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# Efficacy of a novel shark bycatch mitigation device in a tuna longline fishery

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Elasmobranchs (sharks, rays, and skates) are caught throughout fisheries globally, leading to over one-third of species being threatened with extinction[1]. Oceanic shark populations have undergone an average 71% decline over the last half century, owing to an 18-fold increase in relative fishing pressure[2]. Incidental capture or 'bycatch' is a primary driver of population declines, and poses an important challenge for species conservation[3]. This threat necessitates mitigation strategies that exist for sharks but are often focussed on haul-back and post-capture effects for longline fishing. We trialled a novel shark bycatch mitigation device ("SharkGuard") in a commercial longline fishery targeting bluefin tuna (*Thunnus thynnus*), where bycatch consists largely of blue sharks (*Prionace glauca*) and pelagic stingrays (*Pteroplatytrygon violacea*).

SharkGuard creates a powerful, short-range, 3D pulsed electric field designed to overstimulate electroreceptors to reduce frequency of hook interaction. Standard fishing gear was deployed, where 1000 branchlines (reduced in latter sets due to loss during fishing operations) containing 'baskets' of eight branchlines were spaced between float lines — alternating between a control branchline (standard branchlines) and a branchline with SharkGuard devices fitted. All branchlines terminated in a circle hook baited with sardines. Sea trials were conducted in July and August 2021 in southern France (Figure S1, see Supplemental information). Two vessels operating the same gear configurations carried out eleven trips (vessel 1, n = 5; vessel 2, n = 6) consisting of 22 sets (vessel 1: n = 10; vessel 2: n = 12), deploying a total of 18,866 hooks (vessel 1: n = 9,955; vessel 2, n = 8,911). Each set comprised a mean 429 ± 29 (range: 387–490) control hooks and 428 ± 30 (range: 383–489) SharkGuard hooks, soaking for a mean 7.5 ± 2.0 (range: 4.6–11.3) hours. A total of 27 bluefin tuna were landed, representing 6.8% of the total catch by number of individuals, with blue sharks (n = 75) accounting for 18.8%, and pelagic stingrays (n = 270) for 67.5% of the total catch, respectively. An additional 28 individuals from a range of species, including sunfish (*Mola mola*) and swordfish (*Xiohias gladius*), were also caught during the trials, representing 7.0% of the total catch.

There was a significant interaction between hook treatment and species (GLMM, $\chi 22$ = 10.56, p = 0.005), meaning catch rates differed significantly across species for different hook types, warranting species-specific investigation of effects (see Supplemental Experimental Procedures). Hooks fitted with SharkGuard significantly reduced catch rates of blue sharks and pelagic stingrays (blue shark GLMM, $\chi 21$ = 62.20, p = <0.001; pelagic stingray GLMM, $\chi 21$ = 87.61, p = <0.001),

