Effects of a shark repulsion device on rocky reef fishes: no shocking outcomes

A. Broad[1], N. Knott[1,2], X. Turon[3] & A. R. Davis[1*]

[1] Institute for Conservation Biology & School of Biological Sciences,

University of Wollongong, NSW 2522 Australia

[2] Jervis Bay Marine Park, PO Box 89, Huskisson, NSW 2540 Australia

[3] Centre for Advanced Studies, Blanes, Girona, Spain

Running Head: Impacts of shark repulsion devices

* author for correspondence: adavis@uow.edu.au

61-2-4221 3432 (fax)

ABSTRACT

Shark Repulsion Devices (SRDs; e.g. Shark Shield™) use an electric field to deter large and potentially dangerous sharks. The use of these devices is becoming increasingly widespread for a range of recreational activities as well as scientific and commercial diving. We sought to determine if SRDs might modify the behaviour of chondrichthyan and osteichthyan fishes and thereby impact on fish assemblages, as well as potentially bias diver census techniques. To assess the potential impacts of this technology, we attached SRDs to Baited Remote Underwater Video (BRUV) units and deployed them on shallow rocky reefs in Jervis Bay Marine Park (NSW, Australia). We did not detect any impacts of the SRD on the diversity or relative abundance of shallow reef fishes. In addition, approach of fishes to the bait did not differ whether the SRDs were on or off. At the smallest spatial scale we investigated – contact with the bait was half as frequent when the SRD was switched on compared to when it was off. Surprisingly, even the cartilaginous species were apparently unaffected by the SRD with the Eastern Fiddler Ray *Trygonorhina fasciata* making contact with the bait several times when SRDs were activated. We contend that the ecological impacts of SRDs at all but the smallest scales are minimal and they are unlikely to introduce bias in assessments of fish assemblages, at least for non-cartilaginous and small cartilaginous species.

Key words: Ampullae of Lorenzini, baited remote underwater video, elasmobranch, electrical pulse, Jervis Bay Marine Park, sampling bias, shark-shield, underwater visual census.

INTRODUCTION

The detection of weak electrical fields is heightened in many fishes, especially the chondrichthyans (von der Emde 1998). Among the sharks and rays, the ampullae of Lorenzini are often concentrated around the head and enable the detection of low frequency (i.e. 0.5 Hz) electric fields as weak as 1 nanovolt per square centimetre (Murray 1962, Kalmijn 1971, von der Emde 1998). In addition, some osteichthyes (e.g. Siluriformes) possess ampullary organs and are capable of some degree of electroreception (von der Emde 1998). The extreme sensitivity of chondrichthyans to electric fields has been targeted to reduce the threat posed to humans by large potentially dangerous sharks. Shark Repulsion Devices (SRDs) producing electrical pulses are now commercially available and it is claimed that they can create an electrical field around a diver (or surfboard, kayak etc) that irritates the ampullae of Lorenzini, creating muscle spasms and driving sharks from the vicinity[1].

Our concerns about the effects of these devices were two fold; we were interested in (i) the general ecological effects of their usage and (ii) the potential scientific bias that they may introduce in the census of fish assemblages. The ecological effects of their usage in marine protected areas, such as Jervis Bay Marine Park, were of particular concern. Marine parks are often required to balance the conservation of biological diversity as well as manage a range of human activities within their boundaries. Significant recreational SCUBA diving is often concentrated in these locations – in the case of Jervis Bay Marine Park more than 20,000 dives occur each year (NSW Marine Park Authority, unpublished data) and the use of SRDs will likely increase. Marine Parks

---

[1] http://www.defence.gov.au/teamaustralia/shark_deterrent_technology_(Shark_Shield).htm

are also popular locations for a range of other activities that in future are likely to involve the use of these devices (e.g. snorkelling, spearfishing, swimming, surfing, kayaking). Hence, it is important for management authorities to assess their potential impacts. From a scientific perspective, the potential for these devices to introduce bias in fish census may be particularly important for long running sampling programmes that may be comparing data collected with and without SRDs where there use may confound an assessment of temporal change.

Our concerns about the effects of electrical repulsion devices were heightened by field observations of several fishes behaving strangely near these devices (authors' pers. obs.). We reasoned that they may not only affect large sharks (the target of these devices) but also common chondrichthyans and possibly osteichthyans. Especially, as there appear to be no published studies assessing the effects of SRDs on fishes generally or over what distances SRD may repel, or possibly attract, chondrichthyans. Hence, we tested two null hypotheses: (i) the diversity and abundance of fishes observed would not differ in the presence of activated or inactive SRDs over scales of metres and tens of metres, and (ii) that the behaviour of fishes would not be affected over smaller spatial scales. In order to assess the potential impacts of this technology, we elected to test these hypotheses by attaching SRDs to Baited Remote Underwater Video (BRUV) units.

