Red List of the International Union for Conservation of Nature (IUCN). Although Bycatch Reduction Devices (BRDs) for teleost fish and Turtle Excluder Devices (TEDs) are now widespread in tropical shrimp trawling, information on their ability to mitigate bycatch of elasmobranchs, particularly rays (Batoidea), is scarce and limited to only a few isolated fisheries. The objective of this study was to evaluate the potential of trawls fitted with a square-mesh panel BRD and super-shooter TED in reducing ray bycatch. In this study, 65 catch-comparison hauls were conducted in the Atlantic seabob shrimp (*Xiphopenaeus kroyeri*) fishery off Suriname. Trawls with a BRD and TED combination reduced ray catch rate by 36%. A 21% reduction in mean size indicated the preferential exclusion of large rays. Hence, high escape ratios were observed for *Dasyatis geijskesi* (77%), a large-sized species, while exclusion of the small species *Urotrygon microphthalmum* was not significant, although their disc width is small enough to pass through the meshes of the BRD. Furthermore, a size-dependent escape for the two most abundant mid-sized ray species *Dasyatis guttata* and *Gymnura micrura* was observed. Exclusion-at-size differed for both species, however, likely related to species-specific morphology or behavior in response to the TED. This study shows that the combination of BRD and TED causes an important reduction in ray bycatch in seabob shrimp fisheries off Suriname. The great reduction in catch of large-sized rays is positive, but the mortality of juvenile rays is likely to have negative consequences for their populations. We therefore recommend gear-based and non-gear adaptations to further reduce the bycatch of small-sized rays.

1. Introduction

Concern has been increasing recently regarding the capture and mortality of elasmobranchs in marine fisheries (Stevens et al., 2000). In contrast to most teleost fish, elasmobranchs are generally slow-growing and long-lived, with late attainment of sexual maturity, low fecundity and low natural mortality (e.g., Fisher et al., 2013; Goodwin et al., 2002). This K-selected life-history strategy makes them particularly vulnerable to exploitation in fisheries, implying that overfished populations have a low ability to recover (Graham et al., 2001). Several species of elasmobranchs have been decimated and even brought to the brink of local extinction due to fishing activity (Baum et al., 2003; Dulvy et al., 2000; Dulvy and Reynolds, 2002). Elasmobranchs are also often of low economic value in fisheries that target teleost fish or invertebrates, and are hence discarded as unwanted bycatch (Stevens et al., 2000). Furthermore, elasmobranch discards often remain unreported (Worm et al., 2013), resulting in insufficient information on their occurrence and population sizes worldwide. This is a major impediment for effective conservation measures (Bonfil, 1994; Stevens et al., 2000).

Many species of elasmobranchs are known to occur as bycatch in tropical shrimp trawling (Shepherd and Myers, 2005; Simpfendorfer, 2000). Nonetheless, efforts to reduce bycatch in shrimp trawls have so far focused mainly on teleost fish and sea turtles through the development of Bycatch Reduction Devices (BRDs) and Turtle Excluder Devices (TEDs) (Broadhurst, 2000). Several types of BRDs have proven to cause significant reductions in the bycatch of non-commercial teleost fish (e.g., Broadhurst, 2000; Heales et al., 2008; Rogers et al., 1997; Rulifson et al., 1992). TEDs,

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http://dx.doi.org/10.1016/j.fishres.2015.11.009

on the other hand, are highly effective in reducing sea turtle bycatch (Eayrs, 2007, 2012; Robins and McGilvray, 1999). Moreover, they act as sorting grids, and exclude any organism larger than the TED's bar spacing (typically 10 cm) from the trawl, including large-sized elasmobranchs (Brewer et al., 2006, 1998; Griffiths et al., 2006).

In the Atlantic seabob shrimp (*Xiphopenaeus kroyeri*) fishery off Suriname, trawls are required by law to be equipped with two widely-used devices: square-mesh panel BRD and super-shooter TED. In this fishery, these trawl adaptations have proven effective in reducing bycatch of non-target teleost fish (Polet et al., 2010) and sea turtles (S. Hall, pers. comm.), respectively. Average bycatch levels have now been reduced to 20–30% of the total catch by weight, and most bycatch species in this fishery are assumed to be within safe biological limits (Polet et al., 2010; Southall et al., 2011). These efforts have contributed to the certification of the Suriname seabob shrimp fishery by the Marine Stewardship Council (MSC) in 2011. Nevertheless, the MSC assessment team raised particular concerns over mortality of rays (Elasmobrachii: Batoidea), which were identified as the most vulnerable bycatch species. Ray bycatch remains a key issue to be tackled by the fishery in order to pass future MSC reassessments (Southall et al., 2011).