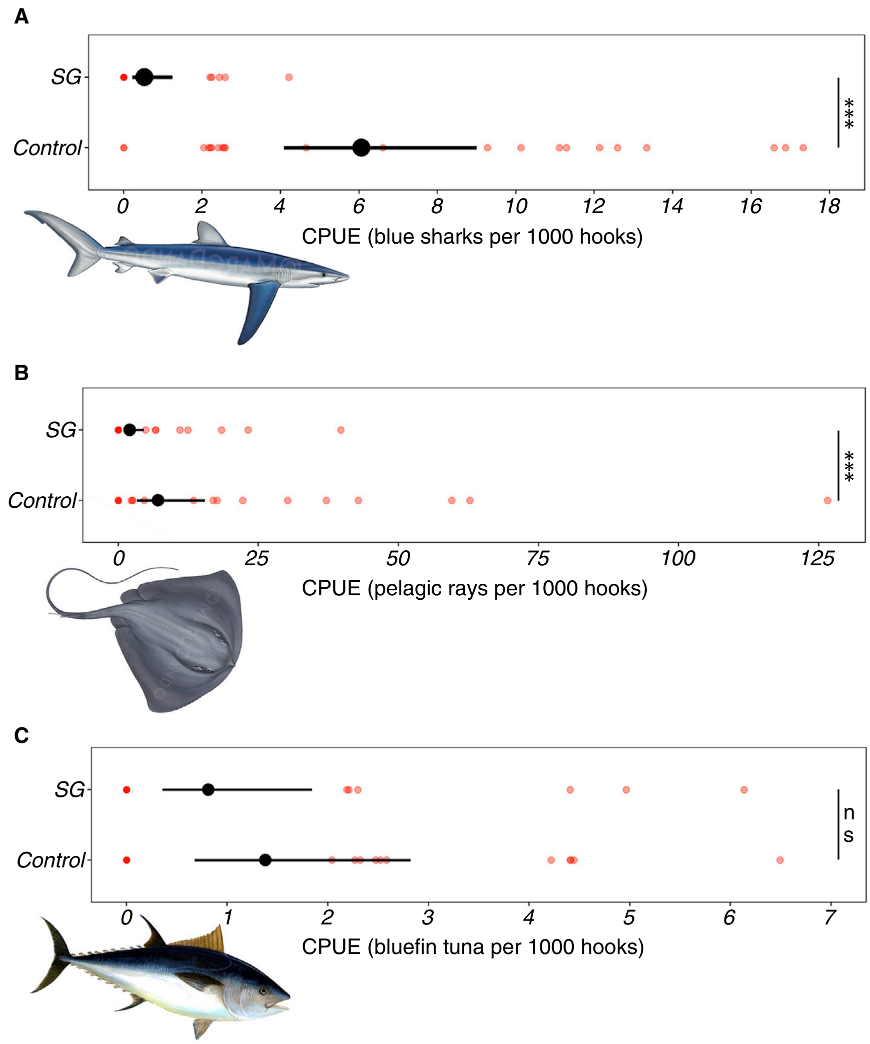


**Figure 1. Catch per unit effort (CPUE; number of individuals caught per 1000 hooks).**
Mean number of (A) blue sharks (*Prionace glauca*), (B) pelagic stingrays (*Pteroplatytrygon violacea*), and (C) bluefin tuna (*Thunnus thynnus*) caught per 1000 hooks for control (unmodified longline gear), and SharkGuard (SG) branchline configurations. Predicted mean estimates (black circles), and standard error (se; solid black lines) from GLMM presented for each level of treatment with red circles denoting raw catch rates. ***p = <0.001; ns = non-significant.

 

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decreasing standardised catch per unit effort (CPUE; individuals per 1000 hooks) by an average 91.3% and 71.3%, respectively (Figure 1; Table S1). Mean standardised CPUE of blue sharks was 6.1 ± 1.2 sharks per 1000 control hooks compared with 0.5 ± 1.6 sharks per 1000 SharkGuard hooks. Mean standardised CPUE of pelagic stingrays was 7.0 ± 1.5 rays per 1000 control hooks compared with 2.0 ± 1.5 rays per 1000 SharkGuard hooks (Figure 1). These results are promising, especially considering methods currently available targeting sensory systems of sharks have largely failed to reduce bycatch substantially and/or are yet to be developed for large-scale fisheries deployment[4]. Catch rates of bluefin tuna (target catch) were not significantly influenced by hook type (GLMM, $\chi 21$ = 1.82, p = 0.18), but standardised CPUE per 1000 hooks showed a significant positive relationship with increasing soak time (GLMM, $\chi 21$ = 3.97, p = 0.046; Figure S1; Table S1). While hook treatment was found to be non-significant, data suggest a reduction of 41.9% on SharkGuard hooks (Figure 1).

SharkGuard was designed specifically for commonly encountered shark species in longline fisheries, thus providing relatable and meaningful results for fishers to try to increase motivation of fishers to take up new technologies[5]. Future uptake of such sensory deterrents will be dependent on the ability to maintain target catch rates. Bluefin tuna catch was unseasonably low during trials, with the possibility of SharkGuard also reducing catch of bluefin tuna, and as such, no definite conclusions can be drawn in this regard. However, the fact that hook type was found to have a non-significant influence on bluefin tuna catch is encouraging, indicating factors such as soak time or local tuna abundance are likely having a greater impact.

