Fisheries Research 208 (2018) 16–21

Contents lists available at ScienceDirect

Fisheries Research

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

Permanent magnets reduce bycatch of benthic sharks in an ocean trap fishery☆

R.J. Richards, V. Raoult*, D.M. Powter, T.F. Gaston

School of Environmental and Life Sciences, University of Newcastle, NSW, Australia

ARTICLE INFO

Handled by Bent Herrmann

Keywords:
Elasmobranchs
Deterrents
Mitigation
Blind shark
Electroreception
Fisheries

ABSTRACT

Sharks and rays are often caught as bycatch by commercial fisheries, and high incidences of bycatch are partially to blame for the declines in many populations of elasmobranchs. In an effort to reduce rates of bycatch, researchers have tested various deterrents that could benefit fisheries. Permanent magnets are one promising form of bycatch reduction device, yet their efficacy has only been tested for hook-and-line fisheries with variable results. Here, we examined the potential benefits of permanent magnets on an ocean fish trap fishery targeting snapper (*Pagrus auratus)* where more than 10% of the total catch is comprised of unwanted elasmobranchs and the presence of elasmobranchs reduces the catch of target species. Over 1000 fish traps were deployed in a fishery-dependent survey in New South Wales, Australia. Standardised catch rates indicate that the incorporation of magnets into fish traps significantly reduced incidences of elasmobranch bycatch (mainly *Brachaelurus waddi*) by over a third, while increasing the amount of target fish caught by an equivalent amount. Together these results suggest that magnets can be used as an effective bycatch reduction device that reduces incidences of elasmobranch bycatch while increasing the profitability of fish traps for fishermen. Future studies should aim to replicate these results in areas where different species of elasmobranchs occur.

1. Introduction

Elasmobranchs are threatened globally by recreational and commercial fisheries (Dulvy et al., 2014), and while they are often directly targeted by these fisheries (Schiller et al., 2015), many species of elasmobranchs that are only caught as undesirable or unmarketable bycatch have been driven to near-extinction (Molina and Cooke, 2012; Fortibuoni et al., 2016). In parallel, a growing understanding of elasmobranch sensory systems (Hart and Collin, 2015; Jordan et al., 2013) has led to multiple research avenues that may potentially lead to effective elasmobranch deterrents, either for bycatch reduction (Favaro and Côté, 2015) or shark interaction mitigation (Kempster et al., 2016). Out of the senses targeted by these deterrents, perhaps the most widely examined are the electrosensory or magnetosensory pathways.

Among marine vertebrates, elasmobranchs are unique in their use of ampullae of Lorenzini to sense weak electric fields (Freitas et al., 2006). This electrosensory ability of elasmobranchs is primarily thought to be used for feeding (Kempster et al., 2016; Kimber et al., 2014), though there is evidence they can rely on it for orientation in turbid waters (O'Connell et al., 2014). Since electric fields inherently generate associated magnetic fields, the high sensitivity of elasmobranchs to electric fields has likely also resulted in a high sensitivity to magnetic fields (Johnsen and Lohmann, 2005; Meyer et al., 2005). Due to the comparatively low sensitivity of bony fish to these electric and magnetic fields, the use of electrosensory stimuli to deter elasmobranchs in fisheries without lowering catches of targeted species of fish is attractive. While generating electrical currents underwater to deter elasmobranchs on a fishery-scale has logistical hurdles, which to some degree can be lowered by the use of electroreactive metals (Tallack and Mandelman, 2009; Hutchinson et al., 2012), the incorporation of permanent magnets is comparatively simple.

To date, the incorporation of permanent magnets as bycatch reduction devices (BRDs) into fishing gear has primarily been conducted in hook-and-line or longline fisheries (e.g. O'connell et al. (2011) and Robbins et al. (2011)). The results of these trials have been variable; some cases increasing the bycatch of elasmobranchs (Porsmoguer et al., 2015), meta-analyses showing that magnets have no statistically significant effect on elasmobranch bycatch (Favaro and Côté, 2015), and additional complications during deployments (Rigg et al., 2009). While pelagic longlines account for a large proportion of global elasmobranch

---

☆ Summary statement: We examined the use of permanent magnets as a shark bycatch reduction tool in ocean trap fisheries. Our results show magnets can reduce shark bycatch and increase catches of targeted fishes.

* Corresponding author.
E-mail address: Vincent.raoult@newcastle.edu.au (V. Raoult).

https://doi.org/10.1016/j.fishres.2018.07.006
Received 8 March 2018; Received in revised form 22 June 2018; Accepted 8 July 2018
0165-7836/

bycatch, oceanic trap fisheries can catch large numbers of poorly-reported benthic elasmobranchs (Uhlmann and Broadhurst, 2015; Foged and Powter, 2015), yet the use of magnets to reduce bycatch in fish traps has not been investigated. The modification of fish traps to reduce bycatch has been identified as an area that could increase the sustainability of fisheries (Gomes et al., 2014; Uhlmann and Broadhurst, 2015). For example, in coral reef trap fisheries including escape gaps suitable to some fish morphotypes reduced undersize bycatch in coral reef trap fisheries without affecting target catch (Johnson, 2010). Escape gaps, however, are unlikely to reduce bycatch of elasmobranchs due to their larger size relative to targeted species, which could lower targeted catch as well as lower bycatch. Unlike hook-and-line fisheries, the use of magnets would not significantly change or affect trap fishing methods since they can be permanently attached to fixed, hard structures without risk of entanglement. Furthermore, the size of the structures allows the placement of additional larger, more powerful magnets that may have a greater effect than the smaller ones used in longlines. Thus, they can be used to create a magnetic field ‘barrier’ to entry into the traps without risking affecting catches of targeted species.