MATERIALS AND METHODS

Study location and shark repulsion device

This assessment of the potential ecological effects of the use of SRD was done in the Jervis Bay Marine Park (JBMP). Large areas of rocky reef occur in the Park similar to many sections of the temperate east coast of Australia. We sampled subtidal reefs along the north-western edge of the Bay extending from Green Point (35.0095ºS, 150.4583ºE) to Dart Point (35.0440ºS, 150.4638ºE) in April (Austral Autumn) 2009. Two identical BRUV units (see Cappo et al. 2004, Malcom et al. 2007) were deployed onto shallow rocky reefs (4-7 metres).

The Shark Repulsion Device (SRD - Shark Shield™, Freedom 7) is a small, battery operated instrument (15x12x4cm) containing two electrodes that when operating and immersed in water produces an elliptical electric field via an antenna. The antenna measures 2.2 m in length and the three dimensional electrical field it creates is approximately 4 metres either side of this antenna[2].

BRUV system & analysis of video footage

BRUV is a widely used technique to assess fish assemblages (eg Cappo *et al.* 2004, Malcolm *et al.* 2007). Our system consisted of a video camera (i.e. Sony or Canon high resolution Mini-DV) in a waterproof housing with the bait within a plastic mesh container attached to a 1m arm extending from the camera housing. The SRD main unit was attach to the camera housing with Velcro straps and the antenna was secured to the plastic bait arm with cable ties. This arrangement meant that the bait was well enclosed within the electrical field. Four hundred grams of crushed pilchards (*Sardinops sagax)* was placed into the bait container and the bait was renewed for each deployment. Thirty minutes of video was recorded at each deployment. Each BRUV was allowed 5 minutes to settle on the reef before video sampling commenced. Previous studies have indicated

[2] www.sharkshield.com.au accessed 28th April, 2009

that a 30-minute deployment provides adequate estimates of the diversity of fishes on an area of reef (Willis & Babcock 2000, Stobart *et al*. 2007, Wraith 2007).

To test the stated hypotheses, half of the BRUV deployments were with operating SRDs and for the remainder they were not operating (n=10); this was determined by random draw. Each BRUV deployment was separated by a minimum of 150m. A single experienced observer (AB) examined the video recordings. Each fish species observed in each deployment was recorded, providing an estimate of Species Richness (S). Relative abundance was determined by recording the maximum number of fish of each species viewed at any one time during the deployment (Max *n)*. To evaluate small-scale effects of the SRD, we quantified approach to and contact with the bait container by fishes. Approach was measured by delineating a hemispherical area 20cm wide and 20cm high centred on the bait container and counting any individuals entering this area during eight random 5-second periods within each deployment. We also quantified contact with the bait container (number of pecks) during the 30 minutes of deployment and the species responsible.

Statistical analysis

We used univariate and multivariate analyses to test our hypotheses. T-tests were used to compare means for Species Richness, Total Max *n,* Max *n* for targeted fish species, as well as approach and pecking rates when SRDs were activate or inactive (Systat Version 12). Assumptions of normality and homogeneity of variances were assessed visually prior to proceeding with each analysis. Data from none of the variables required transformation. Multivariate patterns in the fish assemblages were displayed with nMDS and analysed with ANOSIM (PRIMER, Version 6). Bray-Curtis measures of dissimilarity were calculated for Max *n* and presence/absence data in order to test for differences in relative abundance and composition (and frequency of occurrence) for the multivariate data set.

RESULTS

A diverse and representative range of shallow rocky reef fishes were observed in our recordings in Jervis Bay consisting of 6 chondrichthyan and 51 osteichthyan species. The operation of the SRD did not affect the assemblages of rocky reef fishes, irrespective of whether abundance or presence/absence data were analysed (Global R = 0.002, 0.001; P = 0.418, 0.421 respectively; Permutations = 999; Fig. 1). Species richness and relative abundance (Max *n*) of fishes were similar with or without the SRD operating (Fig. 2a, b). The relative abundance of the osteichthyans, and the surprisingly the chondrichthyans, did not differ and none of the individual species of fishes showed a response. All species had very similar maximum numbers within the field of view around the bait independent of the operation of the SRD. Southern Maori wrasse (*Ophthalmolepis lineolatus*) and crimson banded wrasse (*Notolabrus gymnogenis*) were the most abundant species at the bait and were representative of the other fishes species as that they were unaffected by the operation of the SRD (Fig. 2c,d).