More recently, encouraging trials of electrical deterrents have concentrated on personal shark deterrents for ocean users[6]. These studies have observed some level of habituation to the devices; however, this is often presented as individuals gradually getting closer to the device, but not necessarily taking the bait[7,8]. This is unlikely to occur in a fishery setting due to reduced interaction times and wide-ranging nature of both species and fishery. Many shark species have similar electrosensory threshold sensitivity, but detection threshold and behavioural response varies among species[9,10]; thus, results from this study should be treated with caution if attempting to infer deterrent effect for other species or fisheries. Additional trials deploying inactivated SharkGuard devices may provide insight into whether the electric field or another effect (e.g., movement/visibility of the device) was responsible for changes in species-specific catch rates. These trials also need to take place in fisheries where assemblages of bycaught species and environmental conditions differ to verify efficacy.

Broad-scale deployment of a device such as SharkGuard could meaningfully reduce the number of sharks caught in longline fisheries, but currently has some limitations due to frequency of battery changes required (every 65 hours) and as such at-sea charging solutions (such as induction-charging devices in the hook-setting bins) are currently being developed and are vital to overcome these problems before acceptance is likely within fisheries. We encourage active involvement of fisheries stakeholders in the further development of technologies and methods to increase suitability, efficacy, and sustainability of mitigation devices and practices, which can be made available and deployed throughout fisheries globally.

## SUPPLEMENTAL INFORMATION

Supplemental information includes one figure, one table, and experimental methods, and can be found at https://doi.org/10.1016/j.cub.2022.09.003.

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## DECLARATION OF INTERESTS

R.E., B.S., B.K., and P.K. are employees of Fishtek Marine Ltd who designed and manufactured the SharkGuard prototypes used in this study. SharkGuard is filed under UK Patent Application GB1916517.4.

## REFERENCES

1. Dulvy, N.K., Pacoureau, N., Rigby, C.L., Pollom, R.A., Jabado, R.W., Ebert, D.A., Finucci, B., Pollock, C.M., Cheok, J., Derrick, D.H., *et al*. (2021). Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. Curr. Biol. *31*, 4773–4787.e8.
2. Pacoureau, N., Rigby, C.L., Kyne, P.M., Sherley, R.B., Winker, H., Carlson, J.K., Fordham, S.V., Barreto, R., Fernando, D., Francis, M.P., *et al*. (2021). Half a century of global decline in oceanic sharks and rays. Nature *589*, 567–571.
3. Molina, J.M., and Cooke, S.J. (2012). Trends in shark bycatch research: current status and research needs. Rev. Fish Biol. Fish. *22*, 719–737.
4. Favaro, B., and Côté, I.M. (2013). Do by-catch reduction devices in longline fisheries reduce capture of sharks and rays? A global meta-analysis. Fish Fish. *16*, 300–309.
5. Senko, J.F., Peckham, S.H., Aguilar-Ramirez, D., and Wang, J.H. (2022). Net illumination reduces fisheries bycatch, maintains catch value, and increases operational efficiency. Curr. Biol. *32*, 911–918.e2.
6. Huveneers, C., Rogers, P.J., Semmens, J.M., Beckmann, C., Kock, A.A., Page, B., and Goldsworthy, S.D. (2013). Effects of an electric field on white sharks: In situ testing of an electric deterrent. PLoS One *8*, e62730.
7. Gauthier, A.R.G., Chateauminois, E., Hoarau, M.G., Gadenne, J., Hoarau, E., Jaquemet, S., Whitmarsh, S.K., and Huveneers, C. (2020). Variable response to electric shark deterrents in bull sharks, *Carcharhinus leucas*. Sci. Rep. *10*, 17869.
8. Kempster, R.M., Egeberg, C.A., Hart, N.S., Ryan, L., Chapuis, L., Kerr, C.C., Schmidt, C., Huveneers, C., Gennari, E., Yopak, K.E., *et al*. (2016). How close is too close? The Eefect of a non-lethal electric shark deterrent on white shark behaviour. PLoS One *11*, e0157717.
9. Kajiura, S.M., and Holland, K.N. (2002). Electroreception in juvenile scalloped hammerhead and sandbar sharks. J. Exp. Biol. *205*, 3609–3621.
10. Thiele, M., Mourier, J., Papastamatiou, Y., Ballesta, L., Chateauminois, E., and Huveneers, C. (2020). Response of blacktip reef sharks Carcharhinus melanopterus to shark bite mitigation products. Sci. Rep. *10*, 3563.

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