This study aimed to determine whether the incorporation of permanent magnets into oceanic fish traps could reduce bycatch of elasmobranchs in New South Wales, Australia. Since local fishermen frequently comment that they believe elasmobranchs are affecting catches of targeted fish (Foged and Powter, 2015), and focused research on targeted catch composition has been highlighted as a research area for elasmobranch bycatch reduction devices (Favaro and Côté, 2015), we first aimed to assess whether traditional fish traps that caught elasmobranchs had lower amounts of targeted fish. We then assessed whether fish traps modified to include magnets as elasmobranch bycatch reduction devices would lower the catch rate of elasmobranchs, and whether their incorporation was likely to increase catches of targeted fish.

2. Materials and methods

2.1. Sampling sites

Field work was conducted onboard two commercial fishing vessels: the 11 m *Sumic* of Hardy’s Bay and the 17 m *Spinaway II* of Pretty Beach, NSW, Australia. Fishery-dependent sampling was undertaken within the Ocean Trap and Line fishery (OTLF) fishing grounds off the NSW coast of eastern Australia (Fig. 1) between December 2013 and August 2014. A total of 38 sea days were completed, with a total of 1015 individual trap-lifts. All traps were primarily set on sandy substrate within surrounding rocky reef, at depths ranging between 5–102 m. Sampling was conducted in the OTLF fishing grounds between Gosford in the north and Manly in the south (Fig. 1).

The areas sampled are prosperous fishing grounds with multiple commercial fishing industries including hand-line, demersal trawling and trap and pot. The species targeted include fish, prawns and shellfish. However, the southern end of this area also incorporates longline commercial industries, which target larger finfish species. Seasonality is a factor that influences both area, with most fishing activity concentrated in the summer and early autumn months for the north, whilst the southern area is predominately used throughout the rest of the year. Both commercial vessels used throughout sampling were trap and pot commercial vessels, primarily focused on the capture of fish species including yellowfin bream (*Acanthopagrus australis*) in the northern area and Australasian snapper (*Pagrus auratus*) throughout these grounds. For this study, the locations of each trap were separated into three sites that relate to the targeted catch and methods employed by the fisheries in these areas: one location in the northern end extending out to the coastal shelf, one location just below the northern area ranging from Palm Beach in the north to North Narabeen in the south, and the third extending south to the north of Manly and further out on the coastal shelf.

2.2. Fish trap design and deployment

The ocean fish traps used throughout this study had a wooden frame (dimensions: 1800 mm L × 1200 mm W × 800 mm H) wrapped in 50 mm hexagonal wire mesh, with an additional escape panel situated at the rear of the trap (100 mm × 60 mm) galvanised metal mesh. These were commercial fishing traps regularly used in the fishery. Each trap had three funnel entrances (290 mm × 540 mm outer and 60 mm × 270 mm inner), with either:

a) four permanent ferrite magnet bars (75 mm long, 12.7 mm high and 16 mm wide) attached to each of the funnels within the experimental group
b) four non-magnetic metal bars of similar size for the procedural control
c) no change to the standard commercial trap as a control.

The magnet bars were chosen due to their high gauss (G) strength and relatively small size, which minimised any protrusion at the funnel neck. Rigg et al. (2009) found that a gauss strength of between 25 and 234 G (field strength) provided the best deterrent responses. Magnets used in this study had a measured gauss strength of 25 G at 10 cm, exponentially increasing to 100 G at 5 cm and 220 G at the magnet’s surface. Non-magnetic metal bars were coated in a bitumen rubber membrane to protect from corrosion, whilst the ferrite magnet bars were corrosion resistant. The magnets were attached equidistantly around the neck of each funnel, with the strongest magnetic field (largest magnet surface) being orientated outward. This orientation emits the strongest magnetic field toward the extremities of the funnel neck, thus creating the maximum potential for shark deterrence (Rigg et al., 2009; O’Connell et al., 2011). Procedural controls were also fixed in the same orientation as the ferrite magnets. The commercial fishers used 36 ocean fish traps, which were randomly split into three equal groups of 12 traps for each of the field treatments. When possible, traps were grouped into sets of three comprising one of each experimental type (experimental application, procedural control and control).

2.3. Data collection

Data collected during the fishery-dependent sampling included identification to species level of all organisms caught, target and byproduct fish catch (kg) per trap, and elasmobranch count per trap. Trap location, water depth and soak time (trap hours in the water) were also recorded. Elasmobranch bycatch catch per unit effort (CPUE) was the standardised number of sharks caught per trap, whereas fish catch per unit effort (CPUE) was the standardised total weight of target fish caught per trap. Standardisation of these CPUE values was conducted using the methods described below.

2.4. Analyses

2.4.1. Effect of elasmobranch presence on target fish catch

Fishermen have a belief that the presence of elasmobranchs in their traps reduces the catch of targeted fish. Using the raw CPUE values from the study (number of elasmobranchs caught per trap, weight in kg of targeted fish per trap), independent sample *t*-tests were used to determine any effect of elasmobranch presence or not in the trap on target fish catch per unit effort. Due to unmatched sample sizes between treatments, equal variances were not assumed, and to test whether variance was equal between these treatments, Levene’s Test of equality of variances was conducted prior to conducting *t*-tests.

2.4.2. Effect of magnets on shark and target fish catch per unit effort

Standardising CPUE is commonly used in fisheries analyses to ensure catch rates across ships, areas, and seasons are comparable, and allow management to assess true differences in catch rates (Cosgrove