The Suriname seabob shrimp fishery is known to capture several ray species which are globally endangered and are listed on the IUCN Red List of Threatened Species, including *Dasyatis geijskesi* and *Rhinoptera bonasus* ('near threatened'), *Dasyatis guttata* and *Gymnura micrura* ('data deficient') (IUCN, 2015). Because these species commonly grow to 80–100 cm disc width (Léopold, 2005), we could expect them to escape through the TED. A fifth frequently caught ray species, *Urotrygon microphthalmum* ('least concern'; IUCN, 2015) is much smaller with a maximum disc width of 25 cm (Léopold, 2005), and might escape through the square-mesh panel BRD because of its small size. On the other hand, due to their flattened body shape and high flexibility, even large rays might still be able to pass between the bars of a TED and end up in the codend. With the exception of very small rays, their size and morphology would also prevent escape through the BRD. It remains unclear how frequently these rays occur in the bycatch of this fishery, and to what degree the current trawl adaptations (i.e., BRD and TED) reduce their capture.

In the present study, we have assessed the effectiveness of the combination of BRD and TED in reducing bycatch of rays in the Atlantic seabob shrimp fishery off the coast of Suriname. We present the results of a catch-comparison study in which we have focused on ray bycatch and analyzed ray catches in trawls with and without the combination of BRD and TED. The aims were to assess whether these devices are effective in excluding rays from the trawls, and whether exclusion of rays is species- and size-dependent.

2. Materials and methods

2.1. Study area

The study was conducted on commercial fishing grounds for seabob shrimp (6.17°N to 6.25°N and 55.39°W to 55.84°W) on the continental shelf off Suriname (FAO Statistical area 31). This area is characterized by mud and sandy mud substrates and water depth is typically 20–25 m (Fig. 1). Commercial shrimp fishing activity occurs year-round in this area.

2.2. Gear specifications

Hauls were done onboard *FV Neptune-6*, a typical 20-m, 425-hp 'Florida-type' outrigger trawler used in the seabob shrimp trawling fleet. The vessel was equipped for quad-rig bottom-trawling, which involves dragging two trawls attached to two steel-footed wooden doors and a sledge at either side of the vessel, resulting in two port- and two starboard-codends. Mesh size of each trawl was 57 mm in the body and wings of the trawl and 45 mm in the codend. Each trawl was fitted with an aluminum super-shooter TED. Bar spacing was 10 cm and each was installed in a downward-excluding configuration in an angle of approximately 50° from the horizontal. A single net flap covered each bottom escape opening, and there was no guiding funnel in front of the TED. Each trawl was also fitted with a square-mesh-panel (11 × 11 meshes, 15 cm stretched mesh size) BRD inserted ca. 40 cm behind the TED in the upper side of the codend (Fig. 2).

2.3. Sea trials and catch sampling

A total of 65 experimental catch-comparison hauls were conducted on eight commercial seabob fishing trips between February 2012 and April 2013. During each trip, seven to ten experimental hauls were conducted to compare ray bycatch in trawls with a BRD and TED combination ('wBT net') versus trawls without a BRD and TED combination ('noBT net'). In the noBT net, both codends with BRD and TED were removed and replaced by codends without any devices. The side of the vessel dragging the wBT and noBT net was alternated every trip to exclude port and starboard effects. Hauls were done under commercial fishing circumstances, except for a shortened dragging time (avg. 1h16′ ±SD 0h16′ versus 3–4 h normal dragging time), to reduce the risk of injury or mortality of vulnerable species in the noBT net. Although the fishery normally operates day and night, experimental hauls were done during daytime only for practical reasons. The wBT net and noBT net were dragged alongside each other at a speed of 2.5–3.5 knots, in accordance with normal fishing practice (Pérez, 2014). To ensure that the catches from the wBT and noBT nets remained separate, the two wBT codends were unloaded separately from the two noBT codends on deck. Per net, the catch from the two codends was combined. All rays were sorted out from the catches, identified to species level and measured (disc width) to the nearest centimeter. The catch was subsequently processed as usual by the crew and could not be analyzed further for practical reasons.

2.4. Data analysis

Ray catches were recalculated to a standardized catch rate (individuals h^{-1}). Differences in mean catch rate between the wBT and noBT net were analyzed using Wilcoxon signed rank tests. Differences in mean ray size between wBT and noBT net were analyzed with Mann–Whitney U tests. Both analyses were done per ray species and for all rays combined.

Differences in mean size among ray species were tested using the Kruskal–Wallis test and Nemenyi-post-hoc pairwise comparisons (Pholert, 2014). For these analyses, only data from noBT net catches were used because size-selection was expected in the wBT net. Non-parametric tests were used because the assumptions for (paired) *t*-tests and ANOVA were not met.

The relationship between ray size and escape from the trawls was explored using Generalized Linear Mixed Models (GLMM). To do so, size classes (originally 1 cm) were lumped and/or hauls with sufficient individuals per size class were selected to obtain enough data-points per size class. The proportion retained by the wBT net at size class *S* can be expressed for each size class and each haul as:

$$\varphi(S) = \frac{N_{S,\mathrm{wBT}}}{\left(N_{S,\mathrm{wBT}} + N_{S,\mathrm{noBT}}\right)}$$