We did not detect differences in the approach of fishes to the bait (within tens of centimetres); the number and diversity of fishes were very similar irrespective of the operation of the SRD (Fig. 2c, d). This indicated that even over relatively small scales the fishes were unaffected by the SRD. The number of pecks to the bait container, however, tended to occur more often when the SRD was not operating with almost twice as many pecks when the SRDs were off ($t= 2.657$, $P=0.016$, $df=18$; Fig. 2e, f). A total of 8 species pecked at the bait container during the course of the experiment, five of these species when SRDs were activated. This included one elasmobranch the Eastern Fiddler Ray, *Trygonorhina fasciata*.

DISCUSSION

The increasing usage of shark repulsion devices (SRDs) for a wide range of recreational activities and scientific and commercial diving necessitated an assessment of their potential ecological effects on non-target species. In this study, we have not detected any substantial effects of an electrical SRD on shallow reef fish assemblages – this included several chondrichthyans. We assessed effects on diversity and abundance of fishes over the scales of tens of metres, metres and down to tens of centimetres. Fish were neither attracted nor repelled by the operation of this electrical device over these spatial scales.

The SRD only affected the behaviour of the fishes directly at the bait. At such close range even humans are affected by the electrical pulses emitted from the transmitter unit and the antenna. This effect at close range may explain our initial observation of strange behaviour of fishes in close proximity to the SRD involving involuntary muscle spasm. Despite this strange behaviour close to the antenna, shallow rocky fishes do not appear to be attracted or repelled over larger distances (e.g. at least over tens of metres) as the abundances and species richness of fishes did not differ when the SRD was operating or not. The lack of the large-scale effect supports statements made by the producers of the SRD that the signal will not affect osteichthyans. We contend, therefore, that SRDs do not represent a threat to fishes at least on shallow rocky reefs in SE Australia, nor would we expect them to bias outcomes of underwater visual census.

As SRDs interfere with electro-reception in chondrichthyans we anticipated that these animals would be particularly sensitive to the devices. Surprisingly, this did not appear to be the case as Fiddler Rays (*Trygonorhina fasciata*), Eagles Rays *(Myliobatis australis*), a Yellowback Stingaree (*Urolophus sufflavus*) and a Spotted Catshark (*Asymbolus rubiginosus*) all approached the bait while the SRD was active; with the Fiddler Rays pecking the bait while the SRD was operating. With just six elasmobranch species encountered on our tapes it may be premature to assert that small cartilaginous species are unaffected. It is also likely that large and potentially dangerous species will be deterred more strongly than those we observed. Further the manufacturers contend that the SRD will not affect demersal elamosbranch species such as rays arguing that the ampullae of Lorenzini are positioned on the underside of the animal (e.g. Wueringer & Tibbets 2008), hence the ampullae may not be exposed to the electric pulses. This description is consistent with our results.

Although this study provides no evidence that these kinds of SRD dramatically affects demersal elasmobranchs, more research will be required to better understand the impacts of the use of these devices. While we predict that large demersal species such as Port Jackson (*Heterodontus portusjacksoni*) and Wobbegong sharks (*Orectolobus* spp.) will be largely unaffected by SRDs, the greater number and density of ampullae of Lorenzini on large potentially dangerous species should render them more sensitive to electrical pulses. This is of particular concern for the endangered Grey Nurse

Shark (*Carcharias taurus*). Currently, in NSW, the use of SRD near Grey Nurse Shark is prohibited. This species poses an excellent example of the issues that need to be considered with the widening use of SRD.

Taken together our data indicate that the wearing of SRDs by those engaging in recreational or scientific activities is unlikely to have negative impacts on fish assemblages or bias censuses of fish assemblages, at least for shallow rocky reef assemblages in SE Australia. However, we recommend that researchers using or planning to use SRD incorporate assessment of their SRD units into their work as effects may vary at locations with different fish assemblages.

ACKNOWLEDGEMENTS

This work was supported by the New South Wales Marine Parks Authority and the Institute for Conservation Biology, University of Wollongong. We thank M Fackerell for his assistance in the field. Comments by Melinda Coleman, Mark Fackerell and Alex Martin improved an early draft. This represents contribution no. xxx from the Ecology and Genetics Group, University of Wollongong.

REFERENCES

Babcock RC, Kelly S, Shears NT, Walker JW, Willis TJ (1999) Changes in community structure in temperate marine reserves. Mar Ecol Prog Ser 189:125-134

Bullock TH (1982) Electroreception. Ann Rev Neurosci 5:121-170.

Cappo M, Speare P, De'ath G (2004) Comparison of baited remote underwater video stations (BRUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. J Exp Mar Biol Ecol 302**:**123-152

Kalmijn AJ 1971. The electric sense of sharks and rays. J Exp Biol 55: 371-383

Malcolm, H. A., W. Gladstone, S. Lindfield, J. Wraith, and T. P. Lynch. 2007. Spatial and temporal variation in reef fish assemblages of marine parks in New South Wales, Australia - baited video observations. Marine Ecology Progress Series 350:277-290.

Murray RW (1962) The response of the Ampullae of Lorenzini of elasmobranches to electrical stimulation. J Exp Biol 39: 119-128

von der Emde G (1998) Electroreception. In: Evans DH (ed) The physiology of fishes. CRC Press, Boca Raton FL, p 313-343.

Willis TJ, Babcock RC (2000) A baited underwater video system for the determination of relative density of carnivorous reef fish. Mar Freshw Res 51:755-763

Wraith J (2007) Assessing reef fish assemblages in temperate marine park using baited remote underwater video. Unpublished Masters Thesis. University of Wollongong pp. 88

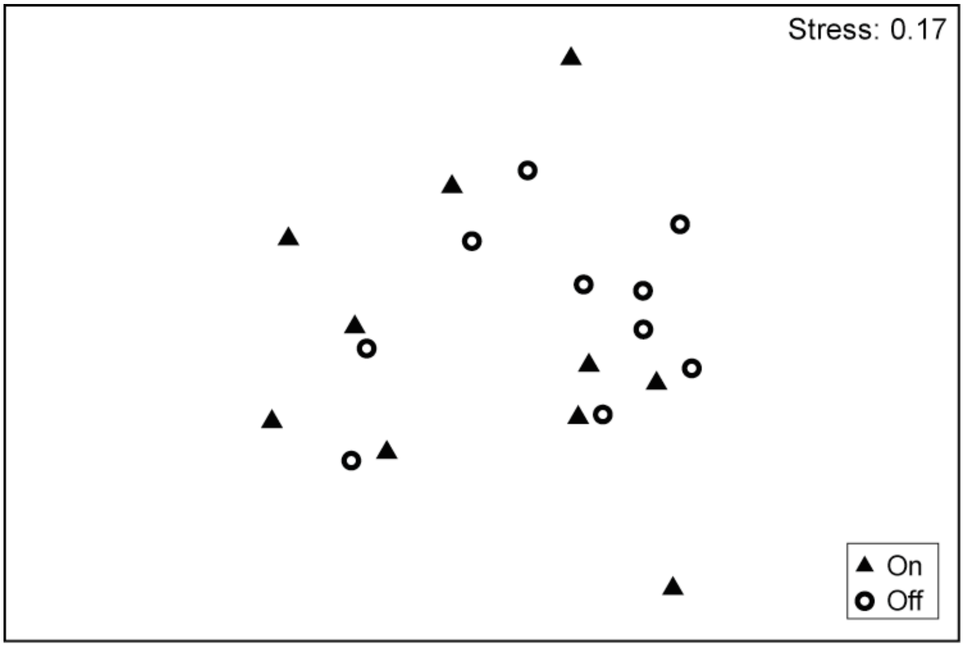
Wueringer BE, Tibbets IR (2008) Comparison of the lateral line and ampullary systems of two species of shovelnose ray. Rev Fish Biol Fisheries 18:47-64

FIGURE CAPTIONS

FIG. 1: Temperate reef fish assemblages in the presence of active and inactive Shark Repulsion Devices (SRDs). Assemblages were sampled using baited video in Jervis Bay Marine Park. Untransformed Bray-Curtis distances are presented in the nMDS.

FIG. 2: Temperate reef fish diversity and relative abundance in the presence of active and inactive Shark Repulsion Devices (SRDs). Bars are means (± SE), n=10. (a) species richness, (b) relative abundance (Max *n*), (c) species richness of fishes approaching the bait container, (d) number of instances fishes approached the bait container, (e) species richness of those contacting the bait container (pecks) and (f) total number of pecks. See text for definition of ‘approach’.

Fig 1.



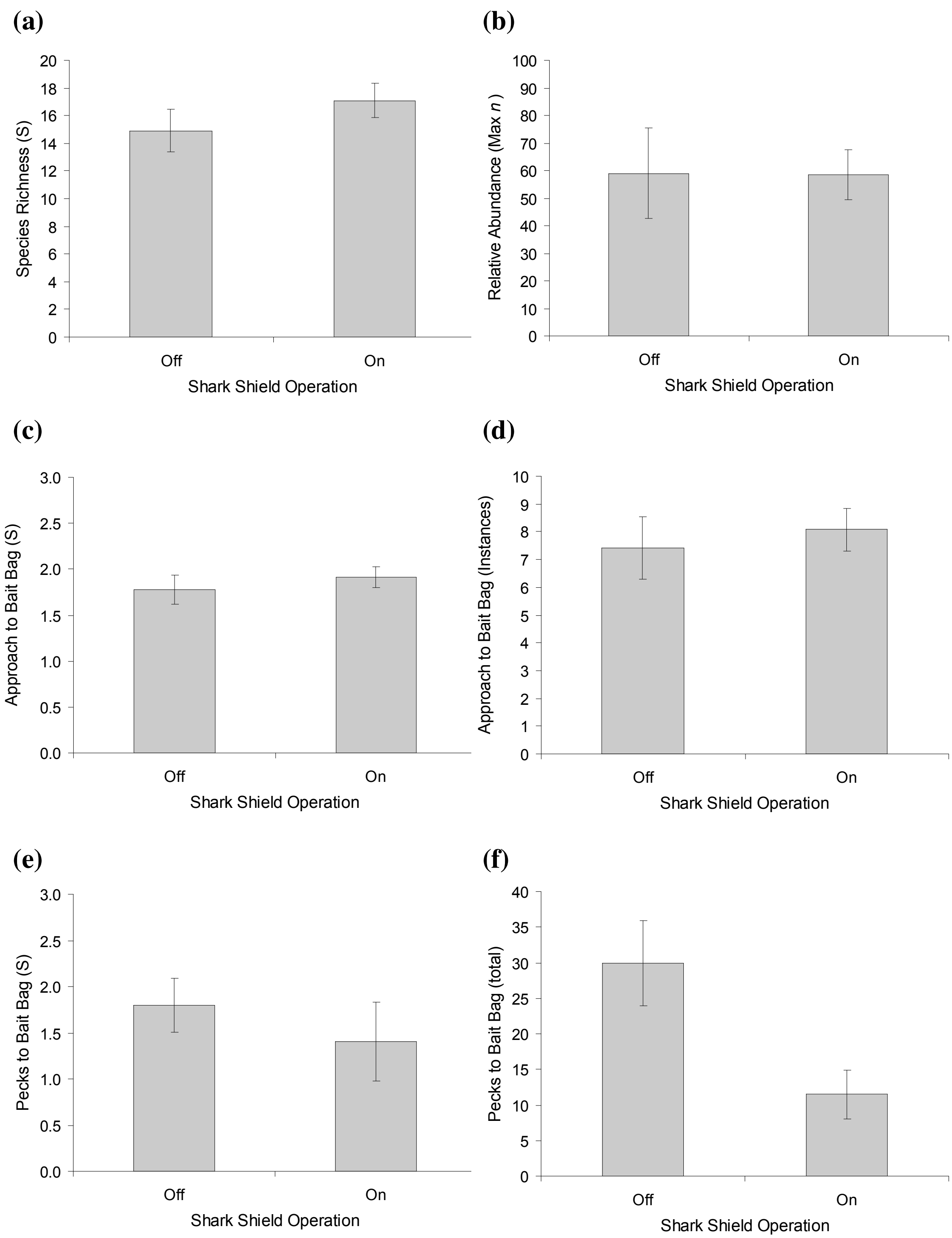

(a)
Species Richness (S)
20
18
16
14
12
10
8
6
4
2
0
Off
On
Shark Shield Operation
(b)
Relative Abundance (Max n)
100
90
80
70
60
50
40
30
20
10
0
Off
On
Shark Shield Operation
(c)
Approach to Bait Bag (S)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Off
On
Shark Shield Operation
(d)
Approach to Bait Bag (Instances)
10
9
8
7
6
5
4
3
2
1
0
Off
On
Shark Shield Operation
(e)
Pecks to Bait Bag (S)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Off
On
Shark Shield Operation
(f)
Pecks to Bait Bag (total)
40
35
30
25
20
15
10
5
0
Off
On
Shark Shield Operation

Fig. 2